Human gait recognition based on feature extraction of support vector machine and pattern network algorithm

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Abstract. Human recognition based on biometric information is important due to its reliability in identity verification. Gait recognition has ability to recognize individuals from a distance. "This study includes human gait recognition based firstly on support vector machine (SVM) and secondly on PatternNet neural network". "Three feature extraction and dimension reduction algorithms were used to increase the recognition performance of these algorithms". These algorithms are: "Liner Discriminant Analysis (LDA),Discrete Fourier Transform (DFT)and Discrete Cosine Transform (DCT)."The performances were compared using mean square error (MSE), PSNR and recognition rate to identify the best model and algorithm. The best results were obtained from the patternNet model especially when it was trained with TrainLM were correct classification rates (CCR) (98%), MSE (0.001) and PSNR (42) where "obtained when adopting LDA algorithm in comparison with DFT and DCT".

Keywords. Gait Recognition(GR), PatternNet, Support Vector Machine (SVM),Liner Discriminant Analysis (LDA), Discrete Fourier Transform (DFT),and Discrete Cosine Transform (DCT).

1. Introduction
In recent years, the growing need for surveillance systems in "banks, airports and human remote identification at a distance" has gained increasing interest from computer field". Where used to overcomes the challenges of other distinctions such as "finger print and face" recognition [1]. It is important to make changes in gait pattern accurately to understand the correct behaviour of human [2]."Human identification using gait is an individual way of identifying each person by walking and related to behavioural characteristics of biometric recognition". Its less disturbing method because it makes the possibility to identify people at a distance [3]. In recent years a series of scientific research has been achieved in this field[4][5].Many researches used "different -techniques and algorithms" for GR [1..7]. Zhaoxiang Z.,Maodi H.,Yunhong W. (2011) [8] "They suggested that a further trends of GR should be more robust features extracted ,which is more accurate of spatial and temporal information and improve gait in real-time surveillance systems". While Jin W., Mary S.,Saeid N., Abbas K., (2010) [9] provided a survey of GR that includes : (1-"gait image representation",2- "feature dimensionality reduction" and 3-"gait classification" ). In recent years used ANN algorithms in many researches related to GR[10..16].

(SVM) is a good way of "binary classification". So many researchers recently developed SVM training algorithms when they noticed increasing dataset [17..20]. Linear discriminant analysis (LDA) used in many fields to extract features because it reduces the dimensions of data so as to maintain as much information as possible [21]. Which has made Many researchers use them in their for GR [5][22][23].

Saeid Fazli, (2011) [5] focused on three steps of GR : "preprocessing; Feature Extraction(FE); and classification". They standardized data then used "LDA and SVM".
"Researchers Jang-Hee Y., Doosung H., Mark N. (2005) [22] described the human gender system using a set of human gait data. This system contain of 3 steps: "1-Discover human motion using image sequences", "2-extraction pointprint of gait through common points and angles for human gait", and "3-motion analysis and feature extraction for classifying gender in gait patterns". Using SVM to "classifier gender in gait patterns for 100 person". Their experiments performed well for gait classification (96%) for this person. The researchers Arun J., Shashi B. Jaspreet K. (2014) [23] used BPNN and SVM to detected binary silhouette from images frame and then extracted a feature from each frame. Many features have been used such as "center of mass, step size length, and cycle length are talking as key feature". The data base of these experiments were conducted on input video for gait person.

"Many(FE) algorithms were suggested in the literature for reduce image dimensionality,(LDA) is statistical approach to reduce dimensionality while preserving class discriminatory information"[21], "computes an optimal transformation between class distance"[25..29]. "While Discrete Cosine Transform (DCT) is a transformation technique used in image processing [30-33] that had been introduced by Ahmed, Natarajan and Rao (1974) [33]. DCT had been used by literature researches [34..39] as a (FE) in recognition process for dimension reduction. The Fourier transform(FT) including Discrete Fourier transform (DFT) represents primary tool of digital signal processing and plays an important role in image processing applications such as enhancement, analysis, restoration, and compression" [30][31].

"DFT converts a finite list of equally spaced samples of a function into the list of coefficients of a finite combination of complex sinusoids, ordered by their frequencies, that has those same sample values. It can be said to convert the sampled function from its original domain to the frequency domain. DFT is used by many literature studies for recognition applications such as iris recognition [40-42]; gait detection [43]; and face recognition "[44].

This research is based on using "ANN, SVM for GR" and contain the parts: "section 2 includes literature related to ANN for GR, Section 3 includes detailed description of SVM, whereas section 4 give a (FE) Algorithms preview of LDA,DFT,DCT. Section 5 includes research methodology and section 6 includes results. Finally section 7 concludes this work".

2. ANN for GR
This section shows the use of ANN in the GR field. Jang-Hee, et al (2008) [10] used (BPNN) for recognizing persons by their gait. They used set of 2D images to represent the person gait that is data for (FE). "The process of GR include 3 parts preprocessing; feature extraction; and recognition " , so Saeid Fazli, Hadis A., Maryam S. (2010) [11] used "ANN -(MLP) to compare the CCR values for the images of persons. Also Sanjeev S., Ritu T., Anupam S. Vikas S. (2011) [12] and Narasimhulu and Jilani (2012) [13] used "Fourier (FFT) and ANN- BPNN for recognizing humans of distance by their gait patterns". Sharma and Bansa (2013) [14] used input video to detect frame of a "binary silhouette" for a person gait and (FE) from each image, then used "BPNN for GR". At the same time Gaba and Kaur (2013) [15] "converted input video into frame" and "BPNN+MDA , BPNN+LDA techniques are used for training and testing purpose". Finally, Parneet Kaur (2013) [16] "detected binary silhouette of a walking person from each frame then extracted feature from each frame and used NN , ENN technique to training and testing purpose".

3. Support Vector Machine"
"SVM can be regarded as one of the successful techniques for classification and optimal discriminate method based on Bayesian learning theory [18][19][45] performs mapping of data into a higher dimensional feature space and finds linear separating hyper plane with maximal margin to separate data [20]and can be used when your data has exactly two classes. SVM classifies data by finding best hyper plane that separates all data points of one class from those of other class. Best hyper plane for SVM means one with largest margin between the two classes. Margin means maximal width of slab parallel to hyper plane that has no interior data points. Support vectors(SV) are data points that are closest to separating hyperplane. These points are on boundary of slab [24]. The data for training is a set of points xi along with their categories yi. For some dimension d, the xi # Rd, and the yi = ±1. The equation of a hyper plane is <w, x> + b = 0, where w # Rd, <w, x> is the inner (dot) product of w and x, and b is real [24]".

The following problem defines best separating hyper plane. Find w and b that minimize ||w|| such that for all data points (xi,yi), yi (<w, xi> + b) ≥ 1. SV are xi on boundary, those for which yi (<w, xi> + b) = 1.
For mathematical convenience, problem is usually given as equivalent problem of minimizing \(<w, w>/2. This is quadratic programming problem. Optimal solution \((w^*, b^*)\) enables classification of vector \(z\) as follows [24]:

\[
\text{class}(z) = \text{sign}(<w, z> + b) \quad \ldots \ldots \ldots \ldots \ldots (1)
\]

The dual is “standard quadratic programming problem”. “To solve and obtain the dual quadratic programming problem, take positive Lagrange multipliers \(\alpha_i\) multiplied by each constraint, and subtract from objective function [24]:

\[
L_{pp} = \frac{1}{2} <w, w> - \sum_{i} \alpha_i \left(y_i(<w, x_i> + b) - 1\right) \quad \ldots \ldots \ldots \ldots \ldots (2)
\]

"Where \(L_{pp}\) is a stationary point over \(w\) and \(b\) [24]. Setting gradient of \(L_p\) to 0, to get [24]: \(w=\text{sum}(\alpha_i y_i x_i)\)"

"Sub situating into \(L_p\), calculate dual \(L_D\): \(L_D = \sum_i \alpha_i - \frac{1}{2} \sum_i \sum_j \alpha_i \alpha_j y_i y_j x_i x_j \quad \ldots \ldots \ldots \ldots \ldots (3)"

"which maximize over \(\alpha_i \geq 0\). Many \(\alpha_i\) are 0 at maximum. Nonzero \(\alpha_i\) in solution to dual problem define hyper plane, Gives \(w\) as sum of \(\alpha_i y_i x_i\). Data points \(x_i\) corresponding to nonzero \(\alpha_i\) are support vectors.

The derivative of \(L_D\) with respect to nonzero \(\alpha_i\) is 0 at optimum [24]. This gives: \(y_i(<w, x_i> + b) - 1 = 0\). This gives value of \(b\) at solution, by taking any \(i\) with nonzero \(\alpha_i\).

Data might not allow for a separating hyper plane. Therefore, SVM can use soft margin (hyper plane) that separates many data points [24]. There are two standard formulations of soft margins that involve adding slack variables \(s_i\) and penalty parameter \(C\). The \(L^1\)-norm problem is [24]:

\[
\min_{w, b, s} \left(\frac{1}{2} <w, w> + C \sum_s\right) \quad \ldots \ldots \ldots \ldots \ldots (4)
\]

such that: \(y_i(<w, x_i> + b) \geq 1 - s_i \quad \text{or} \quad s_i \geq 0 \quad \ldots \ldots \ldots \ldots \ldots (5)\)

"The \(L^1\)-norm refers to using \(s_i\) as slack variables instead of their squares. The SMO svmtrain method minimizes the \(L^1\)-norm problem. The \(L^2\)-norm problem is used eq 4 where \(S_i^2\)"

"We can see increasing \(C\) places more weight on slack variables \(s_i\) using these formulations. This meaning optimization attempts to make stricter separation between classes. Reducing \(C\) towards 0 makes misclassification less important [24]. For easier calculations, \(L^1\) dual problem to soft-margin formulation. Using Lagrange multipliers \(\mu_i\) function to minimize for \(L^1\)-norm problem is [24]:"

\[
L_{pp} = \frac{1}{2} <w, w> - C \sum_s \sum_i \alpha_i \left(y_i(<w, x_i> + b) - (1 - s_i)\right) - \sum_i \mu_i s_i \quad \ldots \ldots \ldots \ldots \ldots (6)
\]

"Using stationary point of \(L_p\) over \(w, b, \) and positive \(s_i. Setting gradient of \(L_p\) to 0 to get [24]:"

\[
b = \sum_i \alpha_i y_i x_i \quad \sum_i \alpha_i y_i = 0 \quad \alpha_i y_i x_i \geq 0 \quad \ldots \ldots \ldots \ldots \ldots (7)\]

4. Feature Extraction Algorithms

It can be used” many feature extraction algorithms to extract the main features of image for recognition process”.

A. Linear Discriminate Analysis (LDA)

"LDA can be used to reduce dimensionality, classification and preserve class discriminatory information as much as possible. The LDA includes the following steps [25-30]:"

1. " Set of \(D\)-dimensional samples \(x_1, x_2, \ldots, x_N\) belong to class \(\omega_1\) and \(N_2\) to class \(\omega_2\).
2. Find to obtain scalar \(y\) by projecting samples \(x\) onto line \(y\) where \(y = w^T x\).
3. Select scalar that maximizes the separability of scalars of all possible lines."
4. Define measure of separation to find a good projection vector.
5. compute mean vector of each class in x-space and y-space according to Eq.8: \( \mu_i = w^T \mu_i \ldots \ldots (8) \)
6. "Choose the distance between the projected means using Eq.9 [25-30]: 
   \[ d_i = |w^T (\mu_i - \mu_j)| \ldots \ldots (9) \]

B. Discrete Fourier Transform (DFT)
The input samples to DFT are real numbers and the output coefficients are complex. The combination of sinusoids obtained using DFT is periodic with that same period [31]. If \( f(m,n) \) is a function of two discrete spatial variables \( m \) and \( n \), a 2D Fourier transform(FT) of \( f(m,n) \) by Eq.14 [32]:

\[
FT(w_1,w_2) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} f(m,n) e^{-jw_1m} e^{-jw_2n} \ldots \ldots (10)
\]

"w1, w2: frequency variables and their units are radians per sample".
F(w1, w2): frequency-domain of \( f(m,n) \) with period 2\( \pi \). For range \(-\pi \leq w1, w2 \leq \pi \).
' F(0,0) is constant of FT. FT is used on a computer because 1- the input/output of DFT are discrete ,2-the fast algorithm for computing DFT known fast Fourier transform (FFT)". "The values F(p, q) are called DFT of \( f(m,n) \) in Eq.11, Eq12 [32]

\[
F(p,q) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} f(m,n) e^{-j(\frac{2\pi}{M})pm} e^{-j(\frac{2\pi}{N})qn} \ldots \ldots (11)
\]

\[
f(m,n) = \frac{1}{MN} \sum_{p=0}^{M-1} \sum_{q=0}^{N-1} f(p,q) e^{j(\frac{2\pi}{M})pm} e^{j(\frac{2\pi}{N})qn} \ldots \ldots (12)
\]

Where: "p or m=0,1,..,M-1 ", " q or n=0,1,..,N-1"

C. Discrete Cosine Transform (DCT)
"DCT transforms input signal or image from spatial domain to frequency domain. DCT uses cosine base functions. DCT of \( N\times M \) image \( f(x,y) \) is defined by Eq.17 [33-40]:

\[
F(u,v) = \alpha(u) \alpha(v) \sum_{x=0}^{N-1} \sum_{y=0}^{M-1} \cos \left[ \frac{\pi u}{2N} (2x+1) \right] \cos \left[ \frac{\pi v}{2M} (2y+1) \right] f(x,y) \ldots (13)
\]

Where: "f(x,y): intensity of pixel in row x and column y, \( u = 0,1,\ldots ,N-1, \quad v = 0,1,\ldots ,M-1\)"
\( \alpha(u) = \sqrt{1/N} \), \( \alpha(v) = \sqrt{2/M} \) : [40-47]:

"Much of signal energy noise at low frequencies for most images. These are relocated to upper-left corner of DCT array. Lower-right values of DCT array represent higher frequencies and turn out to be small to be removed with little visible distortion especially when \( u \) and \( v \) approach respectively the sub-image width and height. This means that the DCT is an effective tool that can pack the most effective features of input image into the fewest coefficients. The recognition rate can be effected by number of DCT coefficients" [33-40].

5. Research Methodology
The research methodology depends on a database taken from CASIA [46 database with different views that have different " silhouette in person’s height and width , the program take images for 15 persons from database , with 3 angles(0,45,90) , 4 cases for each angle and 50 states for each case equal 9000 images for database". "Each size image ( 240x352 ) dimension and resized to 190x100".
A. **GR system**

1. "Read 50 images for each one of the 4 states”.
2. " resize each size image(240×352) to (190×100) size image the main goal is producing a dataset with the same position of the person in the middle of each frame and same size in whole image sequence. The idea is to fix the head for each frame in a predefined position and resize the body to achieve a preset height. We perform a three stage preprocessing: extract rectangle including the person without extra black pixels and obtain height and width of the person; sequence is calculated and each frame is converted to biggest height and width; and finally, move head of each frame in a fixed point. Figure 1 explain resize process".

![Figure 1. Resize process](image)

3. "The OR logical gate will be applied on each 50 images to produce only one image for each case of the 4 cases. This is applied for each angle. Then the total number of images resulted from this process are: 15 × 3 × 4 × 1= 180 images for 15 persons. This process is explained in Figure 2 and Figure 3. Figure 2 shows the image of person 1 after applying the OR gate on 50 images of gait of person1 for angle 0°. Whereas Figure 3 shows the image of person 2 after applying the OR gate on 50 images of gait of person2 for angle 90°".

![Figure 2. "applying OR for per1 angle 0"](image)

![Figure 3. "applying OR for per2 angle 90"](image)

4. "Convert each image after applying OR gate from 2D array to 1D array. Compute centroid shape (xc, yc). After converting outer contour to distance signal. Every element of distance signal S={d1, d2, di,… dNb} is distance between point of outer contour and shape’s centroid ".

\[ d_i = \sqrt{(x_i - x_c)^2 + (y_i - y_c)^2} \]  

(14)

5. "Then, normalized these distance signals with considering magnitude and size"
6. The feature extraction of the persons will be extracted by applying LDA or DFT or DCT algorithm.

7. The first experiment is applied "SVM algorithm and PatternNet ANN algorithm will be executed in the second experiments". As shows in Figure 4 while Figure 5 Show "PatternNet models".

![GR system](image)

**Figure 4. GR system**

**B. PatternNet Model**

PatternNet Model is contain:
1. Input layer = 190×100 = 19000 neurons.
2. "Output layer = 19 neurons::(4-bit)of (15) persons + (2bits) for 3 angles + 2bits for 4 cases."
3. The number of cases that will input(epoch) to the network(50*3*4) = 180 images for inputs and outputs.

![PatternNet model](image)

**Figure 5. PatternNet model**

6. **Experimental Results**

Many experiments were conducted for the GR system on the "CASIA Gait Database" [46. The DataBase of executed program includes "15 persons with 3 angles (0, 45 and 90), each angle with 4 cases and 50 images for each case. Finally the database contain 9000 images each size images is 240×352 and resized images to 190×100". The performance of the suggested method is computed using "correct classification rates (CCR)" using Eq.15:

\[
CCR = \frac{N_c}{N} \times 100 \ldots \ldots \ldots \ldots \ldots (15)
\]

Where: "NC is the total number of correct recognition samples, While N is the number of total gait samples". The experiments were based firstly on executing one of ( LDA, DFT, DCT ) with SVM and secondly one of ( LDA, DFT, DCT ) with PatternNet ANN. Tables 1, 2 and 3 show the values of "CCR,PSNR and MSE" for the experiments.

| Table 1. Result "PatternNet(LM) and SVM with (LDA) " | | |
From table 1, when extract features by LDA algorithm we noted that the values CCR for all persons did not exceed (95) when we used SVM, but when we used PatterNet(LM) the value reach CCR is (98). Also the values of PSNR for all persons reach (42) when we used the PatterNet(LM) when as did not exceed (39) in SVM, while the MSE reduced to (0.0011) by using PatterNet(LM) while it reach (0.0087) by using SVM.

| CCR  | PSNR | MSE   |
|------|------|-------|
| Per1 | 98.4 | 95.6  | 42   | 39   | 0.0011 | 0.0056 |
| Per2 | 98.6 | 95.3  | 41   | 39   | 0.0010 | 0.0087 |
| Per3 | 98.7 | 95.5  | 42   | 38   | 0.0012 | 0.0067 |
| Per4 | 98.3 | 96.6  | 42   | 39   | 0.0011 | 0.0082 |
| Per50| 98.52| 95.1  | 42   | 38   | 0.0010 | 0.0071 |

From table 2, we noted that when we used DFT algorithm to extract features images that the values CCR for all persons did not exceed (95) when we used SVM, but when we used PatterNet(LM) the value reach CCR is (96). Also the values of PSNR for all persons reach (38) when we used the PatterNet(LM) when as did not exceed (35) in SVM, while the MSE reduced to (0.0057) by using PatterNet(LM) while it reach (0.0143) by using SVM.

Table 2. Result " PatternNet(LM) and SVM with (DFT) "

| CCR  | PSNR | MSE   |
|------|------|-------|
| Per1 | 97.6 | 95.11 | 38   | 35.41 | 0.0057 | 0.0143 |
| Per2 | 96.5 | 95.21 | 38   | 35.33 | 0.0073 | 0.0145 |
| Per3 | 96.2 | 95.41 | 38   | 35.12 | 0.0067 | 0.0161 |
| Per4 | 96.1 | 95.32 | 36   | 35.35 | 0.0078 | 0.0154 |
| Per50| 96.55| 95.62 | 37   | 35.63 | 0.0075 | 0.0168 |

From table 3, we noted that when we used DCT algorithm to extract features images that the values CCR for all persons did not exceed (95) when we apply the SVM, while the value reach (96) by using PatterNet(LM) with applying DCT algorithm to extract features images, also the values of PSNR for all persons reach (37) when we used the PatterNet(LM) when as did not exceed (35) in SVM. While the MSE reduced to (0.0067) by using PatterNet(LM) and reach it (0.0154) for apply SVM.

Comparative the pervious tables we noted that the LDA algorithm is better than the other algorithms extract more features for any person images with less error to improve recognition achievement and more accurate, we notes that from raising the value of PSNR that reach (42) when we used LDA algorithm, while the values of CCR are (98%) and MSE are (0.001).

Table 3. Results " PatternNet(LM) and SVM with (DCT) "

| CCR  | PSNR | MSE   |
|------|------|-------|
| Per1 | 96.54| 95.554| 37   | 35.46 | 0.0087 | 0.0165 |
| Per2 | 96.66| 95.674| 37.5 | 35.78 | 0.0056 | 0.0155 |
| Per3 | 96.55| 95.532| 37.7 | 35.23 | 0.0078 | 0.0178 |
| Per4 | 96.68| 95.543| 37.82| 35.75 | 0.0065 | 0.0154 |
| Per50| 96.63| 95.423| 37.32| 35.56 | 0.0067 | 0.0187 |

7. Conclusion

"GR is a type of biometric recognition and related to the behavioural characteristics of biometric recognition. Person identification using Gait is method to identify an individual by the way he walk. A GR system was implemented in this paper firstly using one of LDA, DFT, DCT with SVM and secondly with PatternNet ANN. The GR algorithm was implemented using MATHLAB 2013. The DataBase of the GR program includes "15 persons which selected with different angles (0, 45 and 90), (4 cases) and (50 states), The final of database contain 9000 images". Many experiments were conducted for executing the GR program based on two ways.
The experimental results showed that the best values of CCR were taken using PatternNet ANN. Also showed that the lowest values of MSE were taken from executing PatternNet ANN. The algorithm (LDA) is the best comparing with DFT and DCT for extracting more features from any person image for any case with less error and more performance recognition. "The best results were obtained from the patternNet model especially when it was trained with TrainLM. Its CCR was (98%) with MSE (0.0011) and PSNR (42) that obtained when adopting LDA algorithm comparing with DFT and DCT”.

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