GAIT RECOGNITION USING PRINCIPLE COMPONENT ANALYSIS IMPLEMENTED ON DSP PROCESSOR

by

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LIST OF SYMBOLS

λ	Eigenvalues Diagonal Matrix
A	N-Dimensional Vector 1
A_s	Training Average Silhouette Frame
B	N-Dimensional Vector 2
C	Two-Dimensional Covariance Matrix
CCD	Code Composer Studio
D_{AB}	Distance Between Two N-Dimensional Vectors
$D_{i,j}$	Two-Dimensional Euclidean Distance Matrix
D_{mi}	Minimum Euclidean Distances Vector
DSP	Digital Signal Processor
E	Empirical Mean Row Vector
e	Two-Dimensional Eigenvectors Matrix
$e_{projected}$	Eigenvectors Matrix After projection
F	Features Vectors Matrix of Training Data
Gs	Gait Silhouettes Sequence
k	Frame Number
M	Total Number of Image Vectors

m Vector Number

N Total Number of Frames

n Number of Silhouette Frames

P Feature Space

R Features Vectors Matrix of The Testing Data

S_{m1} Data Sample 1

S_{m2} Data Sample 2

T_s Testing Training Average Silhouette Frame

X Two-Dimensional Zero-Mean Testing Data Matrix

Z Two-Dimensional Zero-Mean Training Data Matrix

Z^T Transpose of The Two-Dimensional Zero-Mean Matrix

LIST OF ABBREVIATIONS

ACDA	Adaptive Component and Discrimination Analysis
AEI	Adjacent Energy Image
AVG	Averages of Different Sequences
CCS	Code Composer Studio
CMC	Cumulative Match Characteristics
CST	Canonical Space Transformation
CDA	Component and Discrimination Analysis
CA	Canonical Analysis
CASIA	The Institute of Automation Chinese Academy of Sciences
CGI	Chrono-Gait Image
CMU	Carniegie Mellon University
DCT	Discrete Cosine Transform
DFT	Discrete Fourier Transform
DSP	Digital Signal Processing
DSP*	Digital Signal Processor
DTW	Dynamic Time Warping
EG	Enhanced Gabor
EDR	Euclidean Distance-Based Recognition
FAR	False Accepted Rate
FDF	Frequency Domain Features
FKNN	Fuzzy Kernel Nearest Neighbor
FPCA	Fuzzy Principal Component Analysis

FRR	False Rejected Rate
GEI	Gait Energy Image
GEnl	Gait Entropy Image
GFI	Gait Flow Image
GMM	Gaussian Mixture Model
HMIR	Hu moment Invariant-Based Recognition
HMM	Hidden Markov Model
ICA	Independent Component Analysis
IDE	Integrated Development Environment
KDA	Kernel Discrimination Analysis
KNN	Kernel Nearest Neighbor
KPCA	Kernel Principle Component Analysis
LBP	Local Binary Pattern
LDA	Linear Discrimination Analysis
LGSR	Constrained Group Sparse Representation
MD	Mahalanobis Distance
MGEI	Mean Gait Energy Image
MHI	Motion History Image
MICA	Modified Independent Component Analysis
MR	Motion Recording Sensor
NED	Normalized Euclidean Distance
NN	Nearest Neighbor
OU-ISIR	Osaka University-Institute of Scientific and Industrial Research
PC	Principle Component

PC*	Personal Computer
PCA	Principle Component Analysis
PDF	Patch Distribution Feature
QDA	Quadratic Discriminate Analysis
RLTDA	Regularized Locally Tensor Discriminate Analysis
ROC	Receiver Operation Characteristics
RT	Radon Transform
SDRAM	Synchronous Dynamic Random Access Memory
STC	Spatio-Temporal Correlation
STHOG	Spatio-Temporal Histogram of Oriented Gradient
SVM	Support Vector Machine
USF HumanID	University of South Florida Human IDentification
VLIW	Very Long Instruction Word

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ABSTRAK

Penyelidikan ini memfokuskan kepada pembangunan sistem pengecaman automatik identiti manusia menggunakan imej gaya berjalan seseorang. Pengecaman identiti seseorang digunakan secara meluas dalam aplikasi komputer seperti sistem pengawasan keselamatan, penyiasatan jenayah dan interaksi antara manusia dan komputer. Kebanyakan sistem pengecaman memerlukan kerjasama daripada penguna seperti perubahan kepada latar belakang atau sesuatu perubahan kepada data. Algoritma ini juga mempunyi kos pengiraan yang tinggi dan memerlukan masa pengiraan yang panjang jadi sukar dibangunkan pada perkakasan. Jujukan gambar mengandungi data yang berubah informasi statistik dan boleh dimodelkan menggunakan teknik model statistik. Teknik pemprosesan untuk projek ini terbahagi kepada tiga tahap yang berbeza. Peringkat pra-pemprosesan mengira purata imej untuk mendapatkan maklumat yang penting dan mendapatkan perwakilan yang lebih baik untuk gaya jujukan berjalan. Kemudian satu teknik analisis komponen prinsip (PCA) digunakan pada imej purata untuk mengekstrak ciri gaya berjalan yang penting dan mengurangkan dimensi data gaya berjalan tersebut. Satu kaedah unjuran linear digunakan pada peringkat ini mampu mengurangkan data berlebihan dan data berulang. Tambahan pula, teknik ini akan meningkatkan kuasa diskriminasi dalam ruang data apabila menggunakan maklumat frekuensi rendah. Dimensi data yang rendah dalam ruang data dimensi diandaikan taburan Gaussian, dengan itu Euclidean distance classifier boleh digunakan di peringkat klasifikasi. Algoritma yang digunaan adalah model bebas yang menggunakan imej jujukan gaya berjalan untuk mendapatkan ciri perwakilan data yang baik yang tidak mempunyai hingar dan data berulang. Algoritma yang digunakan telah diuji dengan menggunakan set data CASIA yang merupakan penanda aras dalam penyelidikan jujukan gaya berjalan. Hasil analisis menunjukkan kadar pengecaman identiti yang terbaik adalah 90% apabila imej diwakili oleh 500 pekali PCA. Jumlah pekali PCA yang rendah membolehkan Euclidean distance classifier dilaksanakan dalam perkakasan seperti DSP prosessor. Perlaksanaan algoritma ini menggunakan pemproses DSP menghasilkan keluaran yang bagus and mengambil masa yang sedikit untuk diproses berbanding dengan menggunakan PC dimana Cuma 0.5s masa pengiraan.

Gait Recognition Using Principle Component Analysis Implemented on DSP Processor

ABSTRACT

This research focus on the development of an automatic human identification system using gait sequence images. Human identification is widely used in computer vision applications such as surveillance system, criminal investigations and human-computer interaction. Many identification approaches have shortcomings thus they require subject cooperation and sensitive to environmental and physiological changes. They also have high computational cost and are time consuming thus difficult to implement in hardware. Gait sequence consists of non-stationary data and can be modeled using a statistical learning technique. The proposed method consists of three different stages. The pre-processing stage computes the average silhouette images to capture the important information and get a better representation for gait silhouette data. Then a principle component analysis (PCA) technique is applied on the average silhouette to extract the important gait features and reduce a dimension of gait data. A linear projection method used in this stage is able to reduce redundant features and remove noise from the gait image. Furthermore, this approach will increase a discriminating power in the feature space when dealing with low frequency information. Low dimensional feature distribution in the feature space is assumed to be Gaussian, thus the Euclidean distance classifier can be used in the classification stage. The proposed algorithm is a model-free based which uses gait silhouette features for the compact gait image representation and a linear feature reduction technique to remove redundant information and noise. The proposed algorithm has been tested using a benchmark CASIA dataset. The experimental results show that the best recognition rate is 90% when the image is represented using 500 PCA coefficients. Low number of PCA coefficients will give a possibility for the Euclidean distance classifier to be implemented in hardware such as DSP processor. The implementation of the proposed algorithm using the DSP-based processor achieved better performance in term of computational time compared to the PC-Based processor with a ratio of 0.5 seconds.

CHAPTER 1

INTRODUCTION

1.1 Overview

Biometrics is a branch of technology that depends on automated methods to verify and identify humans. Biometric identification must be an automated process. Using manual feature extraction is undesirable and time consuming because of the large size of data being processed to produce a biometric template. Two main types of biometric characteristics, namely, physiological and behavioral, are used in biometric identification methods. Physiological characteristics are based on direct measurement of human body parts. The most common types of measures are related to the face, fingerprint, iris, palm print, and DNA. Behavioral characteristics are based on extracting the characteristics of actions performed by humans. This type of biometrics uses an indication to measure the characteristics of human motion and time as a metric. The types of behavioral measure include gait, voice, keystroke, and speech (Kaur, 2014). Fig. 1.1 shows several existing physiological and behavioral biometric recognition methods used for human identification.

Human biometrics are methods used to automatically recognize humans depending on their physiological and behavioral characteristics (P. S. Huang, Harris, & Nixon, 1999). Currently used human recognition biometric methods include face, fingerprint, iris, palm print, DNA, voice, keystroke, and speech recognition. Recently, gait recognition has become a highly active area of research. Recognizing humans and their activities from video sequences is important because of wide applications in video surveillance, design of realistic entertainment systems, multimedia communications, and medical diagnosis. Understanding the human performance factors that mediate successful person identification can help in the development of automatic gait recognition algorithms (Roark, O'Toole, & Abdi, 2003).

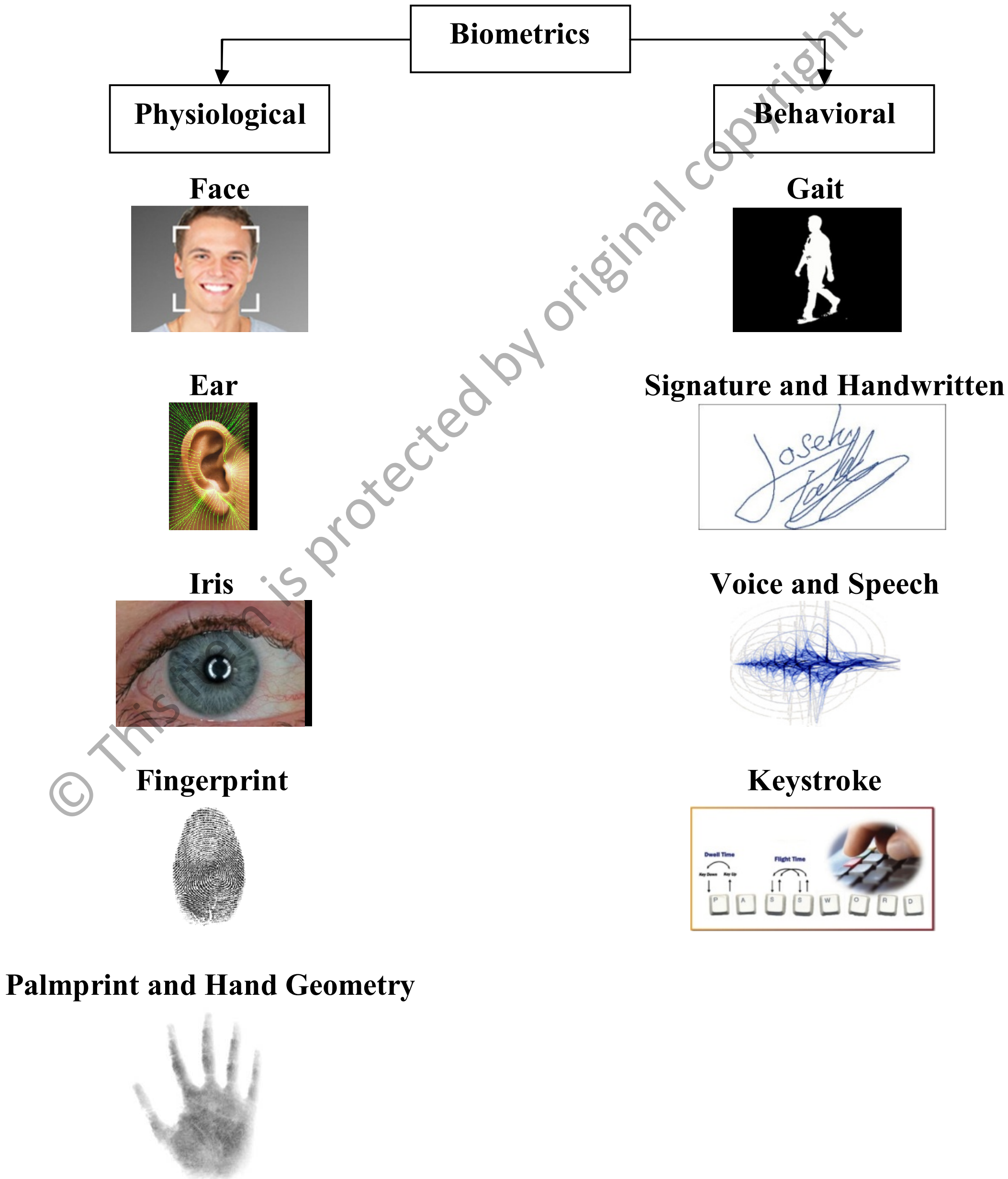

Figure 1.1: Biometric Recognition Methods

Gait recognition is the process of identifying individuals by their gait or walking style. Gait can be captured at a distance using low-resolution devices, whereas other biometric methods require subject cooperation and high-resolution sensors. Gait is difficult to disguise and capturing gait information requires no body-invading equipment. Gait recognition has become the second-generation biometric recognition technology based on vision movement and is one of the main technologies for identifying a person's identity at a long distance. Gait recognition has become an emergent area in computer vision and can be adopted in many high-security places such as airports and air bases, banks, military bases, car parks, and railway stations. Apart from enabling police officers to identify criminals, gait recognition also assists in anti-terrorist operations to improve the automatic protection of all types of places (Su, Liao, & Chen, 2009).

The three basic approaches used for gait recognition (Kaur, 2014) are as follows: (1) motion-based gait recognition, (2) floor sensor-based gait recognition, and (3) wearable sensor-based gait recognition. In the vision-based gait recognition method, gait motion is captured from a distance using a video camera. The gait features (e.g., stride, cadence, and static body parameters) are then extracted using image processing techniques. In the floor sensor-based gait recognition method, a set of floor sensors or force plates are installed to measure gait features (i.e., maximum time value of heel strike or maximum amplitude value of the heel strike) when the human walks on these sensors. In wearable sensor-based gait recognition, gait motion is captured using worn motion-recording (MR) sensors. These sensors can be worn on the human body at various locations. Gait features are recorded by the MR sensors. Over the past years, researchers have developed several motion vision-based gait recognition algorithms that can be classified into two main approaches: (1) model-based approach and (2) model free-based approach. Fig. 1.2 shows the model-based gait recognition approach that considers each human as an articulated subject represented by different body poses. It is used to model the structure of the human body based on 2D fronto-parallel body models. Gait model parameters are found in the solution space by matching the region-based information. Two searching methods are used to identify parameters, namely, exhaustive and Bayesian hypothesis. The parameters can be estimated directly or through feature extraction techniques (H. Lu, Wang, & Plataniotis, 2010). Model-based algorithms are less sensitive to noise because of shadows and clothes.

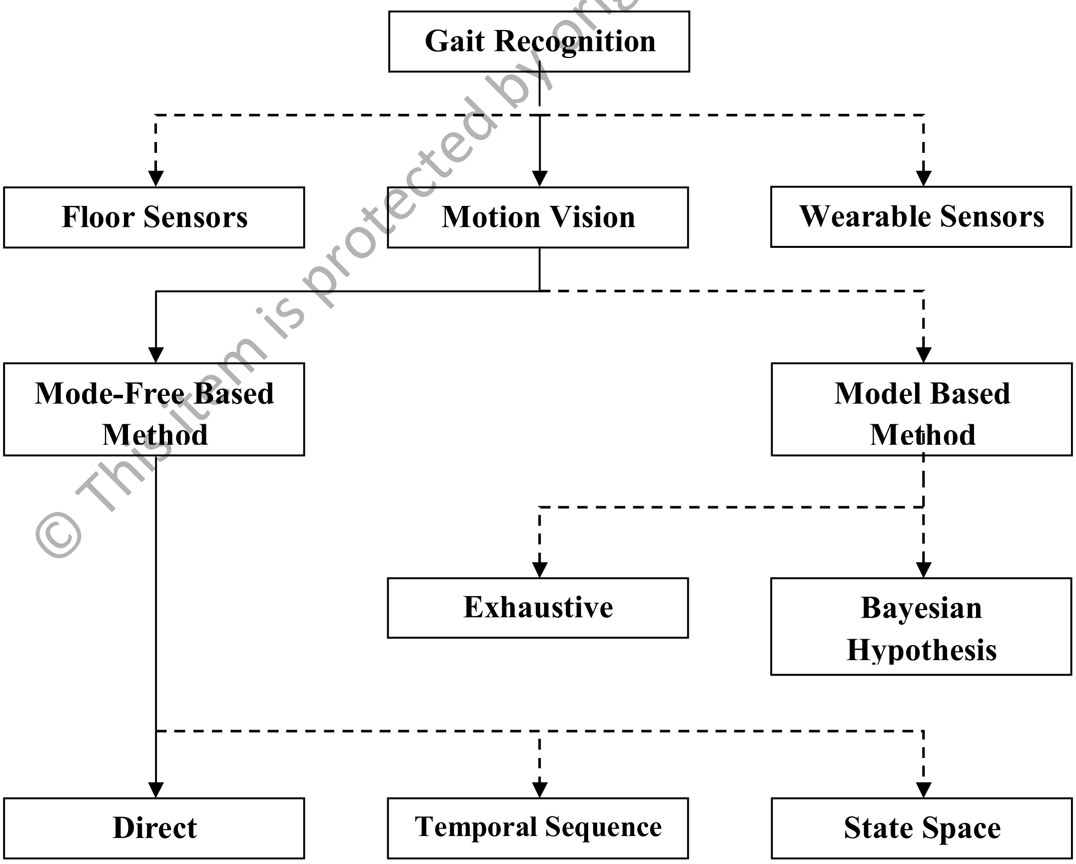

Figure 1.2: Gait Recognition Main Approaches

The model-free based gait recognition approach, which is used in this study, represents each human as a full-body subject using silhouettes or contours and considers the human gait as a holistic pattern. Most existing algorithms used in gait recognition are model-free based methods based on silhouettes. Average silhouettes are also used by these algorithms as a gait representation technique. Three searching methods are used to identify parameters: (1) direct method, (2) similarity of temporal sequence method, and (3) state space model method (Shirke, Pawar, & Shah, 2014).

1.2 Motion Vision-Based Gait Recognition

The human gait is a periodic activity and each cycle has two sides, namely, the right foot forward and the left foot forward. Gait biometric recognition consists of three operations: (1) capturing the walking subject video, (2) analyzing gait sequence to detect gait cycle, and (3) extracting relevant features, such as shape and dynamic of each stride, from each cycle (Roy, Sural, Mukherjee, & Rigoll, 2011). Vision-based gait recognition depends on the video sequence captured using an optical sensor. This video sequence represents the human walking repetition used to identify biometric information. Gait cycles and sensor views, the frame number of each gait cycle, starting frame in each gait cycle, a human's walking angle, and camera facing direction are important factors (X. Huang & Boulgouris, 2010).

In the gait recognition system, a digital gait video is captured by a digital camera. This video is preprocessed to extract the gait sequence. Features from this gait sequence are then extracted using feature extraction techniques. The extracted features are matched with the features stored in the gait database using a classifier to perform the recognition. Fig. 1.3 shows an example of a typical gait recognition system.

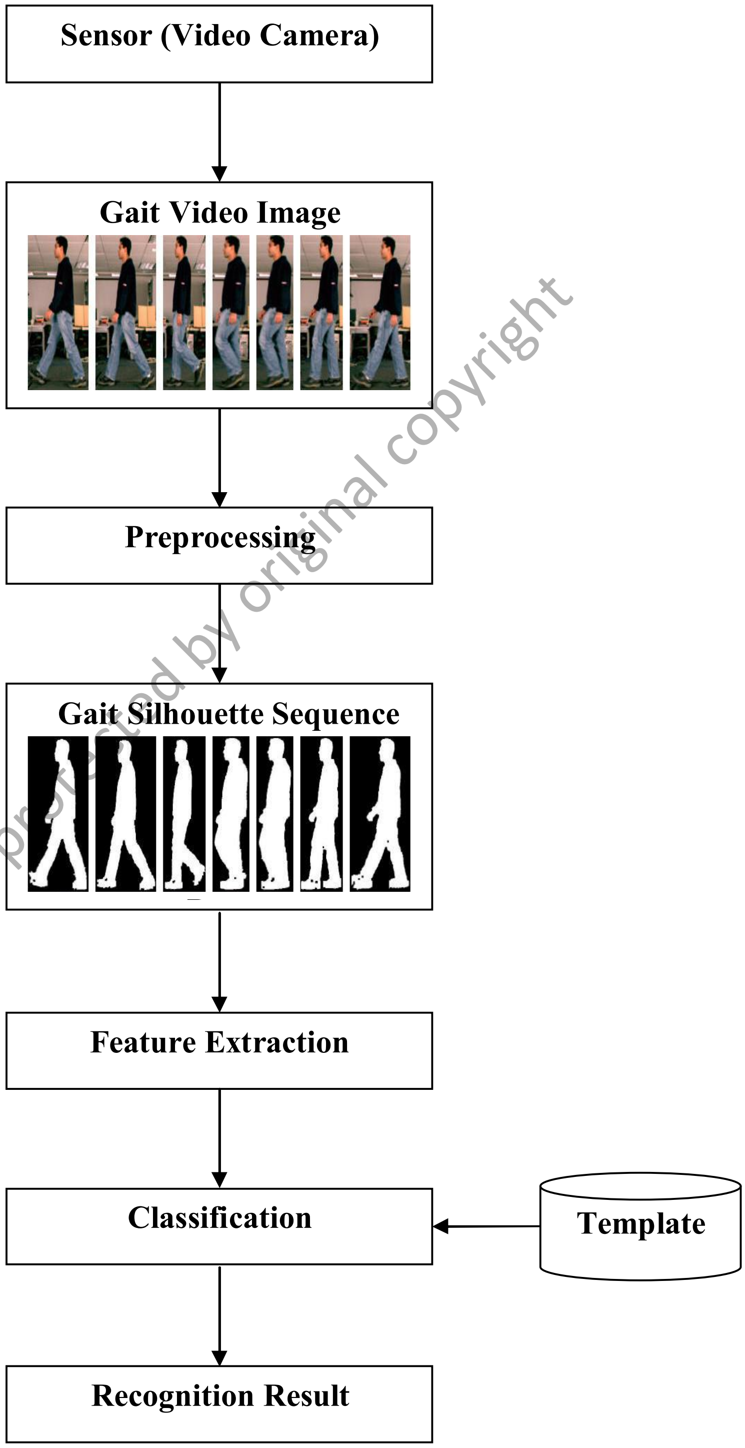

Figure 1.3: Typical Gait Recognition System

Binary silhouettes are extracted from gait data using a background subtraction technique. The extracted silhouettes are then resized and cropped based on a specific standard (H. Lu et al., 2010). Gait motion can be captured using a static video camera (Iwama, Muramatsu, Makihara, & Yagi, 2012; Kawai, Makihara, Hua, Iwama, & Yagi, 2012; Muramatsu, Makihara, & Yagi, 2013). Gait databases provided by academic organizations are used for academic research such as that in the Chinese Academy of Science Institute of Automation (CASIA), CMU, and USF. A sequence of 2D gait silhouette images can be extracted by sampling the video at certain frame rates.

Binary silhouettes with averaged silhouette gait and gait energy image (GEI) (Han & Bhanu, 2006) carry unique information for each person. Researchers have proposed various feature extraction techniques to extract important features that are useful for discriminating persons; these techniques include Gabor wavelet (X Yang, Zhou, Zhang, Zheng, & Yang, 2008), Enhanced Gabor (EG) (H. Hu, 2013), Gait Entropy Image (GEnl) (Bashir, Xiang, & Gong, 2010), Patch Distribution Feature (PDF) (Xu, Huang, Zeng, & Xu, 2012), Spatio-Temporal Histogram of Oriented Gradient (STHOG) (Kawai et al., 2012) and Gaussian Mixture Model (GMM) (Murukesh & Thanushkodi, 2013). The extracted features from the gait sequence is usually high-dimensional data, so the computational cost is high. Researchers have proposed dimensionality reduction algorithms such as Principle Component Analysis (PCA) (Hosseini & Nordin, 2013), Linear Discrimination Analysis (LDA) (Su et al., 2009), Component and Discrimination Analysis (CDA), Adaptive CDA (ACDA) (Bashir et al., 2010), and Regularized Locally Tensor Discriminate Analysis (RLTDA) (Shirke et al., 2014). to decrease the dimensionality of features. Dimensionality reduction algorithms reduce the computation time and cost required for the process. Finally, a classification method is required to complete the recognition process. Many classification techniques are used by researchers, such as Locality-constrained Group Sparse Representation (LGSR), its aggregation schema (RLTDA), Averages of different sequences (AVG) and Dynamic Time Warping (DTW), Similarity and Hu Moment Invariant-Based Recognition (HMIR) with Euclidean Distance-based Recognition (EDR), and Mahalanobis Distance classifier (MD) (H. Hu, 2013; M. Hu, Wang, Zhang, Zhang, & Little, 2013; Javed, Yasin, & Ali, 2010; Xu et al., 2012) Classification is based on frames extracted from the sequence of gait features or similarity of shapes and shape appearing probabilities.

1.3 Motivation and Problem Statement

All previous biometric recognition approaches have shortcomings that can negatively influence the accuracy of such approaches. Most challenges on the recognition approaches is that they require subject cooperation and certain aspects such as physical contact, close proximity, and sensitivity to changing environmental conditions. They also have problems with viewing angles, lighting conditions, outdoor/indoor environments, clothes, walking surface conditions, shoe types, objects carried, sickness, or other physiological changes in the body because of aging, drunkenness, pregnancy, and gaining or losing weight (Hayder Ali, 2010).

Gait is a contactless biometric trait that is easy to capture with a lower-resolution camera from several meters from the image sensor. Thus, it can be used as a biometric recognition system similar to the face, fingerprint, and iris.

Classifying gait motion is a challenge because non-stationary information exists in a gait image. Several existing gait recognition methods use a nonlinear feature extraction techniques which contain complex calculations that can affect the accuracy of such methods.

Gait images consist of non-stationary information where statistical information that exists in the gait image changes over time. Thus, a proper technique is required to capture the underlying information in each gait image.

Most of the existing gait recognition methods were implemented using a PC based processor which has high computational cost and is time consuming compared with the DSP processor which has lower complexity and internal architecture that can improve the computational time.

1.4 Aim and Objectives

The aim of this project is to develop a feature extraction and classification technique for gait sequence images used for human identification. The objectives of this study are as follows:

1. To design gait silhouette features extraction based on low-frequency information for compact gait image representation.
2. To develop a classification technique using Euclidean distance classifier in a Gaussian feature space.
3. To investigate the performance of classification process using offline and real time processing method.