An Efficient Gait Recognition System For Human Identification Using Modified ICA

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ABSTRACT

Biometric systems are becoming increasingly important, as they provide more reliable and efficient means of identity verification. Human identification at a distance has recently gained enormous interest among computer vision researchers. Gait recognition aims essentially to address this problem by recognising people based on the way they walk. In this paper, we propose an efficient self-similarity based gait recognition system for human identification using modified Independent Component Analysis (MICA). Initially the background modelling is done from a video sequence. Subsequently, the moving foreground objects in the individual image frames are segmented using the background subtraction algorithm. Then, the morphological skeleton operator is used to track the moving silhouettes of a walking figure. The MICA based on eigenspace transformation is then trained using the sequence of silhouette images. Finally, when a video sequence is fed, the proposed system recognizes the gait features and thereby humans, based on self-similarity measure. The proposed system is evaluated using gait databases and the experimentation on outdoor video sequences demonstrates that the proposed algorithm achieves a pleasing recognition performance.

KEYWORDS

Gait Recognition, Modified Independent Component Analysis (MICA), Human detection and tracking, Skeletonization, Morphological operator.

1. INTRODUCTION

Biometric systems for human identification at distance have ever been an increasing demand in various significant applications. Many biometric resources, for instance iris, fingerprint, palmprint, hand geometry have been systematically studied and employed in many systems. In spite of their widespread applications, these resources suffer from two main disadvantages: 1) Failure to match in low resolution images, pictures taken at a distance and 2) Necessitates user cooperation for accurate results [4]. For these reasons, innovative biometric recognition methods for human identification at a distance have been an urgent need for surveillance applications and gained immense attention among the computer vision community researchers in recent years. In this modern era, the integration of human motion analysis and biometrics has fascinated several security-sensitive environments such as military, banks, parks and airports etc and has turned out to be a popular research direction.

Human gait recognition works from the observation that an individual's walking style is unique and can be used for human identification. So as to recognize individual's walking characteristics, gait recognition includes visual cue extraction as well as classification. But the major issue here is the representation of the gait features in an efficient manner.

Two common categories of gait recognition are appearance-based and model-based approaches. Among the two, the appearance-based approaches suffer from changes in the appearance owing to the change of the viewing or walking directions [13]. But, model-based approaches extract the motion of the human body by means of fitting their models to the input images. Model-based ones are view and scale invariant and reflect in the kinematic characteristics of walking manner [7]. In general, a gait is considered as being composed of a sequence of kinematic characteristics of human (i.e. human motion) and most systems in existence recognize it by the similarity of these characteristics.

Compared with those traditional biometric features, such as face, iris, palm print and fingerprint, Gait has many unique advantages such as non-contact, non-invasive and perceivable at a distance. The introduction of gait has turned video-based intelligent security surveillance system [8] as a technology for the future [3].But, gait features have a high intra-personal variation in shape and also it is influenced by external conditions like footwear, clothing and load carrying. The variation of gaits is also influenced by mood, ground surface condition and time difference [12]. In spite of its individual pros and cons, gait recognition can be thought of as an effective means for human identification at a distance.

This research paper proposes a gait recognition system for human identification using modified Independent Component Analysis (MICA). The proposed system consists of three major modules namely, i) Human detection and tracking ii) Training using Modified ICA and iii) Human recognition. The algorithm is tested on a NLPR gait database consisting of images with subjects walking at different angles in an outdoor environment.

The rest of this paper is organized as follows: Section 2 presents a review of significant researches on Gait recognition. The proposed Gait recognition system based on MICA is presented in Section 3. Experimental results of the proposed system and the comparative analysis are presented in Section 4. Section 5 concludes the paper.

2. REVIEW OF RECENT RESEARCHES

Literature presents a number of researches based on appearance-based and model-based approaches for gait recognition. Of them, a few make use of Independent Component Analysis (ICA) for gait recognition. A concise description of those recent significant researches is presented below:

A simple method for gait recognition on the basis of human silhouettes using multiple feature representations and Independent Component Analysis (ICA) has been proposed by Jiwen Lu and Erhu Zhang [3]. In this they have offered a gait recognition method by fusing the multiple features and views on the basis of Genetic Fuzzy Support Vector Machine (GFSVM). Their proposed method is just recognizing human through three view fusion, i.e. perpendicularly, along and oblique with the direction of human walking, But in the real environment, the angle between the walker's direction and the camera is unpredictable. A useful experiment which can determine the sensitivity of the features from different views ought to be put forward and more multiple views fusion should be performed which can provide us with conviction results.

Dacheng Tao *et al.* [4] have focused on the representation of appearance-based models for human gait sequences. Two important novel representation models are offered, Gabor gait and Tensor gait. Some extensions of them are being made so as to improve upon their abilities for the recognition tasks. In their paper, three different approaches using Gabor functions have been developed to reduce the computational complexities in calculating the representation, in training classifiers, and in testing. Yang *et al.* [7] have made use of the variation analysis to acquire the dynamic region in Gait Energy Image (GEI), which reflects the walking manner of an individual. On the basis of this analysis, a dynamics weight mask is built in order to improve the dynamic region and suppress the noises on the unimportant regions. As a result a representation called enhanced GEI (EGEI) is obtained. Then, it is represented in low dimensional subspace by Gabor-based discriminative common vectors analysis.

Jianyi Liu *et al.* [9] have proposed a method called silhouette quality quantification (SQQ) to evaluate the quality of silhouette sequences. The quality of the sequence is examined by the SQQ, which analyzes on the basis of the 1D foreground-sum signal modelling as well as signal processing techniques. A common enhancement framework named silhouette quality weighting (SQW) is designed to enhance most of the current gait recognition algorithms by considering sequence quality and it can be considered as an immediate application of SQQ. The experiments are performed on the USF HumanID gait dataset v1.7 (with 71 subjects). Two instantiations of the SQW have been implemented on the basis of the Gait Energy Image (GEI). Enhanced recognition performance is obtained when compared to the original GEI as well as baseline methods.

Xiaoli Zhou and Bir Bhanu [10] have presented an approach that utilizes and integrates information from side face and gait at the feature level. The features of face and gait are obtained separately using principal component analysis (PCA) from enhanced side face image (ESFI) and gait energy image (GEI), respectively. Multiple discriminant analysis (MDA) has been made use on the concatenated features of face and gait to attain the discriminating synthetic features. Their process allows the generation of better features and also reduces the curse of dimensionality. It is illustrated from their experimental results that the synthetic features, encoding both sides face and gait information carry more discriminating power when compared to the individual biometrics features. This feature level fusion scheme outperforms the match score level as well as traditional feature level fusion schemes.

A shape variation-based frieze pattern representation as well as a symmetry map representation for gaits that capture the intra and inter-shape variations respectively is proposed by Seungkyu Lee et al. [12]. It works under the assumption that combining features into gait recognition improves recognition performance particularly, when there is a serious silhouette appearance variation between gallery as well as probe sequences. The algorithm is verified experimentally against a number of recent published gait recognition systems on CMU MoBo database and UoS HumanID image database. Their test results using only key frames have shown how the shape component contributes to gait recognition

A view-based approach in order to identify humans from their gait is proposed by Kale *et al.* [16]. Two distinct image features have been taken into account: the width of the outer contour of the binary silhouette of the walking person and the entire binary silhouette itself. The first method is referred to as the indirect approach in which the high-dimensional image feature is transformed to a lower dimensional space by means of generating the frame to exemplar (FED) distance. The gait information in the FED vector sequences is captured in a hidden Markov model (HMM) for compact and effective gait representation and recognition. In the second method, direct approach, works with the feature vector directly (as opposed to computing the FED) and trains the HMM.

A model-based moving feature extraction analysis is presented by Cunado *et al.* [22]. It automatically extracts and explains human gait for recognition. First, the gait signature is extracted directly using the Fourier series to depict the motion of the upper leg and then temporal evidence gathering techniques were applied in order to extract the moving model from a sequence of images. The potential performance benefits even in the presence of noise are highlighted by the results of the simulation. Classification makes use of the k-nearest neighbour rule applied to the Fourier components of the motion of the upper leg. It is illustrated from the experimental analysis that an enhanced classification rate is provided by the phase-weighted Fourier magnitude information when compared to the usage of the magnitude information.

3. GAIT RECOGNITION USING MODIFIED INDEPENDENT COMPONENT ANALYSIS

In this research, we propose an efficient human gait recognition system using modified Independent Component Analysis (MICA). The proposed gait recognition system characterizes gait in terms of a gait signature computed directly from the sequence of silhouettes. The system can be seen as a generic pattern recognizer composed of the three main modules namely, i) Human detection and tracking ii) Training using Modified ICA and iii) Human recognition. Initially, the moving objects (human) are segmented and tracked in each frame of the given video sequence (tracking module). Then, the person's identity is determined by training and testing using MICA on the extracted feature vectors (pattern recognition module). Fig.1. depicts the block diagram of the Proposed Gait Recognition System

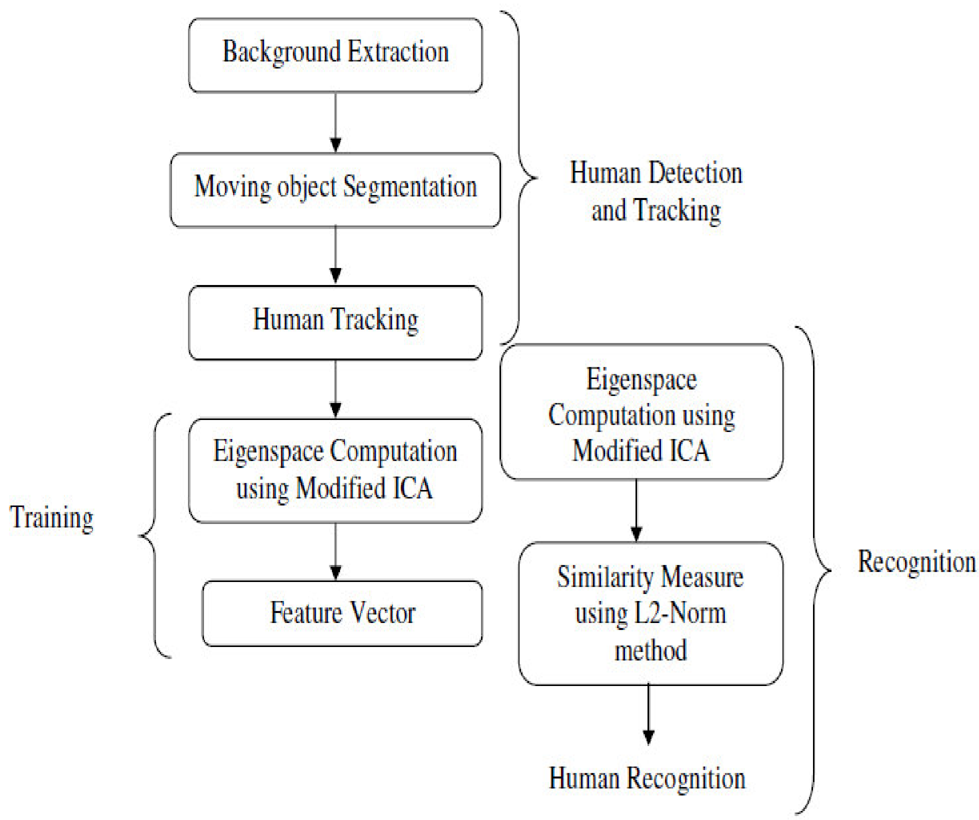

Figure 1. Block diagram of the Proposed Gait Recognition System

3.1. Human Detection and Tracking

Detection and tracking of human from a video sequence is the first step in gait recognition. The proposed system works with the assumption that the video sequence to be processed is captured by a static camera, and the only moving object in video sequence is the subject (person). Given a video sequence from a static camera, this module detects and tracks the moving silhouettes. This process comprises of two submodules:1) Foreground Modelling and 2) Human tracking using skeletonization operation.

3.1.1. Foreground Modelling

Background subtraction has been extensively used in foreground detection, where a fixed camera is usually used to capture dynamic scenes. To reliably generate the background image from video sequences is critical [5]. In the proposed system a simple motion detection method based on median value is adopted to model the background from the video sequence. Let P represent a video sequence having N image frames. The background $P(x, y)$ can be constructed using the formula:

$$P(x, y) = median[P_1(x, y), P_2(x, y), ...P_N(x, y)] \quad (1)$$

The value of $P(x, y)$ is the background brightness to be calculated in the pixel location (x, y) and $median$ symbolizes its median value. In the proposed gait recognition system, we have computed the median value rather than mean value of pixel intensities over N frames, since,

1) Distortion of the mean value for a large change in pixel intensities while the person moves. The median is impervious to spurious values and
2) Median value Computation is comparatively faster than the least mean square value [5]. Both these statements hold with the assumption that a person continuously moves around over the frames [24].

Subsequently, the extracted background and the original image frames are provided for the foreground modelling. The background subtraction algorithm subtracts the background from the original image frames to obtain the moving foreground objects i.e. human subject in binary.

3.1.2. Human Tracking

The next step is to the track the moving silhouettes of a walking figure from the extracted binary foreground image. We adopt the morphological skeleton operator for human tracking. Skeletonization is defined as the process for reducing foreground regions in a binary image to a skeletal remnant that greatly preserves the degree and connectivity of the original region while removing a good number of the original foreground pixels.

If A is a set in the plane, then the disk rD_x of radius r and centered at x is maximal with respect to A if it is contained in A and is not properly contained in any other disk contained in A. Blum [26] defines the skeleton (medial axis) of A, denoted by $SK(A)$, to be a set of centers of all disks maximal with respect to A. Each point x in the skeleton corresponds to the radius of the maximal disk centered at x. The skeleton function $S(x)$ returns the radius of the maximal disk centered at x. The r^{th} skeleton subset of $SK(A)$, denoted by $S_r(A)$, is defined to be the set of all skeleton points x such that $S(x) = r$. An important property of the skeleton function is that, it contains all necessary information to reconstruct the original image, i.e.

$$A = \bigcup_{r>0} [S_r(A) \oplus rD] \quad (2)$$

The above fact has been made use of to efficiently encode binary images by their skeletons [27]. Lantuejoul [28] has shown that the skeleton can be defined by means of morphological operations,

$$SK(A) = \bigcup_{r>0} S_r(A) = \bigcup_{r>0} [(A \Theta rD) - (A \Theta rD) \circ drD] \quad (3)$$

where rD denotes the open disk of radius r, drD is the closed disk of infinitely small radius dr and "-" denotes set difference [29].

3.2. Training using MICA

We use the modified Independent Component Analysis (MICA) to extract and train the gait features . The purpose of training the skeletonised silhouettes with the modified ICA is to attain a number of independent components to represent the original gait features from a high-dimensional measurement space to a low-dimensional Eigenspace. The concept of ICA can be noticed as a generational of Principal Component Analysis (PCA) and its fundamental idea is to symbolize a set of random variables using basic functions, where the components are statistically independent or as independent as possible [25]. ICA aims to identify the vectors that describe data to its best in terms of reproducibility; nevertheless these vectors may not comprise of any effective information for classification, and may eliminate discriminative information [30]. The training process is illustrated as follows:

Let $\{x_1, x_2, x_3, ..., x_n\}$ be the N samples from L classes $\{w_1, w_2, w_3, ..., w_L\}$ for training and each class represents a sequence of distance signals of one subject's gait and $p(\mathbf{x})$ their mixture distribution. In a sequel, it is assumed that a priori probabilities $P(w_i)$, $\mathrm{i} = 1,2,...,\mathrm{L}$, are known. Let m and $\sum$ denote the mean vector and the covariance matrix of samples, respectively. ICA algorithm can be used to find a subspace whose basis vectors correspond to the maximum variance directions in the original n dimensional space.

$$m = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{4}$$

$$\sum = \frac{1}{n}\sum_{i=1}^{n} (x_i - m)(x_i - m)^T \tag{5}$$

If the rank of the matrix $\sum$ is N, then we can compute N nonzero eigenvalues $\lambda_1; \lambda_2; \lambda_3; .....; \lambda_N$ and the associated eigenvectors $E_1; E_2; E_3; .....; E_N$ based on SVD (Singular Value Decomposition) [33]. The orthonormal eigenvectors of $\sum$ corresponding to the $M \le N$ largest eigenvalues $\{\lambda_1, \lambda_2, \lambda_3, ..., \lambda_N\}$ are,

$$w_j = \frac{1}{\sqrt{\lambda_j}}(x_i - m)^T E_j \tag{6}$$

Where $j = 1,..,M$. After the projection of input vector x onto the eigenvectors w_j, we obtain the j^{th} feature, $Y_j = {w_j}^T (x_i - m)^T$

$$Y_j = \frac{1}{\sqrt{\lambda_j}}(x_i - m){E_j}^T (x)^T \tag{7}$$

Thus the feature vector is given by, $Y = Rx^T$ (8)

Where $R = {w_j}^T = \frac{1}{\sqrt{\lambda_j}}(x_i - m){E_j}^T$

which represents the projection operator formed by e_j in its row.

3.3. Human Recognition

With the trained MICA in hand, the final step is to test the effectiveness of the proposed system for gait recognition. Gait recognition has been a traditional pattern classification problem which can be solved by calculating the similarities between instances in the training database and the test database. Gait can be described as a kind of spatiotemporal motion pattern; hence we transform the input gait video sequence into an equivalent parametric eigenspace using the modified ICA (section 3.2.1). Then, based on the similarity measurement computed between the reference patterns and test sample in the parametric eigenspace, we achieve gait recognition. To be more particular, we have used the L2 Norm Distance for measuring the similarity between two gaits. The L2 Norm Distance measure is calculated as,

$d = \|P_R - P_N\|_2^2$, where $\|\cdot\|_2$ denotes the l^2-norm, P_R the reference pattern and P_N the new pattern of video sequence.

4. EXPERIMENTAL RESULTS AND ANALYSIS

Extensive experimentation has been carried out to portray the effectiveness of the proposed system and a detailed comparative analysis and discussion on the results are presented in the sub-sections below.

4.1. Data Acquisition

The experimentation of the proposed gait recognition system is performed with images publicly available in the National Laboratory of Pattern Recognition (NLPR) gait database. A brief description of the gait database taken for study: A digital camera (Panasonic NV-DX100EN) fixed on the tripod was used for capturing gait sequences in an open-air environment. The images correspond to a single subject poignant in the field of view without occlusion.

Figure 2. Sample image sequences in the NLPR gait database

The subjects were asked to walk to a stationary camera frontally, laterally, and obliquely (0^o, 45^o, 90^o with respect to the image plane) respectively. The resulting Chinese National Laboratory of Pattern Recognition (NLPR) gait database [6] included 20 subjects and four sequences per view per subject. The properties of the images are: 24-bit full colour, capturing rate of 25 frames per second and the original resolution is 352 x 240. The database comprises a total of 240 sequences. The length of each sequence varies with the time each person takes to traverse the field of view. Some of those image samples are shown in Fig. 2.

4.2. Results

This subsection contains the results of the experiments. The publicly available NLPR gait database is employed in training the MICA. The intermediate results of the presented gait recognition system are depicted in Figure 3, Figure 4, Figure 5 and Figure 6 respectively.

Figure 3**.** Sample images of a subject in the database

Figure 4. Extracted Background

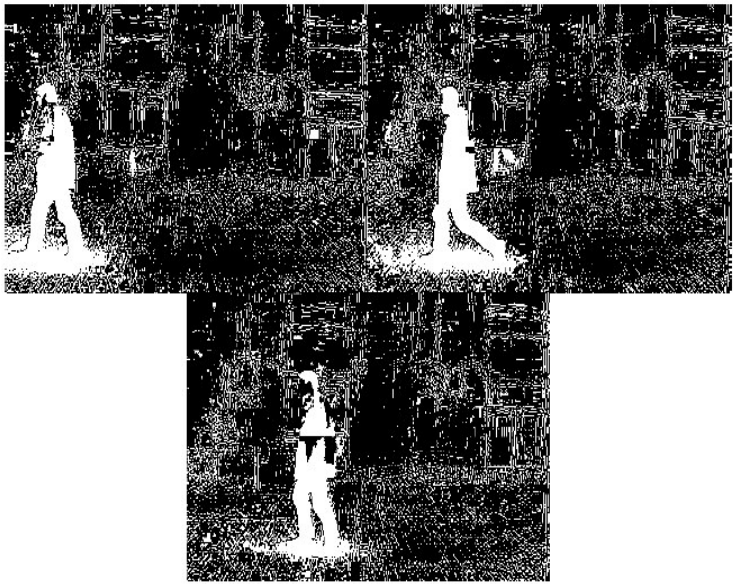

Figure 5**.** Extracted silhouettes of frames in Figure. 4

Figure 6. Human tracked by skeletonization

We have evaluated the effectiveness of the proposed system with a set of gait images available in the NLPR database. Moreover, we have measured the False Acceptance Rate (FAR) and False Rejection Rate (FRR) corresponding to the proposed gait recognition system and presented in Table. 1.

Table 1. Results of evaluation

Data (in different degrees & view)	**False Acceptance Rate (%)**	**False Rejection Rate (%)**
0° Left View	2.8986	1.2769
0° Right View	2.6571	1.6571
45° Left View	1.9124	2.0124
45° Right View	1.8431	1.8139
90° Front View	1.5615	1.0235
90° Back View	2.91206	2.8766

4.3. Comparative Analysis

A comparative analysis of the proposed approach for gait recognition with existing techniques like Principal Component Analysis (PCA) and Independent Component Analysis (ICA), was performed using the images available in the NLPR database. Every individual image has been recorded at four different views and three different angles, namely laterally (0^o), obliquely (45^o) and frontally (90^o) walking on their normal speed. For the techniques adopted for comparison, FRR and FAR determined was calculated and the results are tabulated (Table. 2). The corresponding FRR and FAR graphs are depicted in Figure 7 and Figure 8 respectively.

Table 2. Comparison results of the proposed system with PCA and ICA techniques

Data set Angle view	**FRR (%)**			**FAR (%)**		
	Proposed	ICA	PCA	Proposed	ICA	PCA
0° , Left	1.2769	2.0989	2.2869	2.8986	3.2211	3.8961
0° , Right	1.6571	2.8001	3.8561	2.6571	2.3930	2.9972
45° , Left	2.0124	2.6689	2.7729	1.9124	1.9811	2.0121
45° , Right	1.8139	2.1819	2.0918	1.8431	1.4234	1.9930
90° , Front	1.0235	1.5821	1.8815	1.5615	2.0001	2.0611
90° , Back	2.8766	2.3896	2.9836	2.9106	2.7201	3.0201

From the graphs , it is evident that the proposed system outperforms the normal gait recognition systems that employ PCA and ICA for gait recognition. Thereby, the proposed approach for gait recognition can serve as an effective tool for human identification.

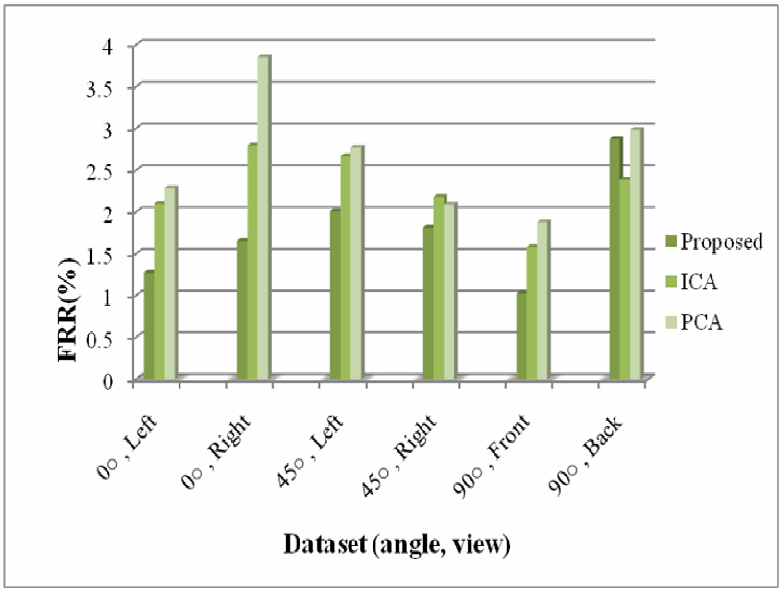

Figure 7. FRR graph

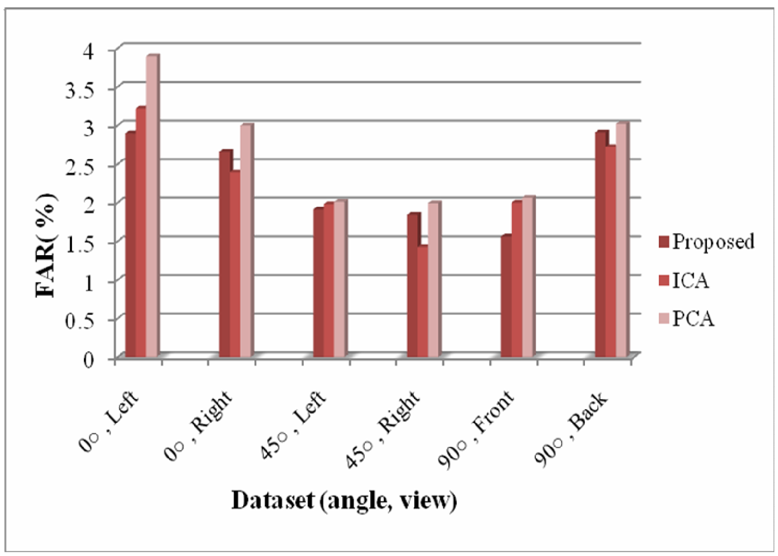

Figure 8. FAR graph

5. CONCLUSION

With mounting demands for visual surveillance systems, human identification at a distance has recently emerged as an area of significant interest. Gait is being considered as an impending behavioural feature and many allied studies have illustrated that it can be used as a valuable biometric feature for human recognition. The development of computer vision techniques has also assured that vision based automatic gait analysis can be gradually achieved. The proposed system has been tested on the gait databases and, the extensive experimental results on outdoor image sequences demonstrated that the proposed system possesses a pleasing recognition performance.

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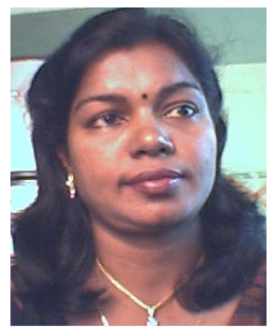

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