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Human Gait Recognition Using Multisvm Classifier

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Abstract: The human gait is an important biometric feature for human identification. Individuals have distinctive and special ways of walking. This methodology comes under the model free approaches, different types of features (e.g., the whole silhouettes silhouette width, height values and joint angles) are first extracted. In the subsequent pattern-matching stage, some approaches exploit the silhouette shape and dynamics information. By the usage of model free approach, it can reduce the dimensionality which in turn reduces time complexity. Nowadays human gait recognition has an increasing research interest in human identification in controlled environments such as airports, banks, and car parks. The human gait is an important feature for human identification in such video surveillance-based applications because it can be perceived unobtrusively from a medium to a great distance. This system uses a new patch distribution feature (PDF) for human gait recognition. It represent each gait energy image (GEI) as a set of local augmented Gabor features, which concatenate the Gabor features extracted from different scales and different orientations together with the X-Y coordinates. Then learn a global Gaussian mixture model (GMM) with the local augmented Gabor features from all the gallery GEIs; then, each gallery or probe GEI is further expressed as the normalized parameters of an image-specific GMM adapted from the global GMM. To enhance the accuracy and to reduce the time complexity of this system a new classification method using multisvm classifier is also combined to this method.

Keywords: Human Gait, Model Free Approach, Model Based Approach, Multisvm Classifier.

1. Introduction

Human gait refers to locomotion achieved through the movement of human limbs. Human gait is defined as bipedal, biphasic forward propulsion of center of gravity of the human body, in which there are alternate sinuous movements of different segments of the body with least expenditure of energy. Different gait patterns are characterized by differences in limb movement patterns, overall velocity, forces, kinetic and potential energy cycles, and changes in the contact with the surface (ground, floor etc.). Human gaits are the various ways in which a human can move, either naturally or as a result of specialized training. Gaits can be roughly categorized into two groups: the natural gaits that nearly every human will use without special training, and the specialized gaits which people train to use under specific conditions and situations. Another classification system applicable humans groups to gaits by whether or not the person is continuously in contact with the ground. The specialized gaits include those trained for martial arts and entertainment, as well as additional gaits for regular motion that don't necessarily occur naturally. Specialized gaits are the ones that are not the natural gaits. The socalled natural gaits, in increasing order of speed, are the meander, walk, jog, run, and sprint. While other intermediate speed gaits may occur naturally to some people, these five basic gaits occur naturally across almost all cultures. All natural gaits are designed to propel a person forward, but can also be adapted for lateral movement. As natural gaits all have the same purpose, they are mostly distinguished by when the leg muscles are used during the gait cycle.

Gait analysis is the systematic study of locomotion, more specifically the study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles. Gait analysis is used to assess, plan and treat individuals with conditions affecting their ability to walk. The study encompasses quantification, (i.e. introduction and analysis of measurable parameters of gaits), as well as interpretation, i.e. drawing various conclusions about the animal (health, age, size, weight, speed etc.) from its gait pattern. The gait analysis is modulated or modified by many factors, and changes in the normal gait pattern can be transient or permanent. The parameters taken into account for the gait analysis are as follows: Step, length, Stride, length, Cadence, Speed, Dynamic, Base, Progression, Line, Foot, Hip, Angle.

There are numerous biometric measures which can be used to help derive an individuals identity. They can be classified into two distinct categories: Physiological these are biometrics which are derived from a direct measurement of a part of a human body. The most prominent and successful of these types of measures to date are fingerprints, face recognition, iris-scans and hand scans. Behavioural extract characteristics based on an action performed by an individual, they are an indirect measure of the characteristic of the human form. The main feature of a behavioural biometric is the use of time as a metric. Established measures include keystroke-scan and speech patterns. Biometric identification should be an automated process. Manual feature extraction would be both undesirable and time consuming, due to the large amount of data that must be acquired and processed in order to produce a biometric signature. Inability to automatically extract the desired characteristics which would render the process infeasible on realistic size data sets, in a real-world application. With a biometric a unique signature for an individual does not exist, each time the data from an individual is acquired it will generate a slightly different signature, there is simply no such thing as a 100% match. This does not mean that the systems are inherently insecure, as very high rates of recognition have been achieved. The recognition is done through a process of correlation and thresholding. Using gait as a biometric is a relatively new area of study, within the realms of computer vision. It has been receiving growing interest within the

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computer vision community and a number of gait metrics have been developed.

Current human recognition methods, such as fingerprints, face or iris biometrics, generally require a cooperative subject, views from certain aspects and physical contact or close proximity. These methods cannot reliably recognize non cooperating individuals at a distance in real-world changing environmental conditions. Moreover, in various applications of personal identification, many established biometrics can be obscured. Gait, which concerns recognizing individuals by the way they walk, has been an biometric without above-mentioned important the disadvantages.

There is an increasing research interest in human identification in controlled environments such as airports, banks, and car parks. The human gait is an important biometric feature for human identification in such video surveillance-based applications because it can be perceived unobtrusively from a medium to a great distance. In the view of biomechanics, individuals have distinctive and special ways of walking. Results from the field of psychology also demonstrated the ability for humans to: 1) distinguish human locomotion from other motion patterns; 2) recognize friends; and 3) recognize gender, the direction of motion, and carrying conditions. The most recent psychological study has further demonstrated that humans can indeed recognize people by their gait.

Gait recognition can be used in a number of different scenarios. One example would be to analyse the video stream from surveillance cameras. If an individual walks by the camera whose gait has been previously recorded and they are a known threat, then the system will recognise them and the appropriate authorities can be automatically alerted and the person can be dealt with before they are allowed to become a threat. The threat has been successfully detected from a distance, creating a time buffer for authorities to take action. Such systems have a large amount of potential application domains, such as airports, banks and general high security area.

The rest of the paper is organized as follows. In section 2, related-works of human gait recognition methods are briefly described. Section 3 describes the framework of human gait recognition based on multisvm classifier. Experimental results of proposed method and its comparison are described in section 4. And finally, section 5 summarizes the conclusion of this paper.

2. Literature Survey

The existing methods for human gait recognition can be divided roughly into two categories, namely model-based approach and model-free approach. Model-based approach generally models the human body structure or motion and extracts the features to match them to the model components. It incorporates knowledge of the human shape and dynamics of human gait into an extraction process. The gait dynamics are extracted directly by determining joint positions from

model components, rather than inferring dynamics from other measures (such as movement of other objects). Thus, the effect of background noise can be eliminated. The advantages of this approach are the ability to derive dynamic gait features directly from model parameters. It is free from background noise as well as the effect of different subjects apparel or camera shooting viewpoint. However, it creates many parameters from extracted gait features and hence resulting in a complex model. Due to that reason, the computational time, date storage and cost are extremely high due to its complex searching and matching procedures. Conversely, model-free approach generally differentiates the whole motion pattern of the human body by a concise representation such as silhouette without considering the underlying structure. Normally, its parameters are obtained from the static gait features like centroid, width and height of the silhouette. The advantages of this approach are speedy processing, low computational cost and small data storage. However, the performance of this approach is highly affected by the background noise and the changes of the subjects apparel.

Hu Ng et al [1] introduced a method In which they presents a human identification system based on automatically extracted gait features. This approach consists of three parts: extraction of human gait features from enhanced human silhouette, smoothing process on extracted gait features and classification by three classification techniques: fuzzy knearest neighbour, linear discriminate analysis and linear support vector machine. The gait features extracted are height, width, crotch height, step-size of the human silhouette and joint trajectories. To improve the classification performance, two of these extracted gait features are smoothened before the classification process in order to alleviate the effect of outliers. This approach has been applied on SOTON covariate database, which comprises eleven subjects walking bidirectional in a controlled indoor environment with thirteen different covariate factors that vary in terms of apparel, walking speed, shoe types and carrying objects. From the experimental results, it can be concluded that the proposed approach is effective in human identification from a distance over various covariate factors.

Dr.Vincent Huang [2] developed the technique for Gait Recognition by combining PCA and CA which performed gait recognition using PCA and Canonical Analysis. In this method, the silhouette of the subject during motion to derive the gait parameters, this motion was then compressed using PCA. Then applied Canonical analysis to derive the signature from which the subject can be recognised. A recognition rate on a small database had a success rate of 100% suggesting that this technique is reliable and has the potential to be improved and extended.

J.E. Boyd and J.J. Little [3] used a technique for recognising people by the shape of motion which identifying individuals by studying the variations in the motion description of a subject as they walked. They took a short video sequence and derived the dense optical flow of the subject in both the x and y direction. Scalars of these values were then created based on moments of moving points in order to characterise the shape of the motion not the shape of individual points. They

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used least-squares linear prediction spectrum analysis to find the fundamental frequency and phase. These were then used as the basis for identification comparison. The results from this looked quite promising with recognition rates of 95% when using the four best recognition signature features, based on the nearest neighbour algorithm.

Ju Han and Bir Bhanu [4] propose a new spatio-temporal gait representation, called Gait Energy Image (GEI), to characterize human walking properties for individual recognition by gait. To address the problem of the lack of training templates, they generate a series of new GEI templates by analyzing the human silhouette distortion under various conditions. Principal component analysis followed by multiple discriminant analysis are used for learning features from the expanded GEI training templates. Recognition is carried out based on the learned features. Experimental results show that the proposed GEI is an effective and efficient gait representation for individual recognition, and this approach achieves highly competitive performance with respect to current gait recognition approaches. Only individual recognition by activity-specific human motion considered, i.e., regular human walking, which is used in most current approaches of individual recognition by gait. Recognition is then carried out based on the learned features.

BenAbdelkader et al. [5] used a motion based approach using Image Self-Similarity, in which segmenting the person from the background, and then computing a self-similarity plot of the of the captured foreground images over a number of frames. The self-similarity plot is a measure of correlation between two different extracted foreground regions at time t_i and t_j . Principle Component Analysis was then performed to reduce the dimensionality of the extracted images followed by clustering analysis. Results were promising with recognition rates up to 78% being obtained from a near-front to-parallel view.

Jyoti Bharti and M. K. Gupta [6] introduced a new gait recognition approach using geometric characteristic and fuzzy logic. This method is based on dynamic body parameters. For that they had taken two component of human body. The first component is hand and second component is feet. The second component is subdivided into two parts i.e. toe and heel of both right and left leg. This method increase the matching accuracy which is lies between 75 to 86 percent. This method shows that the concept of fuzzy logic with mean values of both angles gives better gait recognition.

Model based approaches to feature extraction, use priori knowledge of the object, which is being searched for in the image scene. Models used are typically stick representations either surrounded by ribbons or blobs. When modelling the human body, there are various kinematical and physical constraints we can place on the model which are realistic i.e. maximum variation in angle of knee joint. The advantages of a model based approach are that evidence gathering techniques can be used across the whole image sequence before making a choice on the model fitting. Models can handle occlusion and noise better and offer the ability to derive gait signatures directly from model parameters i.e. variation in the inclination of the thigh. They also help to reduce the dimensionality needed to represent the data. The disadvantage of implementing a model based approach to is that the computational costs, due to the complex matching and searching that has to be performed are high. Although this is a limitation computing power is always increasing so this can be seen as less of a disadvantage, especially in non real-time applications, and efficiency improvements can be found for most algorithmic implementations, which help to reduce the computational costs. The aim of a model based approach is to model the motion of a human, and then fit this model to the motion of a human being tracked.

Aaron F. Bobick and Amos Y. Johnson [7] introduced Gait Recognition Using Static, Activity-Specific Parameters, gaitrecognition technique that recovers static body and stride parameters of subjects as they walk is presented. This approach is an example of an activity-specific biometric: a method of extracting identifying properties of an individual or of an individuals behaviour that is applicable only when a person is performing that specific action. To evaluate parameters, derive an expected confusion metric related to mutual information - as opposed to reporting a percent correct with a limited database. This metric predicts how well a given feature vector will filter identity in a large population. Then test the utility of a variety of body and stride parameters recovered in different viewing conditions on a database consisting of 15 to 20 subjects walking at both an angled and frontal-parallel view with respect to the camera, both indoors and out. Also analyze motion capture data of the subjects to discover whether confusion in the parameters is inherently a physical or a visual measurement error property.

N. Boulgouris[8] et al proposed a new feature extraction process for gait representation and recognition. The new system is based on the Radon transform of binary silhouettes. For each gait sequence, the transformed silhouettes are used for the computation of a template. The set of all templates is subsequently subjected to linear discriminant analysis and subspace projection. In this manner, each gait sequence is described using a low-dimensional feature vector consisting of selected Radon template coefficients. Given a test feature vector, gait recognition and verification is achieved by appropriately comparing it to feature vectors in a reference gait database. By using the new system on the Gait Challenge database, very considerable improvements in recognition performance are seen in comparison to state-of-the-art methods for gait recognition. The set of all templates was subsequently subjected to LDA and subspace projection.

D. Xu et al [9] presented Human gait recognition with matrix representation. First, binary silhouettes over one gait cycle are averaged. As a result, each gait video sequence, containing a number of gait cycles, is represented by a series of gray-level averaged images. Then, a matrix-based unsupervised algorithm, namely coupled subspace analysis (CSA), is employed as a pre-processing step to remove noise and retain the most representative information. Finally, a supervised algorithm, namely discriminant analysis with tensor representation, is applied to further improve classification ability. This matrix-based scheme demonstrates a much better gait recognition performance than state-of-theart algorithms. Then a two-stage scheme, called

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CSA+DATER, for gait recognition based on gray-level average silhouettes over a gait cycle is performed. In the conventional PCA and LDA algorithms, the image matrix is concatenated into a vector, thus the image object is often represented in a very high dimensional feature space, whereas, in many recognition applications, the number of available training samples is small, typically resulting in the well-known curse of dimensionality and the small sample size problem. Furthermore, in real applications, the extracted feature of an object often has some specialized structure in the form of a second-order or even higher order tensor. For example, the gray-level average silhouette is a second-order tensor or matrix. Therefore, it would be highly desirable to uncover such underlying structure in gait recognition. Each sequence was represented as several gray-level average silhouette images, which correspond to gait cycles. A twostage scheme called CSA+DATER has been employed for dimensionality reduction directly based on the matrix representations. The experiments on the standard USF HumanID Gait database demonstrate encouraging performance improvements over the state-of-the-art algorithms for human gait recognition.

Dr. D. Cunado [10] proposed a new method in which he modelled the leg as a pendulum. The method of identification was defined by calculating the difference between SHM and the motion of the subjects thighs. The gait signature was successfully extracted and could withstand differing amounts of noise and occlusion. This method achieved recognition rates of 100 on a database of ten subjects.

Dacheng Tao et al [11] introduced three new representations of the averaged gait images. These are the sum over directions of Gabor functions based representation (GaborD), the sum over scales of Gabor functions based representation (GaborS), and the sum over scales and directions of Gabor functions based representation (GaborSD). The most important benefit of these new representations is that the cost of computing them is low. This method focus on the representation and pre-processing of appearance-based models for human gait sequences. Two major novel representation models are presented, namely, Gabor gait and tensor gait, and some extensions of them are made to further enhance their abilities for recognition tasks. Gabor gait is based on the well-known Gabor functions. Three different approaches using Gabor functions are developed to reduce computational complexities in calculating the representation, in training classifiers, and in testing. Tensor gait is also introduced to represent these Gabor gaits. To take the feature selection into account, the size of the tensor gait is reduced by the general tensor discriminant analysis (GTDA), which is based on a low rank approximation of the original data. Apart from reserving discriminative information, GTDA has another advantage - it significantly reduces the effects of under sampling on classification.

Dong Xu et al [12] proposed an effective method which yields better performance on the common databases, reduces computational complexity and improves the accuracy. This system is based on a new Patch Distribution Feature(PDF).To extract Gabor-PDF, each GEI is taken as a set of local augmented Gabor features from which the

distribution is estimated by exploiting a two-stage approach to learn an image-specific GMM. Also developed a new classification method referred to as LGSR by enforcing both group sparsity and local smooth sparsity constraints. This method presents a systematic and comprehensive gait recognition approach, which can work just as fine as other complex published techniques in terms of effectiveness of performance while providing all the advantages associated with the computational efficiency for real-world applications.

3. Proposed Method

Existing systems were concentrating on model-based approaches, the human body structure is characterised using the model parameters fitted based on the extracted features. The parameters can be dynamic parameters (e.g., the stride length and speed) or static body parameters (e.g., the size ratios of various body parts).

- There is no way for compact representation to characterize the motion patterns of the human body.
- Computational and time complexity.
- Inaccurate recognition results.

A new methodology for extracting human gait features from a walking human based on the silhouette image is proposed. In this system it employs the silhouette shape similarity, the binary silhouettes over one gait cycle are averaged such that each gait video containing a number of gait cycles is represented by a set of gray-level average silhouette images [i.e., gait energy images (GEIs)]. Following are the various stages included in gait recognition. Figure 3.1 summarizes the main steps in the proposed human gait recognition system.

- 1. ROI selection by blob detection in the given silhouette image
- 2. Measuring the width and height of the human silhouette
- 3. Separating the enhanced human silhouette into six body segments
- 4. Applying morphological skeleton to obtain the body skeleton
- 5. Applying radon transform to obtain the joint angles from the body segment skeletons



Figure 1: Main steps in the proposed Human Gait Recognition System

3.1 Original Image Enhancement

In most of the human silhouette images, shadow is found especially near to the feet. It appears as part of the subject body in the human silhouette image. The presence of the artefact affects the gait feature extraction and the measurement of joint trajectories. The problem can be reduced by applying morphological erosion and dilation. The opening first performs erosion, followed by dilation. The width and height of the subject from each frame during the walking sequences are measured from the bounding box of the enhanced human silhouette. These two features will be used for gait analysis in the later stages.

3.2 Silhouette Segmentation

Segmentation of the image helps to determine regions for blobs. Then separate the correct blobs from accidental noise connecting blobs with existing detections, register new detections and removing ones that are not present any more. Blob Analysis is used to calculate statistics for labelled regions in a binary image. The block returns quantities such as the centroid, label matrix, and blob count and bounding box measurements. Thus the detected degraded pixels will be enclosed by means of bounding boxes.

Segmentation can be improved by building a model of the background pixel intensities. The model of the background can be built on a combination of statistical range and colour values for each pixel in the scene. If the background is continually changing gradually over a period of time, the model will have to be updated over time to reflect these changes. Various simplification assumptions can be made in controlled environments to enhance the performance of segmentation. As well as creating a better model of the background in the image, it is also possible to apply image filters to the foreground image map, which help to reduce noise (pixels which have been misclassified as foreground pixels) and classify pixels into groups. The enhanced human silhouette is divided into six body segments based on anatomical knowledge which represents head and neck, torso, right hip and thigh, right lower leg and foot, left hip and thigh and left lower leg and foot.

3.3 Skeletonization of Silhouette

Skeletonization plays an important role in digital image processing and pattern recognition, especially for the analysis and recognition of binary images. It has been widely used in gait recognition. The silhouette binary image is then subjected to skeletonization. The process can be viewed as a transformation to transform the width of a binary pattern into just one single pixel. Essentially, such transformation can be achieved by successively removing points or layers of outline from a binary pattern until all the lines or curves are of unit width. The resulting set of lines or curves is called the skeleton of the pattern. As we know, the purpose of skeletonization is to reduce the amount of redundant data embedded in a binary image and to facilitate the extraction of distinctive features from the binary image thereafter. Until now, thinning is still the most frequently used method to achieve the skeletonization goal and distortion. To remedy the problems produced by traditional thinning methods, a novel approach to skeletonize binary images with faster speed is proposed.

To reduce the segments to a simpler representation, morphological skeleton is used to construct the skeleton from all the body segments. Skeletonization involves consecutive erosions and opening operations on the image until the set differences between the two operations are zero.

3.4 Feature Extraction and Angle Computation

The skeleton image is useful for the extraction of features such as angle at joints. Before computing angle the skeleton image is partitioned into six parts. Each and every partitioned portion, with that of the corresponding portion from the reference frames are used for the angle computation. Gabor filter is basically a Gaussian with variances S_x and S_y along x and y directions modulated by a complex sinusoid with center frequencies F_x and F_y along x and y directions. Gabor filter selects the feature along a particular direction under consideration. This reduces the number of points for which radon transform need to be calculated. Even though Gabor filter consider less number of points, the computation requires more time reducing the overall speed. The Radon transform is the projection of the image intensity along a radial line oriented at a specific angle. The radial coordinates are the values along the x-axis, which is oriented at θ degrees counter clockwise from the x-axis. The origin of both axes is the center pixel of the image. For example, the line integral of f(x,y) in the vertical direction is the projection of f(x,y) onto the x-axis; the line integral in the horizontal direction is the projection of f(x,y) onto the y-axis. The Radon transform of a 2-D function f(x, y) is defined as:

$$R(r,\theta)[f(x,y)] = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x,y) \,\delta(r-x\cos\theta - y\sin\theta) dx \,dy$$

Where r is the perpendicular distance of a line from the origin and θ is the angle between the line and the y-axis. The Radon transform can be used to detect linear trends in images. The Radon transform along this direction usually has larger variations. Therefore, the variance of the projection at this direction is locally maximum.

To extract the joint trajectory for each body segment, Radon transform is applied on the skeleton. Radon transform maps pixels in the image space to straight lines in the parameter space. The skeleton in each body segment, which is the most probable straight line, is indicated by the highest intensity point in the parameter space.

3.5 Multisvm Model

After feature extraction, multiclass Support Vector Machine (SVM) is employed for classification. SVM is based on structural risk minimization principle, which optimises the training data to create machine learning model. Given a training set of instance-label pairs: (x_i, y_i) , i = 1, 2..., l where $x_i \in \mathbb{R}^n$ and $y_i \in 1, -1^i$ (*n* and *l* denote the space dimensions and size of training set). In this case if x belongs to positive category then $y_i = 1$; if x belongs to negative category then $y_i = -1$. Basically SVM is a classifier that focuses on finding an

optimal hyper plane to separate different classes by solving the quadratic optimization problem.

4. Experimental Results

In order to be able to perform recognition there needs to be a set of data which the query can be compared against and classified. Here the gait signatures of five different individual was recorded, each person had some video sequences taken at different times. The training data is created by choosing randomly one sequence of each of the different people (a total of six subjects) and storing the details. Queries are then compared against this database. First created a database by capturing walking data from 5 peoples. Each individual performs their walks of approximately same distance. Taking all the data for each subject, arms, legs, head, hip and knee joint locations are recovered. For each subject, there are approximately thirty sets of walking sequences, which are from left to right and vice-versa on normal track. In total, there are 154 walking sequences that are used for training and testing process. The underlying skeleton is connected through these joints joint angle trajectories are recovered. Then select randomly a walk sequence from the database to be a walking template and then we time-warp all the data to that template. After the signal normalization process, all the signals have the same footstep structure and same temporal length.

The USF HumanID gait database collected by Sarkar et al is currently the largest publicly available database for evaluating human gait recognition algorithms. Sarkar et al. also proposed a baseline algorithm to extract the binary silhouette, calculate the gait period length, and conduct final matching. In order to facilitate the subsequent research in this field, Sarkar et al. made the binary silhouettes and the gait period lengths publicly available in http://figment.csee.usf.edu/Gait Base line/.

One of the most important measures in the whole project, as it is the aim of the project is the recognition rates, for the various measures. A comparative analysis of the proposed approach for gait recognition with LGSR classifier was performed using the images available in the database. For the techniques adopted for comparison, Recognition rate of each individuals was calculated and the results are tabulated in Table 1. The corresponding graph is depicted in Figure 2.

 Table 1: Comparison of LGSR and MultiSVM Classifier

Person	LGSK Classifier		MULTISVM Classifier	
	Recognition Rate	End Time	Recognition Rate	End Time
Dorson 1	66 6667	10 1109	80	2 2665
Person 1	00.0007	10.1198	80	2.3003
Person 2	62.4554	12.4436	83.3333	2.6557
Person 3	37.5000	23.4153	70.8333	3.4837
Person 4	45.8333	13.0543	62.6667	5.4546
Person 5	37.7833	13.4980	76.3333	5.5076



Figure 2: Performance analysis based on Recognition Rate

From the graph, it is evident that the proposed system outperforms the normal gait recognition system that employs LGSR classifier for gait recognition. Thereby, the proposed approach for gait recognition can serve as an effective tool for human identification.

5. Conclusion

A novel model-free approach for extracting the gait features from enhanced human silhouette image has been developed. The gait features are extracted from human silhouette by determining the skeleton from body segments. The joint angles are obtained after applying Radon transform on the skeleton. To extract features (Gabor-Patch distribution features), each GEI is taken as a set of local augmented Gabor features from which the distribution is estimated by exploiting a two-stage approach to learn an image-specific GMM. Also developed a new classification method using multisvm classifier which presents a systematic and comprehensive gait recognition approach, which can work just as fine as other complex published techniques in terms of effectiveness of performance while providing all the advantages associated with the computational efficiency for real-world applications. The resulting gait recognition system yields better performance on the common databases, reduces computational complexity and improves the accuracy.

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