A Parametric Approach to Gait Signature Extraction for Human Motion Identification

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Abstract

The extraction and analysis of human gait characteristics using image sequences are currently an intense area of research. Identifying individuals using biometric methods has recently gained growing interest from computer vision researchers for security purposes at places like airport, banks etc. Gait recognition aims essentially to address this problem by identifying people at a distance based on the way they walk i.e., by tracking a number of feature points or gait signatures. We describe a new model-based feature extraction analysis is presented using Hough transform technique that helps to read the essential parameters used to generate gait signatures that automatically extracts and describes human gait for recognition. In the preprocessing steps, the picture frames taken from video sequences are given as input to Canny edge detection algorithm which helps to detect edges of the image by extracting foreground from background also it reduces the noise using Gaussian filter. The output from edge detection is given as input to the Hough transform. Using the Hough transform image, a clear line based model is designed to extract gait signatures. A major difficulty of the existing gait signature extraction methods are the good tracking the requisite feature points. In the proposed work, we have used five parameters to successfully extract the gait signatures. It is observed that when the camera is placed at 90 and 270 degrees, all the parameters used in the proposed work are clearly visible. The efficiency of the model is tested on a variety of body position and stride parameters recovered in different viewing conditions on a database consisting of 20 subjects walking at both an angled and frontal-parallel view with respect to the camera, both indoors and outdoors and find the method to be highly successful. The test results show good clarity rates, with a high level of confidence and it is suggested that the algorithm reported here could form the basis of a robust system for monitoring of gait.

Keywords: Parametric Approach, Biometric, Gait Signature Extraction, Hough Transform, Canny Edge Detection, Gaussian Filter

1. INTRODUCTION

Gait analysis is a challenging research topic and recently that identification from gait has received attention and has become an active area of computer vision. For biometrics research, gait is usually referred to include both body shape and dynamics, i.e. any information that can be extracted from the video of a walking person to robustly identify the person under various condition variations. The demand for automatic human identification system is strongly increasing and growing in many important applications, especially at a distance and it has recently gained great interest from the pattern recognition and computer vision researchers for it is widely used in many security-sensitive environments such as banks, parks and airports [1].

The extraction and analysis of human walking movements, or gait, has been an on going area of research since the advent of the still camera in 1896 [2]. There two areas dominate the field of gait research at the present. Clinical gait analysis focuses on collection of gait data in controlled environments using motion capture systems and Biometric goals of human gait analysis analyze an individual's gait in a variety of different areas and scenarios. Because of these limitations, gait analysis for use in biometric systems are largely based on visual data capture and analysis systems which process video of walking subjects in order to analyze gait. The limitations that are inherent in these techniques necessitate the use of sophisticated computer vision systems to generate parameters which describe the gait motion.

Although considerable research has been done in the above areas, very limited successful research has been done in the area of gait extraction. The first scientific article on animal walking gaits has been written 350BC by Aristotle [3]. He observed and described different walking gaits of bipeds and quadrupeds and analyzed why all animals have an even number of legs. Recognition approaches to gait were first developed in the early 1990s and were evaluated on smaller databases and showed promise. DARPA's Human ID at a Distance program [4] then collected a rich variety of data and developed a wide variety of technique and showed not only that gait could be extended to large databases and could handle covariate factors. Since the DARPA program, research has continued to extend and develop technique, with especial consideration of practical factors such as feature potency. In Silhouette Analysis-Based Gait Recognition for Human Identification [5] a combination of background subtraction procedure and a simple correspondence method is used to segment and track spatial silhouettes of an image, but this method generates more noise which leads to poor gait signature extraction. Therefore the rate of recognition is low. In gait recognition by symmetry analysis[6], the Generalized Symmetry Operator is used which locates features according to their symmetrical properties rather than relying on the borders of a shape or on general appearance and hence does not require the shape of an object to be known in advance. The evaluation was done by masking with a rectangular bar of different widths in each image frame of the test subject and at the same position. A recognition rates of 100% were obtained for bar size of 5 pixels. This suggests that recognition is likely to be adversely affected when a subject walks behind a vertically placed object. There are also certain other limitations, Mark Ruane Dawson[6], like the legs were not being tracked to a high enough standard for gait recognition. The segmentation process leads to a very crude model fitting procedure which in turn adversely affects the rate of recognition. In other method of gait recognition, the subjects in the video are always walking perpendicular to the camera[7]. This would not be the case in real life as people would be walking at all angles to the video camera. Using of fewer parameters for gait signatures is a major drawback which has to be addressed. Cunado et.al. [8] use the Hough transform to extract lines that represent legs. Then they perform Fourier analysis on the resulting joint-angles for gait recognition. Specifically, they weight the magnitude spectra by the phase, to distinguish between different subjects. A CCR of 90% was obtained with the leave one out strategy. However, the algorithm was tested on only 10 subjects. The majority of published approaches fall into the model fitting category. Some rely on first processing each frame independently and then using PCA [9] or HMM[10] to model the transitions from one frame to the next. In [11], Nash et al. proposed a new model-based technique to allow the automated determination of human gait characteristics. Their technique employs a parametric two-line model representing the lower limbs. To speed up the search of the parameter space, they used a genetic algorithm (GA) based implementation of the Velocity

Hough Transform (VHT) rather than an exhaustive search. Although their approach is promising, the accuracy of the estimated hip rotation patterns is still insufficient for biometric purposes. More recently, methods that rely on dense optical flow by J. Little [12] or self similarity plots computed via correlation of pairs of images as by C. BenAbdelkader [13] have been proposed. The main drawback of these appearance based approaches is that they are usually designed only for a specific viewpoint, usually front to-parallel. Furthermore guaranteeing robustness against clothing and illumination changes remains difficult even though much effort has been expanded to this end, for example by processing silhouettes or binary masks instead of the image itself [13]. Among model-based methods, is the one by Yam et al. [14] in which leg motion is extracted by temporal template matching with a model defined by forced coupled oscillators. Individual signatures are then derived by Fourier analysis. Another good recent example of model-based gait recognition can be found in [15]. The gait signature is extracted by using Fourier series to describe the motion of the upper leg and by applying temporal evidence gathering techniques to extract the moving model from a sequence of images. However these techniques are still 2–D, which means that a near fronto-parallel view is assumed. The approach we propose can be viewed as an extension of this philosophy to full 3–D modeling by replacing the Fourier analysis by the fitting of our PCA-based motion.

The motivation behind this research is to find whether increase in number of gait signature can improve the recognition rate? Improvement over model fitting can give us better results? What factors affect gait recognition and to what extent? And what are the critical vision components affecting gait recognition from video? The objective of this paper is to explore the possibility of extracting a gait biometric from a sequence of images of a walking subject without using markers. Sophisticated computer vision techniques are developed, aimed to extract a gait signature that can be used for person recognition.

In the proposed study, pre-processing is performed on the images in the walking sequence using the Canny edge detector is applied to produce edge images of the input data. Essentially, the human gait model describes a moving line whose inclination is constrained by a periodic signal and velocity governed by some initial conditions and characteristics. Then the model parameters are extracted and the line images are produced by Hough transform for lines. Using video feeds from conventional cameras and without the use of special hardware, implicates the development of a marker less body motion capture system. Research in this domain is generally based on the articulated-models approach. Haritaoglu et al. [10] presented an efficient system capable of tracking 2D body motion using a single camera. Amos Y. Johnson[11] used a single camera with the viewing plane perpendicular to the ground plane, 18 subjects walked in an open indoor-space at two view angles: a 45◦ path (angle view) toward the camera, and a frontal-parallel path (side-view) in relation to the viewing plane of the camera. The side-view data was captured at two different depths, 3.9 meters and 8.3 meters from camera. These three viewing conditions are used to evaluate our multi-view technique. In this research, we use images captured at different views as the image captured from the frontal or perpendicular view does not give required signatures. Segmentation is done on the captured image in order to extract foreground from back ground using Canny edge detection technique, as the purpose of edge detection in general is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing. In order to obtain the gait model the output of segmentation is processed using Hough transform, which is a technique that can be used to isolate features of a particular shape within a Hough transformed image.

2. GAIT SIGNATURE EXTRACTION: THE PROPOSED MODEL

In medical science, the goal of most gait research has been to classify the components of gait and produced standard movement patterns for normal people that were compared to the gait patterns for pathological patients. No statistical or mathematical analysis was performed on the collected data [16]. We propose a gait signature extraction model having the following steps- picture frame capture, Segmentation, feature Extraction which leads to gait signature identification which are shown in figure.1.

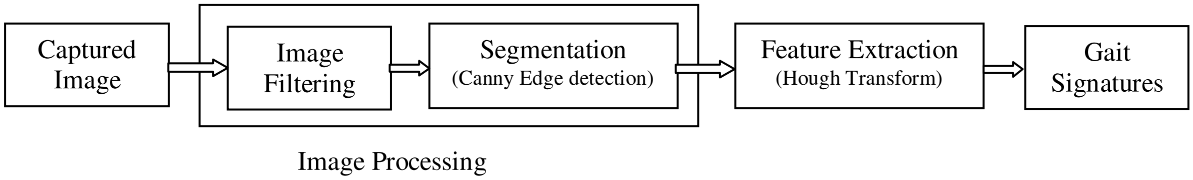


FIGURE 1: Components of the proposed model for Gait Signature Extraction System.

2.1 GAIT CAPTURING

At this step the subjects are asked to walk for capturing of gait. This is a very important step as the total result depends on the quality of the gait captured. So the care should be taken to see that the quality of gait capturing is maintained, this step includes video sequence and XML data store.

2.1.1. Video Sequence – the video sequence is the medium used for viewing the gait of an individual. Video will be taken in two side views(90 degree and 270 degree) so that we can get clear signature of each subject and the Video will be transformed into Frames and frames are stored in an intermediate format, bitmap or JPG, once being loaded into the program in order to allow process of the information within the program.

2.1.2. XML Data Store – the data store is used to record all of the captured data about each subject in XML format. Users gait data can either be stored in individual query files, or concatenated together to create a database file.
In our proposed research the following preprocessing steps are carried out before segmenting an Image

1. [Reading a RGB image]
2. [Converting an RGB image to Gray Scale]
3. [Converting Gray Scale Image to Indexed Image]

So, we can defined the captured image as two dimensional array of pixels $P = (P_x , P_y)$ and each pixel is an intensity I_p in 2D vector (B/W image). The indexed image is the input to the segmentation algorithm for further processing. The above preprocesses of an image is shown in figure. 2.

2.2. SEGMENTATION

In order to be able to perform analysis on the gait of the individuals caught on video the subject needs to be extracted from the video sequence. Image segmentation is used to separate dynamic objects such as people, which are part of the foreground, from the background of the image sequence. In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyse. We use Image segmentation to locate an object and the boundaries of the object in images.

2.2.1 Edge Detection: Canny Edge Detector Algorithm

Segmentation by edge detection is a fundamental tool in image processing and computer vision, particularly in the areas of feature detection and feature extraction, which aim at identifying points in a digital image at which the image brightness changes sharply or more formally has discontinuities. The purpose of detecting sharp changes in image brightness is to capture important events and changes in properties of the world. In the ideal case, the result of applying an edge detector to an image may lead to a set of connected curves that indicate the boundaries of objects, the boundaries of surface markings as well as curves that correspond to discontinuities in surface orientation. Thus, applying an edge detection algorithm to an image may significantly reduce the amount of data to be processed and may therefore filter out information that may be regarded as less relevant, while preserving the important structural properties of an image. The implementation of The Canny Edge Detection Algorithm runs in four separate steps [17]:

1. Image Smoothing:
   Before doing any type of edge detection, it is important to filter the image to smooth out any noise picked up during image capture. This is essential because noise introduced into an edge detector can result in false edges output from the detector. The Canny edge detector uses a filter based on the first derivative of a Gaussian, the Gaussian Blur ξ has the form:

$$\xi[I]_p = \sum_{q \in S} G_\sigma(x, y) I_q \qquad (1)$$

where σ is the size of the window, I_p and I_q are the values of intensity at pixel *p* and *q*, and the Gaussian function is defined as

$$G_\sigma(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x^2 - y^2)}{2\sigma^2}}$$

   Equation 1 indicates the filtered image at pixel *p*.

2. Finding gradients:
   After smoothing the image and eliminating the noise, the next step is to find the edge strength by taking the gradient of the image. The edges should be marked where the gradients of the image has large magnitudes. The Canny algorithm basically finds edges where the grayscale intensity of the image changes the most. These areas are found by determining gradients of the image. First step is to approximate the gradient in the x- and y-direction respectively by applying the kernels. The gradient magnitudes or the edge strengths $\Im_s(x, y)$ can then be determined as an Euclidean distance measure by applying the law of Pythagoras given by equation

$$\Im_s(x, y) = \sqrt{\xi_x^{\,2}(x, y) + \xi_y^{\,2}(x, y)} \qquad (2)$$

   where, ξ_x and ξ_y are the estimated gradient in the form of 3x3 convolution masks in the x and y directions, respectively. The direction of the edges are determined as

$$\Im_o(x, y) = \tan^{-1}\left(\frac{\xi_y}{\xi_x}\right) \qquad (3)$$

3. Non-maximum suppression:
   Only local maxima should be marked as edges. The purpose of this step is to convert the “blurred” edges in the image of the gradient magnitudes to “sharp” edges. Basically this is done by preserving all local maxima in the gradient image, and deleting everything else. The non-maximum suppression is defined as:

$$\Re_N(x, y) = \begin{cases} \Im_s(x, y) & \text{if} \quad \Im_s(x, y) > \Im_s(x', y') \;\&\; \Im_s(x, y) > \Im_s(x'', y'') \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

where $\Im_s(x', y')$ and $\Im_s(x'', y'')$ are the gradient magnitudes on both sides of edge at (*x*,*y*) in the direction of the gradient.

FIGURE 2: image of a walking person used in this study. [a] Original Image [b]. RGB to Grayscale [c] Grayscale to Indexed Image [d] Edge Detected Image.

4. Canny hysteresis thresholding:
   Intensity gradients which are large are more likely to correspond to edges than if they are small. It is in most cases impossible to specify a threshold at which a given intensity gradient switches from corresponding to an edge into not doing so. Therefore Canny uses thresholding with hysteresis. For that we find out the local maximums that are true edges. We assume that true edges should have large strength and pixels belong to true edges are connected to each other. Now on the basis of the first assumption, we thresholded $\Re_N(x, y)$ using hysteresis algorithm. The algorithm uses two thresholds, τ_l and τ_h.

$$\Re_N(x,y) = \begin{cases} \Re_{Ns}(x,y) & if\ \Re_N(x,y) > \tau_h \\ \Re_{Nw}(x,y) & if\ \Re_N(x,y) \le \tau_l \\ \Re_{Nc}(x,y) & otherwise \end{cases} \quad (5)$$

   where $\Re_{Ns}(x, y)$, $\Re_{Nw}(x, y)$ and $\Re_{Nc}(x, y)$ are the strong, weak and candidate pixels at pixel (*x,y*) respectively. In each point of (*x,y*), discard $\Re_{Nw}(x, y)$ and allow to pass $\Re_{Ns}(x, y)$. If the pixel is $\Re_{Nc}(x, y)$, then follow the chain of connected local maxima in both directions along the edge, as long as $\Re_N(x, y) > \tau_l$. Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge as shown in figure 2.

2.3. GAIT SIGNITURE EXTRACTION

Model based approaches to feature extraction, use a priori knowledge of the object, which is being searched for in the image scene. In this research, we are designing a line base model using Hough transform. When modeling the human body, there are various kinematical and physical constraints, we can place on the model which are realistic. 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.

In this study, we model the human body using the Hough transform technique. Modeling the human body as a skeleton is a good representation due to the underlying skeleton of the physical body and the restrictions it creates. The model can be a 2- or 3-dimensional structural (or shape) model and motion model that lays the foundation for the extraction and tracking of a moving person. A gait signature that is unique to each person in the database is then derived from the extracted gait characteristics. One of the most important aspects in gait recognition is capturing accurately the positions of the legs, these are the best source for deriving a gait signature and will contain most of the variation in the subjects gait pattern. The legs of a human are usually modeled.

2.3.1. Hough Transform:

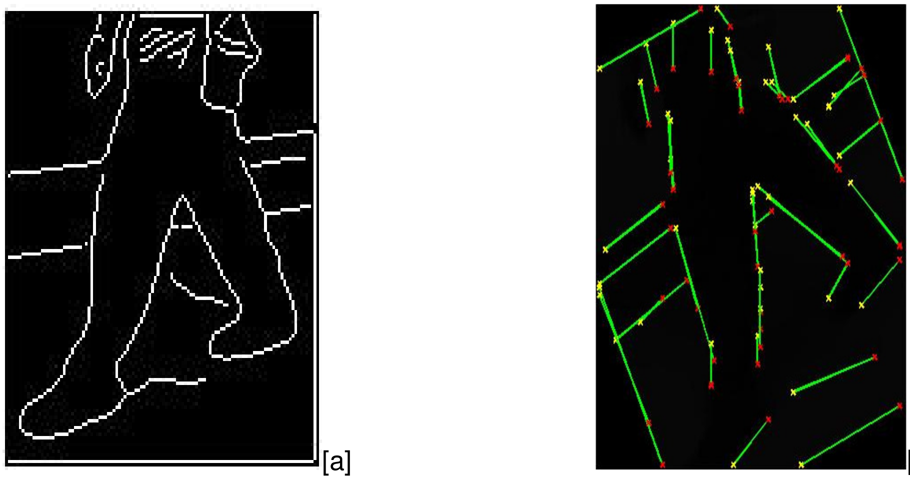
Hough (1962) proposed an interesting and computationally-efficient procedure for detecting lines in images- known as the Hough Transform. It is a technique which can be used to isolate features of a particular shape within an image. Because it requires that the desired features be specified in some parametric form, the classical Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses, etc. A convenient equation for describing a set of lines uses *parametric* or *normal* notion in general form as:

$$x\cos\theta + y\sin\theta = r \tag{6}$$

where r is the length of a normal from the origin to this line and θ is the orientation of r with respect to the x-axis. The output from the Canny edge detection algorithm is given as input to the Hough transform to extract gait signatures in the form of lines. So for any point $\Re_{Ns}(x, y)$ on this line, r and θ are constant for $0 < \theta < 180$ is defined as

$$A(\theta, r) = +\{\Re_{Ns}(x, y) \in X \times Y \,|\, \Re_{Ns}(x)\cos\theta + \Re_{Ns}(y)\sin\theta + r = 0\} \tag{7}$$

where, $A(\theta, r)$ is an accumulator array and X x Y are the image domain. Then we search for the local maxima of $A(\theta, r)$ and which can be used to reconstruct the lines in the image. The edge detected image and the image after Hough transform is shown in figure 3.



[a] [b]

FIGURE 3: The Hough transform of an image. [a] Edge Detected Image and [b] Image after Hough Transform.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Results

A video camera is used to collect data, and its output is recorded on a video recorder. The camera is situated with a plane normal to the subjects path in an environment with controlled illumination. Data collection is performed indoors, with lighting at a constant level. Subjects walked in front of a plain, static background. Each subject wore a special set of normal pant. In this way the camera-side leg could be distinguished visually from the other leg at all times. Fig. 3 shows an example image of a walking person used in this study. Each subject is asked walk past the camera a total of five times. From these five sequences, the first and last three are discarded and only the middle four sequences are used for experimentation. In the first few sequences the subject would be getting comfortable with the experiment, and in the last few the subject would be anxious to finish the experiment. As such, the middle four sequences were considered to offer the most consistent walking cycles.In all, 20 walking trials were completed, yielding the events for subsequent data analysis. This is a very important step as the total result depends on the quality of the gait captured. So the care should be taken to see that the quality of gait capturing is maintained, this step includes video sequence and XML data store. All post-processing and analysis was carried out off-line using the MATLAB programming environment.

We used an analytic approach, describing the legs and the motion of walking as a model. The human leg is modelled as two joined in series. The upper part is the thigh and is suspended between the hip and the knee. The lower part is the lower leg suspended from the knee to the ankle. We find that if all gait movements are considered, gait is unique and 5-7 distinct gait parameters are enough to identify a person. Using image processing techniques, lines representing legs in a sequence of images are extracted using the Hough transform. The inclination of the line representing the leg in each frame is collated to create the hip rotation pattern for the subject. Figure 4 shows the Hough transform of the image in Figure 3. Figures 4b-4g shows the different parameters used in this study.

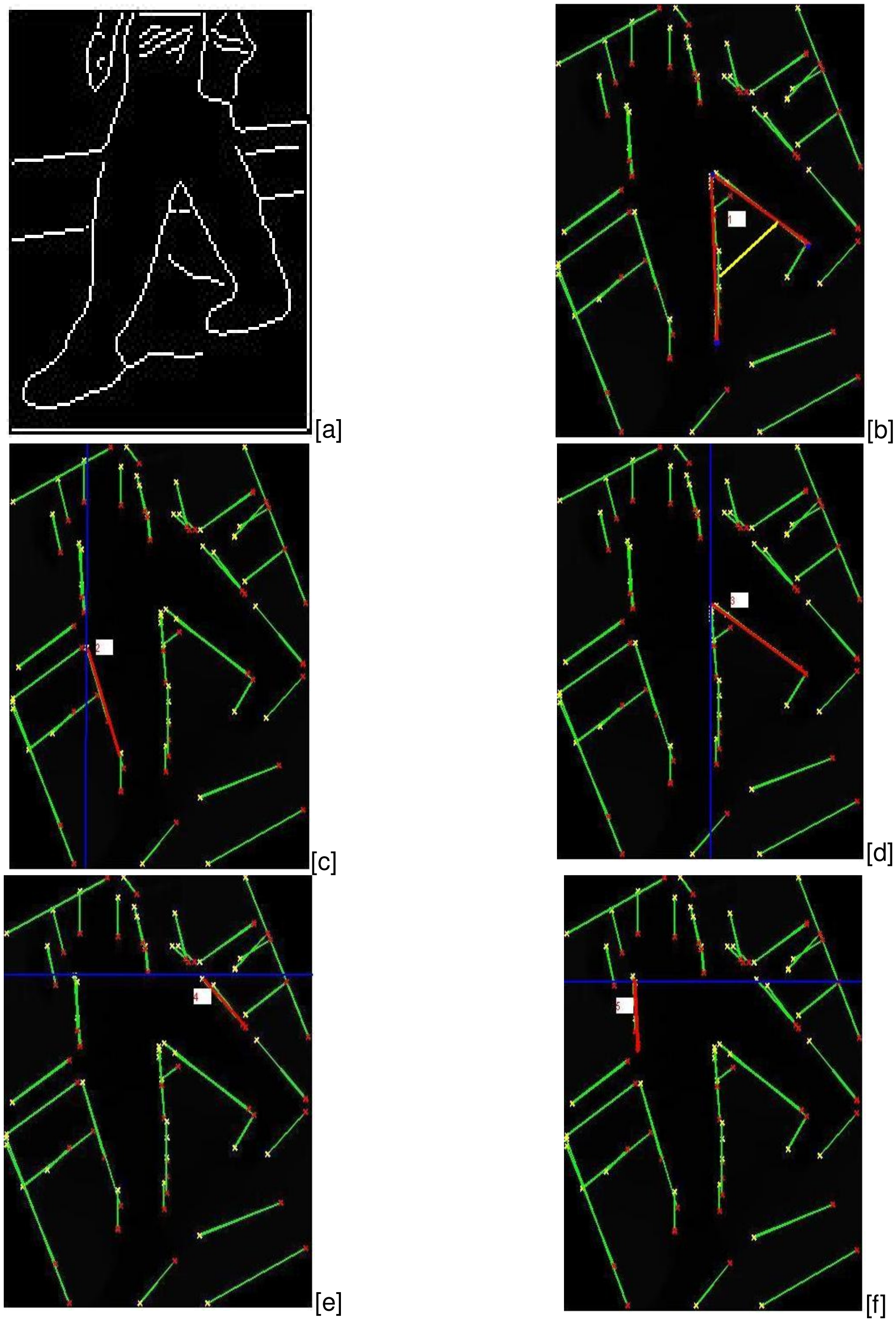


FIGURE 4: The Hough transformed image indicating different parameters. [a] edge detected image [b] distance between legs [c] right knee angle [d] left knee angle [e] left thigh angle [f] right thigh angle.

One of the most important aspects of this research is to extract the gait signatures for a successful recognition rate. Below table shows the number of parameters which are used to generate a gait signature for different view of a subject(90 degree and 270 degree).The attempts column shows how many persons were used to extract the signature. The success column shows how many of the subjects give successful gait signatures.

Parameter	Signature Parameter	Subjects	Clarity	Percentage %
1	Distance between legs	20	20	100
2	Right knee angle	20	18	90
3	Left knee angle	20	20	100
4	Left thigh angle	20	19	95
5	Right thigh angle	20	20	100

TABLE 1: Camera placed at 90 degree angle to the subject for frame 1.

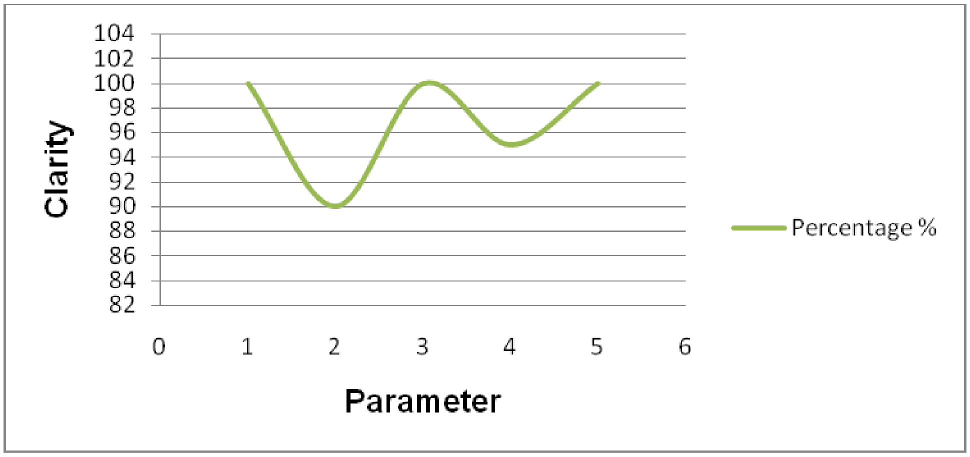


FIGURE 5: Graphical representation of clarity for frame 1,camera placed at 90 degree.

Parameter	Signature Parameter	Subjects	Clarity	Percentage %
1	Distance between legs	20	17	85
2	Right knee angle	20	18	90
3	Left knee angle	20	19	95
4	Left thigh angle	20	20	100
5	Right thigh angle	20	19	95

TABLE 2: Camera placed at 270 degree angle to the subject for frame 1.

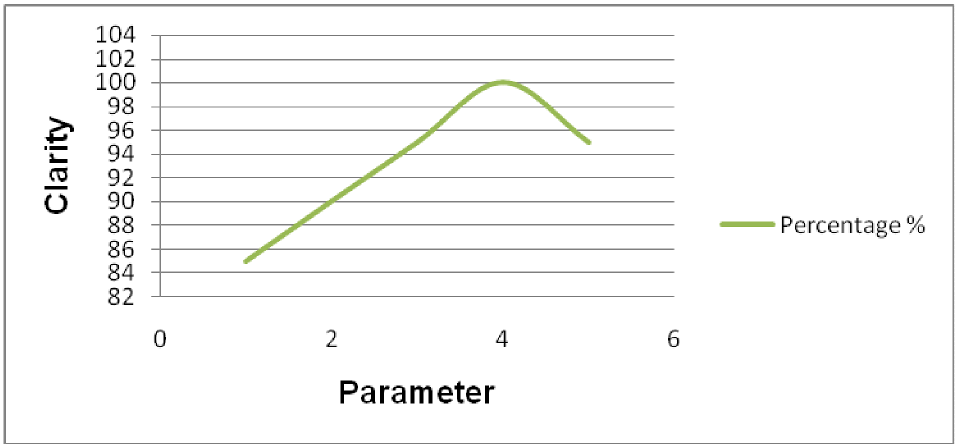


FIGURE 6. Graphical representation of clarity for frame 1,camera placed at 270 degree.

Parameter.	Signature Parameter	Subjects	Clarity	Percentage %
1	Distance between legs	20	18	90
2	Right knee angle	20	18	90
3	Left knee angle	20	19	95
4	Left thigh angle	20	20	100
5	Right thigh angle	20	20	100

TABLE. 3: Camera placed at 90 degree angle to the subject for frame 2.

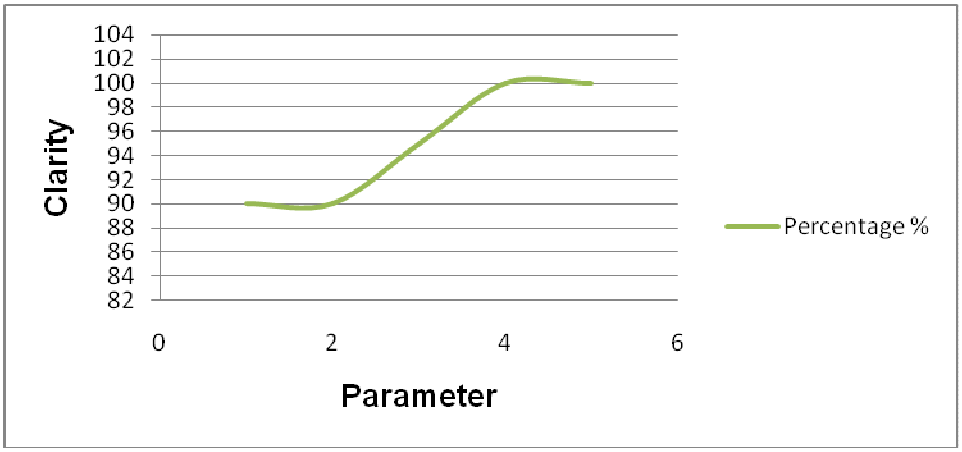


FIGURE 7: Graphical representation of clarity for frame 2,camera placed at 90 degree.

Parameter	Signature Parameter	Subjects	Clarity	Percentage %
1	Distance between legs	20	18	90
2	Right knee angle	20	18	90
3	Left knee angle	20	18	90
4	Left thigh angle	20	20	100
5	Right thigh angle	20	19	95

TABLE 4: Camera placed at 270 degree angle to the subject for frame 2.

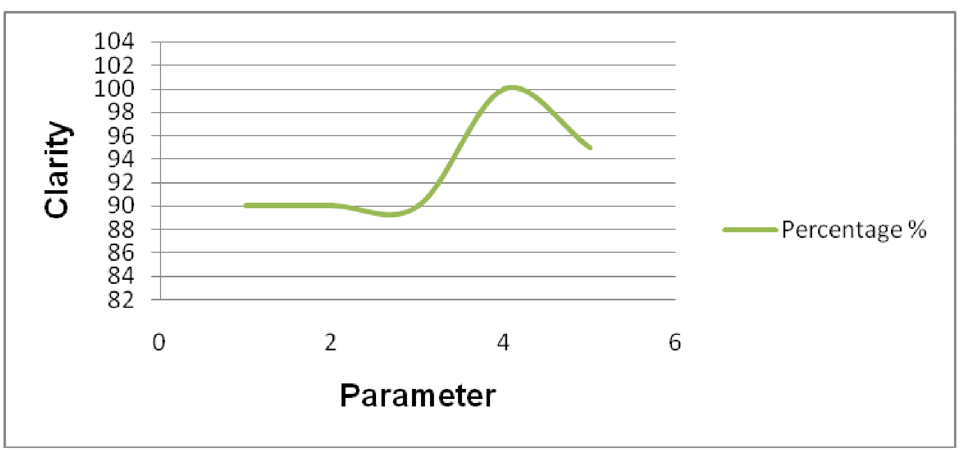


FIGURE 8. Graphical representation of clarity for frame 2,camera placed at 270 degree.

Parameter	Signature Parameter	Subjects	Clarity	Percentage %
1	Distance between legs	20	18	90
2	Right knee angle	20	19	95
3	Left knee angle	20	20	100
4	Left thigh angle	20	19	95
5	Right thigh angle	20	18	90

TABLE 5: Camera placed at 90 degree angle to the subject for frame 3.

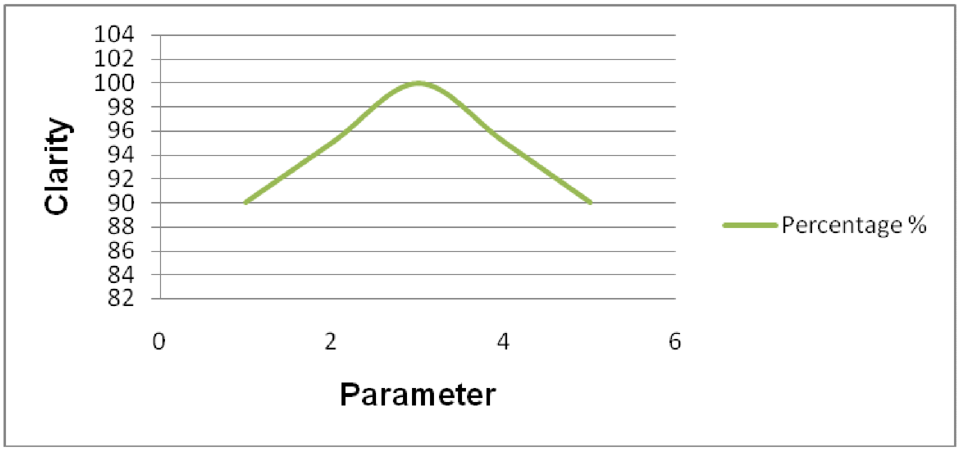


FIGURE 9: Graphical representation of clarity for frame 3,camera placed at 90 degree.

Parameter	Signature Parameter	Subjects	Clarity	Percentage %
1	Distance between legs	20	18	90
2	Right knee angle	20	17	85
3	Left knee angle	20	20	100
4	Left thigh angle	20	20	100
5	Right thigh angle	20	20	100

TABLE 6: Camera placed at 270 degree angle to the subject for frame 3.

FIGURE 10. Graphical representation of clarity for frame 3,camera placed at 270 degree.

3.2 Discussions

While placing camera at 90 degrees and 270 degrees for frame 1, it is found that the clarity for the parameter distance between the legs is higher, the y axis is taken as the reference axis for the subject. Therefore this can be used to extract gait signatures for better recognition. It is also observed that the parameter right thigh angle can also be considered for extraction of gait signature.

While placing camera at 90 degrees and 270 degrees for frame 2, it is found that the clarity for the parameter right thigh angle is higher. Therefore this can be used to extract gait signatures for better recognition.

While placing camera at 90 degrees and 270 degrees for frame 3, it is found that the clarity for the parameter left thigh angle is higher. Therefore this can be used to extract gait signatures for better recognition. So the proposed study gives positive results in the use of gait as a biometric measure. A gait signature is extracted using computer vision techniques and produced a high correct classification rate on a small database of subjects.

4. CONCLUSION & FUTURE WORK

We were trying to prove a feature-based method could be used for gait recognition. It was shown that a gait signature based on parametric model gives an improved correct clarity rates for human gait recognition. This research has shown that gait signatures can be extracted in a better way by using Hough transform for extracting temporal features from image sequences. As a pre-processing step, Canny edge detector is applied to produce edge images of the input data. The experimental results for a database of 20 subjects showed that the proposed method for gait analysis could extract parameters for the human gait model with a high fidelity to the original image data. When the camera is placed at 90 and 270 degrees it is found that most parameters listed in the research are providing us clarity. Since the lines are clearly visible they can easily be labeled and the distance and angle between them can be measured accurately. The proposed research gives highest results if the camera is placed at 90 degrees to the subject and it is recommended that the subjects must be made to pass through a area which has a white background because it will help in getting a better gait signature extraction model. The research achieved 100 percent clarity if the parameters angle of left, right leg and distance between the legs are analyzed at 90 degree angle. Further experimentation will shows how these novel techniques can extract and describe gait, and results will be presented how they can be used to recognise people by their gait. Furthermore, the new technique extracts the gait signature automatically from the image sequence, without human intervention, one of the major aims of this work.

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