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Image Detection And Retrieval For Biometric Security From An Image Enhancement Perspective

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ABSTRACT

Security methods based on biometrics have been gaining importance increasingly in the last few years due to recent advances in biometrics technology and its reliability and efficiency in real world applications. Also, several major security disasters that occurred in the last decade have given a new momentum to this research area. The successful development of biometric security applications cannot only minimise such threats but may also help in preventing them from happening on a global scale. Biometric security methods take into account humans' unique physical or behavioural traits that help to identify them based on their intrinsic characteristics. However, there are a number of issues related to biometric security, in particular with regard to surveillance images. The first issue is related to the poor visibility of the images produced by surveillance cameras and the second issue is concerned with the effective image retrieval based on user query. This research addresses both issues.

This research addresses the first issue of low quality of surveillance images by proposing an integrated image enhancement approach for face detection. The proposed approach is based on contrast enhancement and colour balancing methods. The contrast enhancement method is used to improve the contrast, while the colour balancing method helps to achieve a balanced colour. Importantly, in the colour balancing method, a new process for colour cast adjustment is introduced which relies on statistical calculation. It can adjust the colour cast and maintain the luminance of the whole image at the same level.

The research addresses the second issue relating to image retrieval by proposing a content-based image retrieval approach. The approach is based on the three well-

known algorithms: colour histogram, texture and moment invariants. Colour histogram is used to extract the colour features of an image. Gabor filter is used to extract the texture features and the moment invariant is used to extract the shape features of an image. The use of these three algorithms ensures that the proposed image retrieval approach produces results which are highly relevant to the content of an image query, by taking into account the three distinct features of the image and the similarity metrics based on Euclidean measure. In order to retrieve the most relevant images the proposed approach also employs a set of fuzzy heuristics to improve the quality of the results further.

The integrated image enhancement approach is applied to the enhancement of low quality images produced by surveillance cameras. The performance of the proposed approach is evaluated by applying three face detection methods (skin colour based face detection, feature based face detection and image based face detection methods) to surveillance images before and after enhancement using the proposed approach. The results show a significant improvement in face detection when the proposed approach was applied.

The performance of the content-based image retrieval approach is carried out using the standard Precision and Recall measures, and the results are compared with well-known existing approaches. The results show the proposed approach performs better than the well-known existing approaches.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLE

LIST OF ABBREVIATION

GW	Gray World
avg	Average
max	Maximum
RGB	Red, Green, Blue
HSI	Hue, Saturation, Intensity
YCrCb	Y - Luminance, CrCb - Chrominance
ACE	Automatic Colour Equalization
MLGD	Maximum Likelihood Gamma Distribution
DHS	Dynamic Histogram Specification
WB region	White Balance region
CIE	Commission Internationale de l'Éclairage (Colour International Commission on Illumination)
CBIR	Content Based Image Retrieval
PCA	Principal Component Analysis
LDA	Linear Discriminant Analysis
INM	Illumination Normalization Model
MRI	Magnetic Resonance Imaging
CIRES	Content-Based Image REtrieval System
HMM	Hidden Markov Models
MCM	Motif Co-occurrence Matrix
CCM	colour co-occurrence matrix
DBPSP	difference between pixels of scan pattern
COG	Centre Of Gravity
FIS	Fuzzy Inference System
FLS	Fuzzy Logic system

LIST OF PUBLICATIONS

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Kashif Iqbal, Michael O detayo, Anne James. (2010) 'An Integrated Framework for Biometrics Security'. *In proceedings of the British Human Computer Interaction Workshops*, British Computing Society Press.

Kashif Iqbal, Michael Odetayo, Anne James, Rosalina Abdul Salam, Abdullah Zawawi Hj Talib (2010) 'Enhancing The Low Quality Images Using Unsupervised Colour Correction Method'. *IEEE International Conference on Systems, Man, and Cybernetics.* 10-13 October 2010 at Istanbul, Turkey.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter discusses biometric security, in particular with regard to surveillance images by presenting a background to this area of research. The main problems related to face detection and image retrieval are discussed. The research aim, objectives and scope are described. A systematic methodology to achieve the aim and objectives of the proposed research is outlined in this chapter.

The rest of the chapter is organised as follows. Section 1.2 provides a background to the research undertaken, particularly focusing on biometric security and the problems associated with this research area. Section 1.3 describes the motivation for the research. Section 1.4 discusses the aim and objectives of the research. Section 1.5 briefly explains the scope of the research. Section 1.6 presents the adopted research methodology and describes its components. Section 1.7 outlines the organisation of the thesis.

1.2 Background

Biometrics security is concerned with identifying humans based on their unique physical and behavioural traits. Physical traits mean the features of the human body such as fingerprint, DNA, Iris recognition, hand geometry, face detection and recognition. Behavioural traits mean voice, gait and typing rhythm including digital signature.

In these days, biometrics security measures are increasingly investigated and being used in several applications based on these traits. The main objective of such applications is to detect and recognize a human for security purposes (Ahrens 2005; An et al. 2010; Hatakeyama et al. 2005; Jain et al. 2004; Kim et al. 2010; Mudigoudar 2009; Wang et al. 2004).

The applications of biometric security are growing in public areas. For example, sensor and surveillance cameras are embedded in the environment ubiquitously. Surveillance cameras are used to monitor traffic flow, threats, and suspicious activities in order to support government and law-enforcement agencies. Surveillance cameras play a vital role in security issues as they are widely deployed in public places to prevent or investigate crimes and to detect a suspicious person in order to make the environment more secure.

The main problem with surveillance images is that they are of low quality (Mudigoudar et al. 2009). This makes the detection and recognition of objects on images captured by surveillance cameras difficult, if not impossible. The quality of surveillance images is low due to several reasons such as: movement of objects (Kim and O’Connor 2009); use of low resolution cameras (Zhang et al. 2010); and environmental factors (Santhaseelan and Asari 2011). The environmental factors include rainfall, fog and snow (Becsi and Peter 2006; Chauhan et al. 2005). These factors obscure object details and create noise which badly affects the performance of object detection and the recognition process (Smids 2006). It is therefore crucial to enhance the quality of surveillance images in order to use them for face detection, recognition and retrieval purposes (Çavuşoğlu and Görgünoğlu 2008; Wang et al. 2004).

In biometric security systems, face detection is the first and very crucial stage, as faces are to be detected from the input image before they can be further processed, recognised or retrieved. In the existing literature, face recognition methods are mostly applied to passport quality pictures. Due to the high quality of these pictures, the systems are able to produce better and accurate results (Chen et al. 2008). Unfortunately, the existing methods are not applied to the surveillance images due to the poor quality of perception. In the existing research, the ambitious problem of biometric security from image enhancement perspective has not been fully addressed. Therefore, this area of research is lacking from two aspects: image detection and image retrieval.

1.3 Motivation

This work is motivated by two main issues in the area of biometric security, in particular with regard to surveillance images. The first issue is related to the poor quality of images produced by surveillance cameras and the second issue is concerned with the effective image retrieval based on user queries.

Firstly, in biometric security systems the surveillance cameras play a very important role as these surveillance cameras are commonly used to monitor the surrounding areas in order to make the environment safe. One of the main aims of this research is to improve the quality of images produced by these cameras. The quality of these images is affected by many factors such as movement of objects, use of low resolution cameras and environmental factors (e.g., rainfall, fog and snow). These factors obscure object details and create noise which affects badly the performance of an object detection and recognition process (Mark Smids 2006). It is therefore important to enhance the quality of surveillance images in order to use them for face detection and recognition purposes

(Abdullah and Salih 2008; Wang et al. 2004). By improving the visibility of images through image enhancement techniques more objects can be seen which were obscured before improving the quality of images.

Image enhancement techniques can significantly help to improve the quality of images by improving the images' visibility. Presently, several software tools are available in research and scientific laboratories as well as in the market that can be used to filter out the undesired properties of an image. Most of the existing image enhancement software tools, such as Adobe Photoshop, ImageJ and CorelDRAW, are semi-automated. Most importantly, these software tools are developed to improve the quality of the normal or ordinary images and therefore they are not able to be used for surveillance images due to the specific problems of this domain as described in section 1.2. Also, their features do not always work with surveillance images. These tools are often very elegant but they are not suitable to apply to the particular phenomena in any specific real world environment. Furthermore, learning to manipulate the colour in surveillance images through computer editing software requires patience and expertise. Therefore, an automated method for surveillance image enhancement is highly desirable in order to improve the quality of images that eventually will help to detect more objects such as human faces. These human faces will be used for image classification and retrieval.

Secondly, image retrieval is very important for image classification. As most relevant images need to be retrieved from image databases in order to classify them, but currently available image retrieval systems mostly rely on text-based query for searching for images. Text-based query, particularly for image retrieval systems involves several problems. Among them, the most important one is related to the description of the image in words.

Often it is almost impossible to describe the image in words. Therefore, these methods are limited in their scope. Content-based image retrieval is highly desirable. It is based on visual features of the image such as colour, texture and shape. As these visual features are automatically extracted from an image without any human given annotation, visual features based methods can produce better results.

Researchers have proposed various methods in order to address the problem of image retrieval using content-based approaches. Mostly, their approaches rely on one algorithm and ignore the existence of others (AlGarni and Hamiane 2008; Cinque et al. 2001; Kekre and Thepade 2008; Krishnamoorthi and devi 2012; Lei et al. 1999; Pun and Wong 2011; Vadivel 2005). Approaches based on one specific algorithm (e.g., colour or texture or shape) can work effectively only on specific types of images. When different types of images are input into these systems their performance is degraded. For example, approaches based on colour histogram takes into account only the visual contents relating to colours and ignores shape and texture. Similarly, approaches based on shape perform well when dealing with the shape of images without taking into account colour histogram and texture. The disadvantage with these approaches is that two totally different images can be shown as a result of a query, for example, if their texture or colour is the same.

A careful and thorough review of the existing literature shows that there exists no specific approach for surveillance image enhancement and retrieval. The above brief description of the issues has motivated the research undertaken in this thesis towards the development of face detection and image retrieval approaches.

1.4 Aim and Objectives

The aim of this research is to investigate and develop a new approach for enhancing the quality of surveillance images in order to improve the efficiency and accuracy of biometric security algorithms for image retrieval. The objectives are as follows:

- Identify and investigate the problem related to image retrieval for biometric security.
- Investigate image enhancement techniques that can be used to improve the visibility of surveillance images.
- Review feature extraction approaches and propose an image enhancement method that can be used to extract optimal features.
- Review approaches related to similarity measures and use the most appropriate similarity measure along with Fuzzy rules.
- Investigate the existing methods used for image retrieval and propose an appropriate method to be used for content-based image retrieval.
- Evaluate the performance of the proposed methods.

1.5 Scope of Research

The scope of this research is to develop an integrated approach consisting of three stages: Image Enhancement; Feature Extraction and Similarity Measures using Fuzzy Rules. In the first stage an integrated image enhancement approach is proposed to enhance the quality of images in order to increase the rate of face detection. In the second stage three feature extraction methods are used to extract an image's features such as colour features, texture features and shape features. In the last stage Euclidean Distance is used to calculate the distances between the features of an image query and the features of images in a database. Based on these distances a set of Fuzzy rules are defined in order to prioritise the results.

A potential application of the proposed research is a content based image retrieval system for biometric security to be used for colour images produced by surveillance cameras which are installed in public places to monitor human activities. The surveillance cameras produce poor quality images which are affected due to several factors such as: movement of objects; use of low resolution cameras; and environmental factors such as rainfall, fog and snow. However due to the difficulty, privacy and security reasons in obtaining surveillance images, the proposed approach is tested on available datasets to which additional biometric images are included.

All the three stages, mentioned above, are interrelated and are important for effective retrieval of surveillance images. For example the accuracy of image retrieval system could be affected by extracting and matching poor quality features and measuring the distances between those features for similarity purpose. Therefore, the first stage of preparing images by enhancing their features for further process is imperative and forms an integral part of the proposed approach.

1.6 Research Strategy

The focus of existing methodologies or software development life cycle such as waterfall model (Preece et al. 1994) and object oriented model (Bennett et al. 2005) is on the development stages of a project instead of a systematic research, development and evaluation. Therefore they are not appropriate to be used for a research project. In order to address the problem of content based image retrieval for biometric security and to achieve the research objectives mentioned above, a systematic research strategy is defined as shown in figure 1.1 and briefly explained in the subsections below.

1.6.1 Problem Identification

In this phase, the problem of surveillance images is investigated so that an appropriate solution to the problem can be provided in relation to the quality of images for face detection, feature extraction, face recognition and image retrieval. The identification and investigation of the problem is carried out by reviewing the existing literature and state-of-the-art technologies.

1.6.2 Analysis of Current Techniques

In this stage current methods and techniques concerning image enhancement, feature extraction, face recognition and image retrieval are to be reviewed. By reviewing the current literature, this stage will identify the strengths and limitations of the existing approaches. This will include a detailed review of existing models, theories, algorithms and state-of-the-art technologies.

1.6.3 Proposed Approach

Following the previous stage in which the existing models, theories, algorithms and state-of-the-art technologies are investigated, this stage intends to propose an integrated approach to address the limitations of the existing techniques and methods, and notably in order to meet the aim and objectives of the research to be undertaken. In order to address the problem of low visibility, an image enhancement approach is to be proposed for effective face detection. Secondly, for content-based image retrieval, an integrated approach is to be proposed to obtain accurate results based on image-based query.

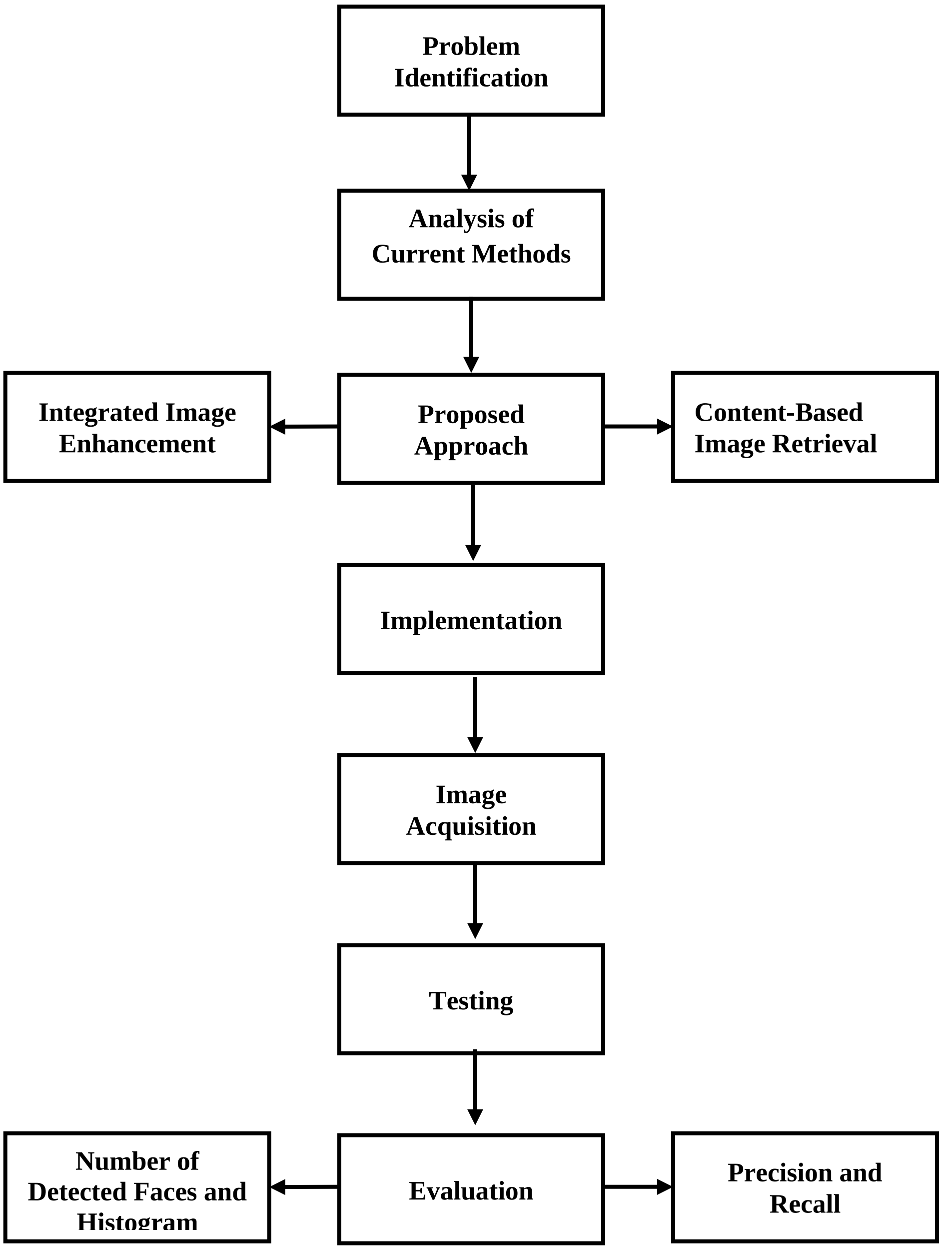

Figure 1.1: Research Strategy

1.6.4 Implementation

This stage is informed by the previous stage in which an integrated approach is proposed. This stage implements the proposed approach using Java and Matlab. Several algorithms are to be implemented in an integrated manner in order to enhance the surveillance images meeting the aim and objectives of the proposed research. Thus, this will help with face detection. Importantly, the image retrieval approach is to be implemented to accurately and efficiently retrieve images based on image query.

1.6.5 Image Acquisition

In the image acquisition stage, the surveillance images are produced on which image enhancement, face detection, feature extraction, face recognition and image retrieval methods are applied. This stage also includes the selection of image data set and the categorisation of images for face detection and retrieval purposes.

1.6.6 Testing

This stage will test the efficiency and accuracy of the proposed approach. This will be assessed based on the quality of the output images. In order to ensure that images are enhanced, rate of face detection will be improved, accurate features will be extracted and eventually the face recognition and retrieval will be improved. Based on the results achieved, the system will be modified and Fuzzy rules will be tuned to produce better results.

1.6.7 Evaluation

In this stage the results of the proposed image enhancement approach are to be evaluated using face detection methods. As well as the standard evaluation metrics Precision and Recall will be used to evaluate the content-based image retrieval approach. The results of the proposed approach will also be compared with the existing approaches in order to demonstrate the effectiveness and accuracy of the proposed approach.

1.7 Structure of the Thesis

This thesis is divided into eight chapters. Chapter 1 contains the motivation for this research work and introduces some problems related to the area of this research. It explains the research scope and objectives of this research. The research strategy is also presented.

Chapter 2 presents literature survey. This chapter discusses the image enhancement techniques and describes how different researchers and scientists have used these algorithms and methods for biometric security. Following that this chapter presents face detection methods and briefly explains them. Finally, different approaches for feature extraction and image retrieval are discussed in this chapter. Importantly, the strengths and limitations of the existing methods are also discussed in this chapter.

Chapter 3 discusses the importance of image processing in brief and explains general image processing stages for image retrieval systems. The chapter reviews the most relevant models and theories related to face detection and image retrieval that can be used as part of the proposed approach. Firstly, this chapter reviews different colour models so that an appropriate method can be chosen for the proposed approach. Secondly, it reviews the methods relating to face detection, and then methods and algorithms relating to image retrieval are discussed. This chapter also discusses the similarity measure methods and fuzzy classification.

Chapter 4 presents the proposed integrated framework for biometric security and discusses the components of the framework. The framework emphasises on the use of different image enhancement techniques in order to improve face detection, feature extraction, face recognition and image retrieval for biometric security.

Chapter 5 discusses the first proposed approach consisting of contrast enhancement and colour balancing algorithms for face detection. The contrast enhancement method improves the contrast in order to make objects visible so that the colour balancing algorithms can be applied more effectively. Colour balancing method is applied to enhance the image by removing any dominating colour that occupies the entire image. Colour balancing is an important algorithm that is used to achieve high quality images.

Chapter 6 discusses the proposed content-based image retrieval approach for biometric security, which is based on colour, texture and shape features. It also employs a set of fuzzy heuristics. This chapter discusses the three well-known algorithms of the proposed approach: colour histogram, texture and moment invariants. This chapter also discusses the importance of using these three algorithms as part of the proposed approach. The similarity metrics based on Fuzzy measure are also discussed in this chapter. The chapter also discusses colour histogram which is used to extract the colour features of an image. Following that it discusses Gabor filter which is used to extract the texture features. Finally, the chapter discusses the moment invariant method which is used to extract the shape features of an image.

Chapter 7 presents the evaluation results achieved by applying the proposed integrated image enhancement approach to biometric security. For evaluation purpose, this chapter discusses three face detection methods which are applied to surveillance images before and after enhancement using the proposed approach. Secondly, this chapter evaluates the proposed content-based image retrieval approach. It discusses the dataset which is used to obtain results. Following that this chapter presents results and discusses them briefly. This chapter also discusses evaluation metrics in brief and presents evaluation results by comparing the proposed approach with the existing well-known approaches.

Chapter 8: This chapter discusses the contribution that this thesis has made to the existing knowledge. It also discusses the strengths and limitations of the proposed approach and outlines some points for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews current literature concerning biometric security. As this thesis intends to investigate the problem of face detection, feature extraction and image retrieval from an image enhancement perspective, the literature is categorised into different subsections for clear understanding of the problem. Along with this discussion, the strengths and limitations of existing algorithms and approaches are described. The limitations of the most relevant approaches will then be addressed in the proposed new approach.

This chapter is organised as follows. Section 2.2 discusses the image enhancement techniques and describes how different researchers and scientists have used these algorithms and methods for biometric security. Section 2.3 discusses different approaches for feature extraction and image retrieval. Section 2.4 provides a summary of this chapter.

2.2 Image Enhancement Approaches for Biometric Security

This section discusses the current literature on biometrics security. The objective of this section is to present the existing approaches and their perceived limitations. We are of the view that most of the existing approaches do not address the problem of biometric security thoroughly and effectively from an image enhancement perspective, with the exception of few approaches (Ahrens 2005; Hatakeyama et al. 2005; Mudigoudar 2009; Wang et al. 2004) which have attempted to address this issue to some extent. It is crucial to improve the quality of surveillance images in order to improve efficiency and accuracy of face detection, feature extraction and image retrieval methods.

2.2.1 Monitor of Traffic Flow and Recognition of Vehicles

This subsection discusses approaches related to biometric security for monitoring traffic flow and recognising vehicles. Only the most relevant approaches from image enhancement perspectives are included in the section.

Smids (2006) has proposed a framework to monitor the city traffic flow. The framework mainly focuses on the subtraction of background and shadow removal from images. Two background subtraction methods are used for this purpose. They include deterministic and statistical methods. These methods use the adaptive background and per pixel Gaussian mixture in order to obtain the background information. The main drawback of this approach is that mostly it cannot detect the complete foreground objects. Also, the approach has not addressed the object recognition and retrieval issues.

Some researchers have enhanced the quality of images by improving the edges' visibility. For example, Abolghasemi and Ahmadyfard (2009) recently proposed a method for the recognition of car license number plates. The method is based on an image enhancement technique which improves edge density for better object recognition. Abolghasemi and Ahmadyfard (2009) have enhanced the Zheng's (2005) work that was developed based on intensity variance of pixel intensities of local neighbourhood pixels in order to improve the contrast of car number plate region (Abolghasemi and Ahmadyfard 2009).

Zhang et al. (2010) have also proposed a method to enhance low resolution images and improve the edges' visibility of surveillance images. The method is based on Weighted Markov Random Field Regularization. The method has been applied to enhance the visibility of edges and to detect car number plates.

The focus of some approaches has been on object detection which can be used for object recognition. To detect moving objects, there are few methods available such as optical flow, background subtraction and frame differencing. (Kim and O'Connor 2009; Yang et al. 2004). Kim and O'Connor (2009) have proposed a method based on Pixel Bit Mask Difference and History Update Values. The later method helps to reduce false detection. In order to detect moving objects, an edge detection method was used.

KaewTrakulPong and Bowden (2003) have proposed an approach in order to detect and track objects in a video stream. The approach relies on multiple factors such as motion, shape and colour of an object. These factors create the connectivity between objects in order to track them. The method fragments the moving objects based on background and shadow for object tracking purposes. The method has not addressed the issues of face recognition and image retrieval.

2.2.2 Face Detection and Recognition

In order to address the problem of low quality of images produced by surveillance cameras, Mudigoudar et al. (2009) have developed an application, based on a gradient method, to enhance the low resolution of surveillance images and videos. A gradient method is used to record the sequence of images at subpixel level in order to improve the resolution and to get the undistorted and sharp images. Another approach addresses the same problem of low resolution using a Genetic Algorithm. The approach is applied to obtain the best set of registration parameters which are used to determine the points using a spread function to improve the resolution of low quality images (Ahrens 2005).

Wang et al. (2004) have proposed a face recognition approach. The approach is applied to increase the resolution of surveillance images. Secondly, it uses the high resolution images for face recognition. To address the problem of resolution from both perspectives (low to high and high to low), the approach uses the Bilinear function along with the Gaussian Pyramid method. Both perspectives were used in order to validate the results against each other. The Gaussian Pyramid method is used to increase the resolution (low to high) of an image and the Bilinear function is used to decrease the resolution (high to low). The Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) methods are used for face recognition purposes (Wang et al. 2004). The advantage of this approach as claimed is that by improving the resolution of images the rate of face recognition can significantly be improved. The main limitation of this method is that very limited number of LDA and PCA components was used in the experiment.

Another important aspect related to quality of image is to maintain uniform illumination throughout the image. Non-uniform illumination destroys the colours. Hatakeyama et al. (2005) have proposed a method to restore the colours in highly illuminated images. The research helps to restore the colour information of highly illuminated images where the colour information has been lost. The approach is based on the correction vectors method which is able to bring back the colours in the image in order to recognise the objects (Hatakeyama et al. 2005).

An integrated method for face recognition has been proposed by Kao et al. (2010). The integration is based on three methods: contrast enhancement, edge enhancement and feature extraction. Kao et al. (2010) firstly used contrast enhancement approach to increase the contrast of an image and enhance the edges. Secondly, they used these enhanced images for feature extraction purposes. In feature extraction stage the texture features were used to train the system. The support vector machine method was used to classify the image. This method has improved the edges visibility for gray scale images. The images affected by illumination were used for testing purpose. The limitation of this method is that in extreme illumination conditions it does not perform well (Kao et al. 2010).

An et al. (2010) have proposed an illumination normalization model (INM) for face recognition. This model is based on two stages. At first stage the image is decomposed into high and low frequencies. Then the illuminated image is generated by low frequency. In second stage the noise is removed and contrast enhancement is carried out. For these experiments passport quality images were used. Such images are normally considered of high quality. Therefore, not surprisingly, they have achieved high quality results.

Kim et al. (2010) have proposed a biometric method which is based on two levels. At the feature level they used modified Sparse Random Matrix for feature extraction. At the second level they used an approximation step function for template transformation in order to minimize the error rate. Before applying these approaches they perform a pre-processing stage and in this stage they have used a histogram equalisation method for image enhancement in order to get better input image. Therefore the limitation of this method is dependent on the image enhancement method that can improve the results.

Another similar approach has used two images, a random image which is used as a reference image and an input image. The reference image is used to correct the input image. Gaussian filter is used to address the blurring problem. After that, the algorithm uses the kernel density function to minimize the energy function and generate the lookup table for each colour channel independently in order to enhance the images (Tehrani et al. 2010). The limitation of this method is that it is not efficient to set up this method on all cameras because baselines are not in parallel between cameras. The valid range is manually adjusted. Secondly, the horizontal baseline, mismatches in horizontal direction can never be detected (Hasan et al. 2011).

Colour balancing method is proposed to remove the colour cast (Gasparini et al. 2004). This method is based on Von Kries hypothesis. The Von Kries coefficients K_R, K_G and K_B are estimated by locating white region which is also known as white balance region (WB region).

$$K_R = White / R_{WB} \tag{3.4}$$

$$K_G = White / G_{WB} \tag{3.5}$$

$$K_B = White / B_{WB} \tag{3.6}$$

Briefly, the WB region is based on the colour cast strength. The WB region represents objects or group of objects that are forced to become white. Only objects with brightness over the set limit are accepted using a threshold value of 30, because the region to be whitened must not be too dark. Gasparini et al. (2004) have adopted such an approach which detects and classifies the presence of a colour cast. It then removes the colour cast using D65 values. The D65 corresponds to the midday colour values which are defined by "Colour International Commission on Illumination". This approach has been applied to improve the quality of images. It does not produce good results when an image is affected by predominant colour cast as the authors described the limitation of their own work by stating, "The cast images are not colour balanced because classified as having no cast or having a predominant colour" (Gasparini et al., 2004).

Another similar method proposed by Chikane and Fuh (2006a & 2006b) also uses predefined threshold values. Briefly, this method follows the following three steps: white object purification, white point detection, and white balance adjustment. It firstly, applies histogram equalisation to the image in order to enhance the contrast of the image pixels. Secondly, it calculates the reference white points using the pre-defined threshold values of luminance and chrominance. This method performs well on most of the images, but it degrades those images which have comparatively low colour cast (small number of white points). This is not an adaptive approach because the pixel threshold values are set to 210. Therefore, it performs well on the images which have pixel values equal to or more than 210 but it degrades those images which have less pixel value than the predefined threshold values. These predefined threshold values have been determined based on experimental work on a range of general images but not specifically related to underwater images, which have low red and green pixel values.

In order to achieve better results, the original histogram of an image is used to apply the Maximum Likelihood Gamma Distribution (MLGD) method to get the midpoints of the histogram in order to divide the histogram into two modes. Then, the histogram is stretched based on these two modes; in other words, the histogram is stretched to two sides (i.e., minimum and maximum). This method has been applied to enhance the bimodal MRI (Magnetic Resonance Imaging) medical images (Al-Manea and El-Zaart, 2007). One of the characteristics of this method is its simplicity. This method has only been used to enhance gray images. The drawback is that it is unable to remove the colour cast as this method tends to stretch both side values.

In another approach, the researchers have integrated the contrast enhancement method with the Gamma correction method. Firstly, they normalize two images based on their histograms. They then combine these images using contrast enhancement image (Wang et al. 2009). Gamma correction method has also been proposed to address the illumination problem (Wong and Bishop 2007). This method uses a reference image to enhance the input image. The underlying algorithm of this method relies on the reference image to find the best illumination solution to address the illumination problem in order to enhance the input image.

To address the problem of illumination, pose and face expression, Moreno et al. (2010) have proposed a method that can create 3D face images based on 2D face images. As 3D face images are highly dependent on the quality of 2D images, the research has used an image enhancement method that can enhance 2D face images in order to create better 3D face images for recognition purposes. That shows the importance of the image enhancement method even for 3D images. In other words we can say even in the creation of 3D images that are known as vector images (not a real image), an image enhancement method plays a vital role in order to improve the results.

Bianco et al. (2010) have used several image enhancement methods, such as gray world, white patch, gray edge (Weijer et al. 2007), to improve the quality of images. Their approach uses the content-based image retrieval rules for classification of suitable image enhancement method. This determines which image enhancement method needs to be applied to improve the quality of a particular image depending on the nature of that image. The selection of a suitable algorithm is made based on the estimation of an illumination using forest tree approach that is based on CART (Classification and Regression Trees) methodology. The limitation of this method is that it does not produce satisfactory results for high colour cast images.

2.3 Image Retrieval

Current research related to image retrieval is divided into two categories: the first category uses the text-based query, for instance the Google image retrieval system; the second category uses image-based query, for instance the IBM QBIC (Query by Image Content) system. The proposed research focuses on the second category of image retrieval systems which are called content based image retrieval system.

In a typical content-based image retrieval approach, a user submits an image query which is then used by the image retrieval system to extract visual features from images in a database. The visual features may include shape, colour or texture depending upon the type of image retrieval system being used. These features are examined in order to search and retrieve similar images from an image database. The similarity of visual features between query image and each image in a database is calculated based on their distance by comparing the feature vectors of two images. The image retrieval system displays images, as the result of an image query that has the closest similarity according to the predefined threshold value in the system. The predefined threshold value is usually set in order to restrict the number of results that the content-based image retrieval system displays. A general content-based image retrieval system is shown in figure 2.1.

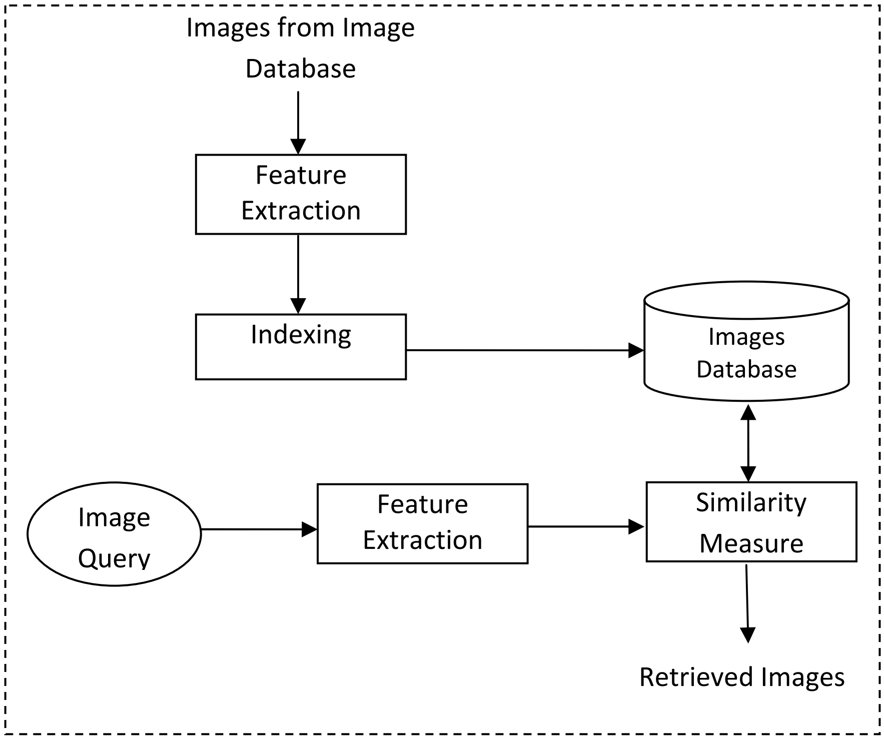

Figure 2.1: A typical content-based image retrieval system

The low level visual feature of an image, for example, colour, shape and texture are directly related to the image content. These visual contents representing an image can be extracted from the image using methods such as colour, texture and shape. Such methods extract visual contents which can be used to measure the similarity between query and database images using Euclidean Distance method.

There exist several methods that can be used to retrieve similar images. For example, in content-based image retrieval systems, the features of an image query are used to search for similar features of images in the database (Grosky 2011; Royal et al. 2007; Shkurko and Qi 2007; Wacht 2006).

IBM has introduced several versions of the QBIC system which are widely used for image retrieval purpose (Flickner el al. 1995). Using the QBIC system, users are able to search for an image by identifying certain characteristics of the image. Latest versions of QBIC use a regional segmentation function to segment the image into different regions, but the previous version was based on the colour histogram (González-Quevedo et al. 2011). The main disadvantage of this system is that it is sensitive to the variation in illumination.

Another system known as SIMPlicity (Wang 2001) is used to segment the image into regions/blocks (such as 4 x 4 pixel blocks) and to extract features from each block. The system uses K-means algorithm for clustering and uses six features. Three of them are colour features extracted from the LUV (L is Luminance; U and V is representing colour/chromatic) colour model and the other three represent energy features that are used for wavelet transform. The values that are assigned to regions are used for the distance function. The system accommodates all the regions equally (Wang 2001; Sahoolizadehi 2007).

Blobworld is a Content Based Image Retrieval (CBIR) system, in which the segmentation process is performed to divide the image into different regions and then these regions are used as the image query. The system searches images based on a region that has a similar relationship with other regions as found in the image query. This system uses Colour and Texture features for image retrieval (Carson 1999). The problem with this approach is that it reduces or increases the regions as a result of imperfect and unsupervised segmentation.

The CIRES (Content-Based Image REtrieval System) is applied to extract the useful features from an image such as structural, textural and colour features (Iqbal and Aggarwal 2002). The colour histogram method is used to extract the colour features that are used for colour comparison. The Gabor filter is used to extract texture features. Lastly image structure such as line junction and line crossing are extracted from an image in order to represent the structural image. The image retrieval process is carried out based on the weighted linear combination using structural, texture and colour histogram values. The values of the linear combination in the CIRES system are predefined (Iqbal 2007).

In another system called VisualSEEK, segmentation is applied to divide an image into segments/regions (Smith and Chang 1996; Sahoolizadehi 2007). The region of an image query is used to find the similar regions from the database images in order to retrieve similar images. The colour region is extracted from the image using the back projection method. The user can sketch a region in query image in order to search similar regions in the database (Smith and Chang 1996; Sahoolizadehi 2007).

For real-time picture annotation, an Automatic Linguistic Indexing of Pictures (ALIPR) system is introduced which is able to generate tags to facilitate image retrieval. The system uses text query to search and retrieve the relevant images. Therefore in the ALIPR system, a very large collection of image datasets have been built based on auto generated tags and human given instructions in order to make it searchable effectively (Datta et al. 2008; Li and Wang 2008).

The consumer electronics control system using moment invariants for hand gesture recognition has been proposed (Zhang 2009) in order to interpret the user hand gesture into predefined commands to control one or many devices simultaneously. The system has been tested and verified under both incandescent and fluorescent lighting conditions. Using the real time system the researchers were able to achieve good results (Premaratne and Nguyen 2008).

In another approach, the moment invariants method is used for object identification (Rizon et al. 2006). More precisely, the moment invariant method is used for facial expression such as anger, disgust, happiness and surprise. Rizon et al. (2006) have used moment invariant and HMM (Hidden Markov Models) for image recognition purposes. Their approach is based on two modules: training and recognition. Seven areas on the face for feature extraction are used: left brow, left eye, right brow, right eye, upper mouth, lower mouth and the area between two eyes. All the values were adjusted manually. A total of 31 images were used for evaluation while 15 images were used to train the HMM method based on neural networks. The researchers claimed that 96.77% accuracy was achieved using their proposed method (Zhu et al. 2002). The approach was only applied to a limited dataset and half of the image dataset was used to train the system.

Two visual features have been used for the development of another image retrieval system (Yue et al. 2011). Colour features were extracted by the HSV (Hue, Saturation and Values) colour model and texture features were obtained by converting the colour image into a gray scale image. The HSV colour model has three colour components Hue (pure colour), Saturation (represents the pureness of colour) and V (illumination). In Hue the colour value range is 0-360. This range was divided into 8 regions in this approach. For example 1-25 values were considered region 1 and 26-40 were considered region 2. Saturation and illumination were divided into 3 regions. Texture features were extracted by converting the colour image into a gray scale image. Then four co-occurrence matrices were produced by driving some functions to four directions. Capacity, entropy, moment and relevance were calculated by using mean and standard deviation. Normalization was applied to the feature vector by assuming the feature component values satisfy as a Gaussian distribution. Normalization was applied in order to get each feature of the same weight. The mean and standard deviation were applied to get a value between (-1,1). The texture feature of each image was calculated and compared by using Euclidean distance. Finally, colour and texture features were combined by using pre-defined threshold values based on the experimental results (Yue et al. 2011).

Huang and Dai (2003) have proposed an Image retrieval system based on texture features. The approach combined two methods such as gradient vector and wavelet decomposition. The approach is associated with two descriptors namely; coarse features and fine image features. The wavelet coefficients of an original image are used to derive these two extracted features. Finally, two stages are performed: firstly the coarse features are used to filter out the irrelevant images. Secondly, the fine image features are used to find the most relevant images (Wang et al. 2008).

Jhanwar et al. (2004) proposed an image retrieval system which is based on the concept of Motif Co-occurrence Matrix (MCM). The method is able to differentiate between pixels and convert them to a basic graphic. It calculates the probability of its occurrence in the adjacent areas in an image feature, in order to get the colour difference between adjacent pixels (Jhanwar et al. 2004). The limitation of this method is that when images contain multiple regions (towards horizontal and vertical) their method is unable to produce good results.

Lin et al. (2009) has proposed a content-based image retrieval application based on colour and texture feature. The application is based on three defined methods: colour co-occurrence matrix (CCM); the difference between pixels of scan pattern (DBPSP) method; and colour distribution for the K-mean (CHKM) method. The CCM calculates the probability of occurrence of the same pixel colour between each pixel and its adjacent one in each image, this probability is regarded as a characteristic of an image. The aim of the DBPSP method is to compute the differences between all pixels of a scan pattern. The CHKM is based on colour histogram, where every colour pixel is replaced by any common colour which is most relevant to the colour thus categorizing all the pixels into a k-cluster. The main limitation of the proposed work is that the shape feature has not been used in this approach. By adding this feature, the accuracy of image retrieval system can be improved due to the fact that shape features are not easily affected by noise and colour appearance of an image.

ElAlami (2011) proposed a content-based image retrieval system. The system is based on three algorithms; feature extraction, image mining, and rule based. Firstly, in feature extraction the colour and texture features are globally extracted from an image, by assuming that these are invariant to image transformation and can be used for object identification. Secondly, the image mining method is used to extract the implicit knowledge from the image data by carrying out clustering. Thirdly, a set of rules are employed in order to refine the results thereby improving clusters. The approach uses histogram method to extract the colour features and Gabor filter is used to extract the texture features of an image. More accurate results could have been produced if their method has used the shape feature as well.

2.4 Summary

This chapter has discussed the literature survey which is divided into different categories such as biometric security issues, image enhancement and image retrieval. Firstly, the important biometric literature has been enumerated identifying the root problem related to biometric security, particularly with regard to surveillance images. The root problems include poor visibility, caused by low contrast, colour cast, low illumination of surveillance images and constraints of text based image retrieval. Secondly, the image enhancement methods related to biometric security have been discussed that emphasise the need for improving the quality of surveillance images in order to achieve better results. Thirdly, face detection methods have been explained which will also be used to evaluate the proposed integrated image enhancement method. Fourthly, the image retrieval systems which are normally based on the visual content of image such as colour, texture and shape are described. Currently available image retrieval systems are also discussed in this chapter as well as the strengths and limitations of the existing methods.

Although the existing literature has provided enough insight to the proposed work, there exists no specific approach which can be used for biometric image retrieval. More precisely, the image enhancement approaches are based on a contrast enhancement method. For example, Kao et al (2010) have used contrast enhancement method to improve the edges visibility. However, biometric images also require the removal of colour cast and enhancement of brightness which are not addressed by the existing approaches. This limitation will be addressed in the new proposed approach.

A few researchers have addressed the problem of colour cast through colour balancing and white balancing methods, (Gasparini *et al.,* 2004; Chikane and Fuh 2006a & 2006b). These approaches have used predefined threshold values. Consequently, these approaches are only able to enhance a limited set of images. In the new proposed approach, no predefined threshold value will be set so that the approach can be applied to a variety of images.

Our literature review shows that there exists no approach that can enhance the quality of images without using predefined threshold values and can address the problem related to the quality of surveillance images affected by contrast, illumination and colour cast. Therefore, the proposed new approach will address these problems by developing an integrated images enhancement approach.

With respect to image retrieval, there are four relevant approaches that address the image retrieval problems (ElAlami 2011, Huang 2003, Jhanwar 2004 and Lin et al. 2009). But these approaches are based on one or two feature extraction methods. Therefore, they do not effectively and thoroughly address the issue of content based image retrieval for biometric security from texture, colour and shape perspectives. The approach proposed by ElAlami (2011) is based on colour and texture features extraction method. In order to refine the retrieved results a set of data mining rules are used (ElAlami 2011). Huang's (2003) approach integrates two methods, namely Gradient vector and wavelet decomposition, in order to extract the texture features for image retrieval (Huang 2003). Jhanwar's (2004) approach extracts the texture features using Motif Co-occurrence Matrix method for image retrieval (Jhanwar 2004). Another approach proposed by Lin et al. (2009) is based on colour and texture feature extraction methods which are used to retrieve the most relevant images from the database (Lin et al. 2009). The integration of two methods has produced better results, for example Jhanwar (2004) and Huang (2003) have used only one method such as texture features and have achieved lower results than Lin

(2009) and ElAlami (2011) who integrated two methods with some data mining rules. The existing approaches have used only texture and or colour features and ignored the shape feature which is even considered more stable than texture and colour features. The proposed approach will focus on all three important features of an image: texture, colour and shape and will also employ Fuzzy rules in order to achieve better results.

The next chapter will discuss the theoretical foundation: concepts and models that form the basis of the proposed approach for face detection and content based image retrieval.

CHAPTER 3

BUILDING BLOCKS

3.1 Introduction

This chapter discusses the concepts and models which provide the building blocks for the proposed approach discussed in Chapter 4. The objective of this chapter is to review the most relevant models and theories that can be used as part of the proposed approach. Firstly, this chapter reviews different colour models so that an appropriate method can be chosen for the proposed approach. Secondly, it reviews the methods relating to face detection; then methods and algorithms relating to image retrieval are discussed. With respect to image retrieval systems, the focus of this chapter will be on content-based image retrieval instead of query-based image retrieval. In content-based image retrieval system, a desirable image is retrieved, from the large collection of images stored in the image database, based on their visual content. This process is usually performed automatically without human intervention. The visual content of an image are called features. They include 'colour of the image', 'texture of the image' and 'shape of the image'.

The rest of the chapter is organised as follows: Section 3.2 discusses Colour Models highlighting the main characteristics of each model. Section 3.3 discusses the image enhancement methods. Section 3.4 discusses the algorithms relating to face detection. Section 3.5 discusses the image retrieval by explaining the colour features, texture features and shape features. Section 3.6 discusses similarity measure methods. Finally section 3.7 provides a brief summary of this chapter.

3.2 Colour Models

Colour is considered an important factor in digital colour image processing. The quality of an image is judged by its appearance (Hung 2006). In fact, a colour image is considered different from a grey-scale image due to its range of colours. In a grey-scale image, the colour space is in the range of 1-dimensional scale ranging from white to grey to black. Due to this factor, a grey-scale image can easily be enhanced by using methods like histogram equalisation based on the spatial domain (Russ 1995). Grey images are constrained to their limited range of colours. In comparison, a colour image has a wider range of colours represented through several colour models, for example, the RGB colour model, the HSI colour model, the CMY colour model, the CIE Lab colour model and the YCrCb colour model. The complex characteristics of a colour image depend on the range of colours of the underlying model. The colour model is also known as the colour system or the colour space that is used to represent the colours numerically or visually for electronic displays. Various colour models are briefly discussed in the following subsections.

3.2.1 The RGB Colour Model

The most commonly used colour model is the RGB (Red, Green and Blue) colour model. The RGB colour model is an *additive* colour model (Sonka et al. 1999), which is used to produce a wide range of colours by mixing red, green and blue light. A colour in the RGB colour model can be achieved by mixing varying amounts of red, green, and blue. The amount of the red, green and blue can vary between the minimum (full dark) and maximum (full intensity). For example, if all the colours are at a minimum (0, 0, 0) the result is black; if all the colors are at maximum (255, 255, 255), the result is a white In absolute red, the green and blue are at minimum and the red is at maximum (255, 0, 0) as shown in Figure 3.1.

Figure 3.1: RGB colour cube (Sonka et al. 1999)

3.2.2 The HSI Colour Model

In colour image processing, the HSI or HSV colour model is very important because it represents the colour in the same way as humans perceive colour. The components of HSI colour model is Hue (H), Saturation (S) and Intensity (I) as shown Figure 3.2 (Black 2007).

Hue illustrates colour in the shape of angle. The range of hue is between (0 and 360) degrees. At 0 degree, it shows red colour; at 120 degrees it shows green colour and at 240 degrees it shows blue colour. Saturation illustrates the impurity of colour with white colour. The range of saturation component is (0, 1). Intensity shows the lightness of colour. The range of intensity/value is represented by (0, 1) where 0 means black and 1 means white.

Fig 3.2 has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 3.2: HSV colour triangle (Black 2007)

3.2.3 The YCrCb Colour Model

The YCrCb colour model (also known as YIQ or YUV) is simple, easier and faster to calculate among the other colour models (Schweng and Detlef 2006). In the YCrCb colour model, Y represents the luminance and Cr, Cb are the chrominance components. The following matrix operation is used to convert the RGB colour model to the YCrCb colour model (Schweng and Detlef 2006):

$$Y = 0.299 R + 0.587 G + 0.114 B \quad (3.1)$$

$$Cr = 0.701 R - 0.587 G - 0.114 B \quad (3.2)$$

$$Cb = -0.299\,R - 0.587\,G + 0.886\,B \quad (3.3)$$

3.3 Image Enhancement

Image is better than any kind of information for human perception. Vision helps us to perceive and understand nature (Sonka et al. 1999). In other words, images are invaluable as they provide an efficient means of communication, recording and storing of information (Gonzalez 2002). Digital image processing techniques contain different ways for the manipulation of digital images and its enhancement, modification and analysis (Russ 1995; Parker 1996). Image enhancement is a technique which helps to improve the quality of an image by enhancing the features of an image using various different methods and filters such as contrast enhancement, noise removal, sharpening and colour balancing (Ebrahim 2005).

In general, image processing stages for image retrieval includes: pre-processing, face detection, feature extraction, and image retrieval as shown in Figure 3.3. Applying different image enhancement methods or techniques to the pre-processing stage ensures the removal of unnecessary characteristics from the image. Image enhancement includes several methods such as statistical, learning and transform. Statistical and learning methods are based on prior information or training and they are limited in their scope because they rely on prior information of the domain and they are also time consuming. On the other hand, the transform based approaches are based on point processing techniques, which directly perform operations on the pixel values therefore they are fast and require less time and resources (Gonzalez and Woods 2002). This research mainly focuses on the 'Transform Based Approach', which contains Gray World, Retinex, Contrast Stretching/Correction and Histogram Equalisation methods.

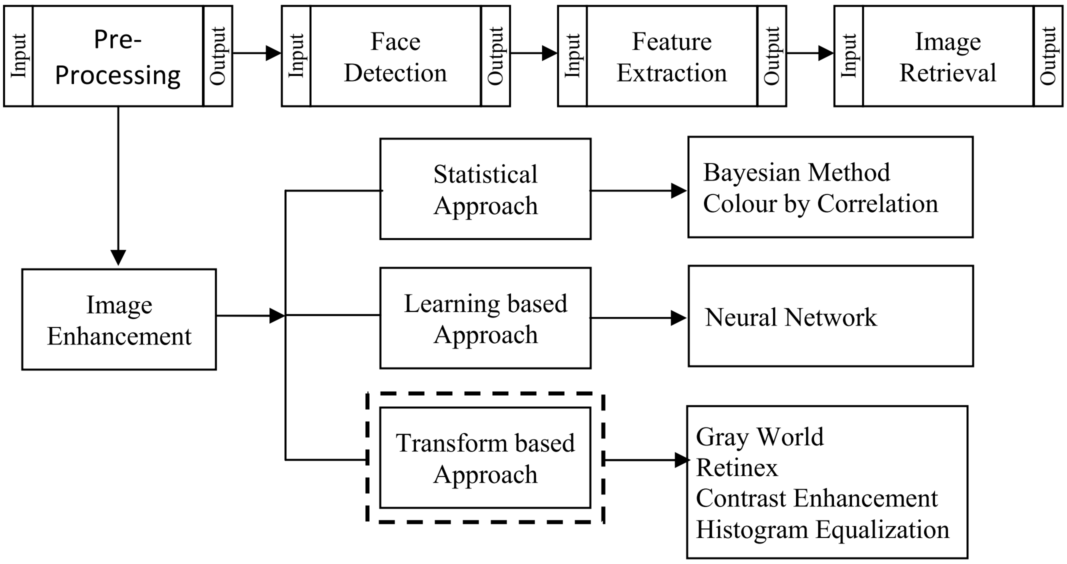

Figure 3.3: General image processing stages for image retrieval focusing on image enhancement phase.

Gray world and Retinex (white patch) are used to remove the colour cast. Many researchers have combined gray world and white patch methods in colour balancing and white balanced approaches (Bianco et al. 2010; Chikane and Fuh 2006a, 2006b; Gasparini et al. 2004).

Contrast stretching and histogram equalisation are commonly used to improve the contrast of an image by stretching a range of intensity values to enhance the image by removing the undesired properties. Generally, image enhancement techniques use different colour models such as RGB (Red, Green and Blue), HSI (Hue, Saturation and Intensity) and YCrCb, which contain different colour and luminance channels.

3.3.1 Colour Constancy Algorithms

Colour constancy is a theory that shows how illumination can change the way an image is perceived and how image can be affected by illumination. Colour constancy theory plays an important role in image enhancement.

"Colour constancy is the perceptual mechanism which provides humans with colour vision which is relatively independent of the spectral content of the illumination of a scene. It may also be referred to as the computation of perceived surface colour" (Cardei 2000). The colour constancy algorithms provide colour constant descriptors for objects. There are two main categories of colour constancy algorithms, as briefly discussed below:

The first category of algorithms includes those that estimate the illuminated area and then correct the given entire image relative to canonical illuminated area. This is a practical approach to colour correction and is closely related to imaging technologies. It performs two tasks: firstly it determines the illuminated area; secondly, it corrects the colour image from one illuminated area to the other. One of the disadvantages of such methods is that they introduce errors in colour appearance (Cardei 2000).

The second category of algorithms includes those which reduce the specific illuminated area in a scene, which determines the colour constant descriptors for an object. These specific descriptors are similar for a particular scene and are independent of the illuminated area under which they are obtained. These types of algorithms are more suitable for colour based object recognition. They provide illumination independent colour descriptions implicitly (Cardei 2000).

3.3.2 Von Kries Coefficient Rule

Johannes Von Kries (1902) proposed a model which is commonly known as the Von Kries model. Many colour constancy algorithms are built upon the Von Kries model as most of the chromatic adaptation theories are based on Von Kries hypothesis (Fairchild 2005).

The adaptation rule of Von Kries hypothesis assumes that the spectral sensitivity functions of the eye are invariant and independent of each other. In addition, Von Kries argued that the adaptation of the visual system to different illuminants can be done by adjusting three gain coefficients associated with each of the colour channels, thus:

$$L' = kL \times L \qquad (3.4)$$

$$M' = kM \times M \qquad (3.5)$$

$$S' = kS \times S \qquad (3.6)$$

Where L, M and S represent the original tristimulus values, and kL, kM and kS represent the gain coefficients that scale the original tristimulus values into post-adaptation tristimulus values, L′, M′ and S′. In fact, the adaptation models depend on the gain coefficients. The RGB channels are often considered an approximation of L, M and S retinal wavebands, therefore:

$$R' = kR \times R \qquad (3.7)$$

$$G' = kG \times G \qquad (3.8)$$

$$B' = kB \times B \qquad (3.9)$$

Where R, G and B are original pixels values in the image, kR, kG and kB are the gain coefficients and R′, G′ and B′ are the adjusted pixel values.

3.3.3 Gray World

One of the most important approaches to colour constancy is the Gray World algorithm, which is based on the assumption of a given image with adequate number of colour variations. The average value of the Red, Green, and Blue components of an image should be close to the average of a common gray value (Buchsbaum 1980). In a real world image, it is usually true that there are many different colour variations. These variations in colour are independent and random.

The simplest approach to colour constancy is to compute a single statistic from the whole scene which is assumed to estimate the illumination uniformly in the region of interest. In physical conditions, the hypothesis indicates that the mean among all the reflectances of the scene is referred to as gray. It is assumed that illuminants and spectral reflectances can be modelled based on the assumption that the entire image can be processed completely with a single reflectance vector (Buchsbaum 1980)

Human visual systems do not achieve the colour constancy based on the average tristimulus values, even in the case of local surrounds (McCann 1997). As a result, the author declared that colour constancy must be based on a normalisation process. This is related to the Retinex algorithm described in the following section.

3.3.4 Retinex Algorithm

The Retinex based methods are used to solve colour constancy problems through a very simplified but effective model of the human vision system (Land 1971). The name 'retinex' derives from two words 'retina' and 'cortex'. The information attained by the human vision system to observe a subject comes from two distinguishable processes. The first process is performed by the retina that acquires the image, while the second process, operated by the cerebral cortex, concurs to distinguish the objects independent of their illumination. For example, the same object can be identified if it is sited in both full sunlight and shadow areas or it is illuminated by an artificial light (Funt et al. 2000).

In this method, light variation is removed based on the assumption that illuminant variation generates small spatial variations on the response, since large variations occur due to changes in the surfaces. The main aim of this method is to estimate the appearance of the colour which is compared with the quantity of the energy obtained for every pixel. The relationship between these quantities is used in such a way that the method absolutely assumes a diagonal model. Moreover, the variations of method depend on the description of Retinex occurrence.

The Retinex theory deals with compensation for illumination effects in the images (PersComm, 1998). The researcher mentioned that a given image 'S' was decomposed into two different images, the reflectance image R, and the illumination image L, such that at each point (x, y) in the image domain.

$$S(x, y) = R(x, y)\ L(x, y) \qquad (3.10)$$

The advantages of this decomposition include: the capability to eliminate illumination effects of lighting and enhance images that involve spatially differing illumination such as images that contain outdoor and indoor regions and to correct them by removing illumination induced the colour changing.

3.3.5 Statistical Colour Constancy Algorithms

In statistical colour constancy algorithms, the basic assumptions of normal distribution of data are calculated based on statistics. Bayesian's method for colour constancy consists of three steps which are as follows (Freeman et al. 1995):

1. In the first step, the establishment of a relation among the reflectances, illuminants and sensor responses is developed.
2. In the second step, the former information of illuminants and surfaces of existence in the world is computed.
3. Finally, subsequent distribution of the illuminant and surfaces in the scene is achieved using the Bayes' rule.

Denison et al. (2002) used two general methods, i.e. 'Maximum A Posteriori' (MAP) and 'Minimum Mean Squared Error' (MMSE), to achieve the approximate calculation from the posterior distribution. The MAP method uses the same technique which is used in various statistical theories.

Another method for the estimation of the illuminant chromaticity and achievement of colour constancy is proposed by Finlayson (1996 & 1997). This method also addresses the assumptions of other colour constancy algorithms in accordance with Land (1977), Buchsbaum (1980) and Gershon (1988) such as the presence of white patch in every image, and the average reflectance of all the surfaces in a scene is achromatic.

3.3.6 Neural Network

Algorithms based on the Neural Network method are built upon an information processing paradigm that is inspired by the human nervous system. In image processing, neural networks are used to classify the probable illuminants in order to generate synthetic scenes (Cardei 2000). The Neural Network approaches can be effective but they require training data. Additionally, the results may not be possible to generalise.

3.3.7 Contrast Stretching

The contrast stretching algorithm (Fisher et al. 2003) is often called histogram normalisation. It is used to enhance the contrast of an image by stretching the range of the intensity values to occupy a wider or desired range. Unlike histogram equalization, the contrast stretching algorithm is only confined to the linear scaling function of the pixel values. Each pixel is scaled using the following function (Fisher et al. 2003):

$$P_o = (P_i - c)\frac{(b-a)}{(d-c)} + a \qquad (3.11)$$

Where:

- P_o is the normalised pixel value;
- P_i is the considered pixel value;
- a is the minimum value of the desired range;
- b is the maximum value of the desired range;

- c is the lowest pixel value currently present in the image;
- d is the highest pixel value currently present in the image;

In addition to applying the contrast stretching algorithm to the colour image, each channel is stretched using the same scaling to maintain the correct colour ratio. One of the main disadvantages is a single outlying extreme pixel value that affects the scaling and thus degrades the performance of the whole normalisation. This problem can be addressed by defining a cut off fraction after identifying the most popular intensity level in an image. The value of 'c' and 'd' is then defined by scanning upward and downward the intensity histogram until the first intensity value above the cut off fraction is obtained.

3.3.8 Histogram Equalisation

Histogram Equalisation (Fisher et al. 2003) is also called Histogram Modelling. It modifies the dynamic range and contrast of an image using a non-linear and non-monotonic transfer function to map between the pixel intensity values in order to obtain a desired shape of the intensity histogram.

It uses the continuous process function instead of the discrete ones. Hence, the image to be enhanced should have continuous intensity levels and the mapping occurs within this interval. The transfer law is single-valued and monotonically increasing in order to be able to define the inverse law. The transfer function is shown below:

$$F(D_A) = \max(0, round\frac{[D_M \times n_k]}{N^2} - 1) \qquad (3.12)$$

Where N is the number of image pixels

n_k is the number of pixels at intensity level k or less.

D_M is the maximum number of intensity levels in the input image

It improves the contrast without affecting the structure of the information in the image. The disadvantage of this approach is that holes may occur when the output image is not fully equalised. The number of pixels and the intensity quantisation levels of the image can be increased. There are two common variations to the histogram modelling method. They include the histogram specification method and the local enhancement. The histogram specification method is able to control the shape of the output histogram instead of the uniform intensity distribution in the conventional histogram equalisation. The local enhancement method allows enhancement of details over small areas. A transfer function is derived based on the histogram characteristic of the neighbourhood.

3.4 Face Detection Algorithms

Following the pre-processing stage, the face detection stage starts. This stage plays an important part in biometric security particularly in relation to surveillance images as faces are to be detected from the input image before they can be recognised and retrieved by the content-based image retrieval systems. There exist two classes of face detection methods (Chen et al. 2004) as shown in Figure 3.4 They include feature based approaches and image based approaches.

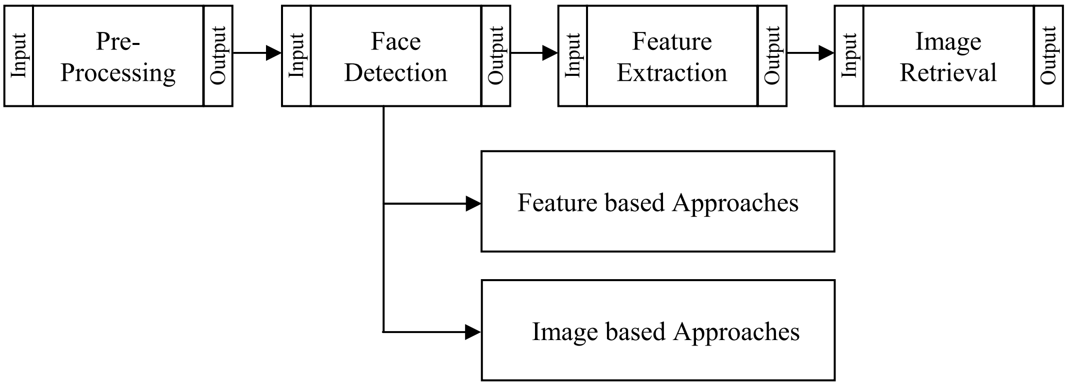

Figure 3.4 : Face detection methods

3.4.1 Feature Based Approaches

Feature based approaches rely on skin colour or edges or global face knowledge. Skin colour is also commonly used to detect faces. In this method the face detection is achieved by firstly applying colour segmentation methods for image segmentation purposes. These methods segment the image based on their colours that eventually help to detect the face based on their skin colour.

In order to apply feature based approaches, the images are firstly converted into different colour models such as HSI, YCrCb, YIQ, CIE-L* u* v* and CIE L* a* b* to process the skin colour easily. Different colour models represent the chrominance (colour) and luminance (brightness) components separately therefore they can help to detect the face more easily. In some cases the face detection methods use the illumination component to detect the highlighted area that is considered face. It can further be matched with the skin colour of face or hand. However, the hand can be discarded as it does not match with the face structure. Recent research shows that colour models that represent luminance and colour channels separately produce better results (Chaves-González et al. 2010).

The skin colour varies for individuals depending on their origin. The skin colour method may not produce better results if a similar colour to the skin colour appears in the background or in other objects of an image. In this situation, there is a high probability of getting a false detection.

Edge detection approaches are used to store images as binary. Due to this, the binary images are not affected by illumination. Edge detection approaches are considered computationally fast. Sobel and Canny edge detector is generally used for edge detection (Kim and O'Connor 2009). The advantage of this method is that it performs well over the existing edge detection methods. The edge based face detection methods are highly dependent on the quality of images. Therefore, a well enhanced image can produce more edges which can help to detect, recognise and retrieve images accurately and efficiently.

3.4.2 Image Based Approaches

Image or appearance based approaches are considered more reliable as compared to the feature based approaches as they can produce better results (Sahoolizadeh et al. 2008). Such approaches allow the system to automatically train itself based on an input image. Therefore, in that situation the image based approaches perform better than the feature based approaches as the feature based approaches rely on the features of an image (Chen et al. 2004). The main problem with the image based approaches is that they require a significant amount of time to process even a single image.

Image based techniques normally rely on machine learning and statistical analysis. These techniques are trained based on the images rather than the abstract level information about the features of face. These techniques include Neural Network, Bayesian Network and

Markov Random Field methods. These methods require significant resources in order to produce better results. The major drawback of these methods is the high computational cost. Therefore these approaches are not practical if they are to be used for real time applications such as surveillance images.

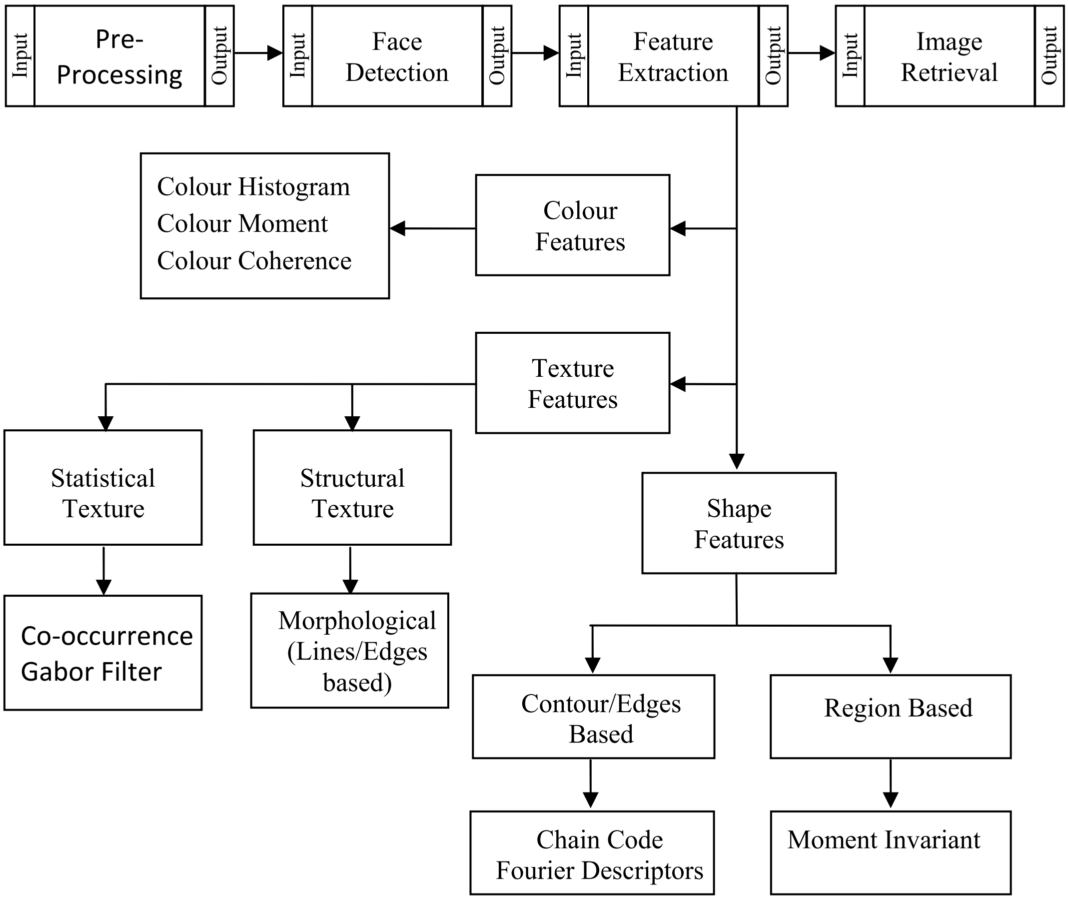

Figure 3.5 : Feature Extraction Methods

3.5 Image Retrieval

In content-based image retrieval systems, a desirable image is retrieved, from the large collection of images stored in an image database, based on their visual content using an image query. This process is usually performed automatically without human intervention.

The visual content of an image is represented by common attributes. They include 'colour of the image', 'texture of the image' and 'shape of the image' (Acharya and Ray 2005) as shown in Figure 3.5 and described below:

3.5.1 Colour Features

3.5.1.3 Colour Histogram

Colour feature is the most commonly used visual feature for image retrieval. In the literature many colour models are available, as briefly described in section 3.2 that can be used to represent images such as HSI, HSV, LAB, LUV and YCrCb. Colours play a major role in human perception. The most commonly used colour model is RGB, where each component represents colour, red, green and blue. The colour models, such as HSI and YCrCb, represent colour and illumination respectively. There are different ways to use colour for image retrieval purposes such as colour histogram, colour moment and colour coherence. But the most effective method is a colour histogram (Pun and Wong 2011).

The colour histogram provides meaningful information for measuring the similarity between two images, as it is robust against object distortion and scaling of the object (Acharya and Ray 2005). Additionally, high effectiveness, simplicity, low storage requirements and real time application possibility makes it the best among others (Jeong, et al. 2004). Due to these characteristics, several researchers have used histogram based colour image retrieval methods (Chora´s 2007; Jeong, et al. 2004; Khan et al. 2011; Yue et al. 2011). The edge based histogram has also been used for image retrieval purposes. A quite recent study examined the use of colour feature for colour based image retrieval using fuzzy measures (Chaira and Ray 2005).

3.5.1.2 Colour Moments

The Colour Moments descriptor method is used for image retrieval purposes. This has been used in the QBIC system. Through three lower order moments, most of the lower level colour distribution information can be extracted from an image. The first order moment (μ) helps to extract the mean colour. Using the second order moment and the third order moment, the variance (σ) and skewness (θ) can be extracted as a vector. The third order moment is better for improving image retrieval performance than the first and second order moments. However, sometimes it makes feature representation sensitive to scene changes. Therefore, possibly it could decrease the performance of the algorithm. These three low order moments (μ, σ and θ) are extracted for each colour components using the equations shown below(Stricker and Orengo 1995).

$$\mu_C = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} p_{i,j}^{C} \tag{3.13}$$

$$\sigma_C = \left[\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(p_{i,j}^{C} - \mu_C\right)^2\right]^{1/2} \tag{3.14}$$

$$\theta_C = \left[\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(p_{i,j}^{C} - \mu_C\right)^3\right]^{1/3} \tag{3.15}$$

Where $p_{i,j}^{C}$ is value of the *Cth* colour component of the colour pixel in the *ith* row and *jth* column of the image. Furthermore, it is a very compact representation of colour feature for characterizing the colour image. Nine features (three moments for each of three colour components) can be extracted from the colour image in order to represent the colour image. The performance can be improved by integrating different colour models. In order to measure the similarity between colour moments of two images, Weighted Euclidean distance has been found to be very effective (Acharya and Ray 2005).

3.5.1.3 Colour Coherence

Colour Coherence Vector technique is used for image retrieval, and it can produce better results where images have mostly uniform colour or mostly texture regions. The Colour Coherence Vector technique divides each histogram bin into coherent and incoherent. Coherent belongs to a large uniform colour region. The HSV colour model provides better results for colour coherence vector representation (Shih and Chen 2002).

3.5.2 Texture Features

Texture is another important feature of an image that can be extracted for the purpose of image retrieval. Image texture refers to surface patterns which show granular details of an image. It also gives information about the arrangement of different colours used to develop a pattern. For example, different patterns can be seen in grass fields and block walls. Figure 3.6 shows an example of two patterns: grass field and block wall that are different in colour arrangement.

There exist two main approaches for texture analysis. They include structural and statistical approaches (Tuceryan and Jain 1998). In the structural texture approach, the surface pattern is repeated such as floor design that contains the same pattern (Tamura et al. 1978). In the statistical texture approach, the surface pattern is not regularly repeated in the same pattern such as different flower objects in a picture that normally contains similar properties but are not exactly the same (Sklansky 1978).

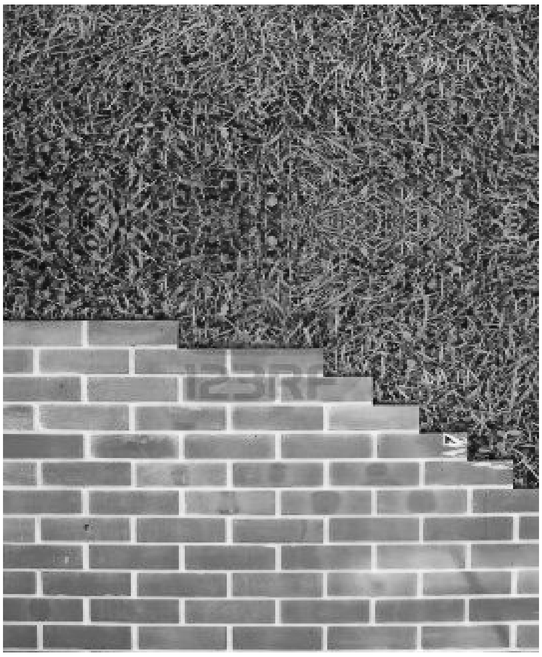

Figure 3.6: Grass field and block wall texture patterns

The structure of an image object can be extracted as texture feature. This structural information can be obtained through edges or lines or sketch of an image object. The Morphological decomposition method can be used to extract the structural texture features of an image (Lam et al. 1997). There are a few factors that are commonly used to extract the structural information of an image such as perimeter, area, eccentricity, orientation and magnitude (Baheerathan et al. 1999; Goyal et al. 1994). The texture methods based on structure have been extended to invariant texture classification but the difficulty of these methods is how to extract texels of a texture (Zhang and Tan 2002). Texels represent the image texture (Todorovic and Ahuja 2009). Similarly, pixels represent the image.

In statistical texture, the co-occurrence matrix is a popular representation of the texture feature of an image. The texture of an image is an illustration of spatial the relationship of gray level image (Pentland et al. 1996). Co-occurrence matrix is constructed based on the orientation and distance between image pixels.

Texture information can be extracted from an image using the co-occurrence matrix. There are many texture features that can be extracted from an image using the co-occurrence matrix, known as entropy, contrast, energy and homogeneity. These features represent the image as texture features and these texture features can be used for image retrieval purposes. The gray level of co-occurrence matrix $C(i, j)$ that is defined by first specifying a displacement vector $d_{x,y} = (\delta x,\ \delta y)$ and then counting all the pairs of pixels split by displacement $d_{x,y}$ and having gray levels *i* and *j* The matrix $C(i, j)$ is normalized by dividing each element in the matrix by the total number of pixels pairs. Using co-occurrence matrix, texture features metrics are computed as follows:

$$Entropy = -\sum_{i}\sum_{j} C(i, j) \log C(i, j) \tag{3.16}$$

$$Energy = \sum_{i}\sum_{j} C^2(i, j) \tag{3.17}$$

$$Contrast = \sum_{i}\sum_{j} (i, j)^2 C(i, j) \tag{3.18}$$

$$Homogeneity = \sum_{i}\sum_{j} \frac{C(i, j)}{1 + |i - j|} \tag{3.19}$$

Practically the co-occurrence matrix is computed for several values of displacement $d_{x,y}$ and the one that maximizes a statistical measure is used. Tamura et al. (1978) proposed a computational approximation to the texture features that is based on the human mental study in the visual perception of texture. The researchers found the texture characteristic visually useful for texture analysis such as contrast, linelikeness, coarseness, directionality, roughness and regularity. These texture features are used in several content based image retrieval systems.

Signal processing and wavelet transform methods are used in texture analysis. The Wavelet transform is used for image classification based on multi-resolution decomposition of images (Chang and Kuo 1993; Manjunathi and Ma 1996). Among the different wavelet transform filters, the Gabor filter is found to be very effective in texture analysis (Acharya and Ray 2005). The Gabor filter is used in various types of applications due to its effectiveness in the area of texture based image analysis (Wu et al. 2010; Acharya and Ray 2005; Do and Vetterli 2002; Manjunathi and Ma 1996).

3.5.3 Shape Features

Shape feature plays a vital role in object detection and recognition. Object shape features provide robust and efficient information of objects in order to identify and recognise them. Shape features are considered very important in describing and differentiating the objects in an image. Shape features can be extracted from an image by using two kinds of methods: contour and regions.

Contour based methods are normally used to extract the boundary of objects by applying edge detection method to an image. The Fourier descriptors and Chain code methods can be used to extract the features from the contour/boundary of an object shape (Gonzalez and Woods 2002). But the limitation of these methods is that it completely ignores the important features inside the boundaries.

Fourier descriptor method has been used effectively in a close shape object such as character recognition. The Fourier descriptor of contour is achieved by applying coefficients in a sequence through Discrete Fourier transform. Generally, the usage of few coefficients produce poor results but applying more coefficients can significantly help to achieve better approximation results as shown in Figure 3.7 (Kuntz 2010).

Fig 3.7 has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 3.7 : The Fourier descriptors show better approximations (in red) by more coefficients (Kuntz 2010)

Chain code is used to represent the contour or boundaries of shapes by a connected line of specified length and direction. There are two components of chain code: the coordinates of starting point and the chain of codes representing the relative position of starting pixel and its followers. The chain code is created using the changing direction of connected pixels that are contained in a boundary. There are two directions of chain code, such as 4 neighbourhood and 8 neighbourhood as shown in figure 3.8. The chain code method is sensitive to noise as a little disturbance of noise along the boundary or imperfect segmentation may affect the code which might not necessarily be related to the shape of the contour.

Region-based methods that rely on shape descriptors are normally able to extract both kinds of features: boundary and region. Region-based methods normally use a moment based theory such as Hu moments, Legendre moments and Zernike moments (Acharya and Ray 2005; Wong et al. 2007). These provide valuable information to represent the shape of an image for feature extraction. The existing literature shows the importance of moment based methods for shape features extraction in the area of image retrieval (Zhang et al. 2009; Premaratne and Nguyen 2008; Rizon et al. 2006; Zhu et al. 2002; Premaratne and Safaei 2009)

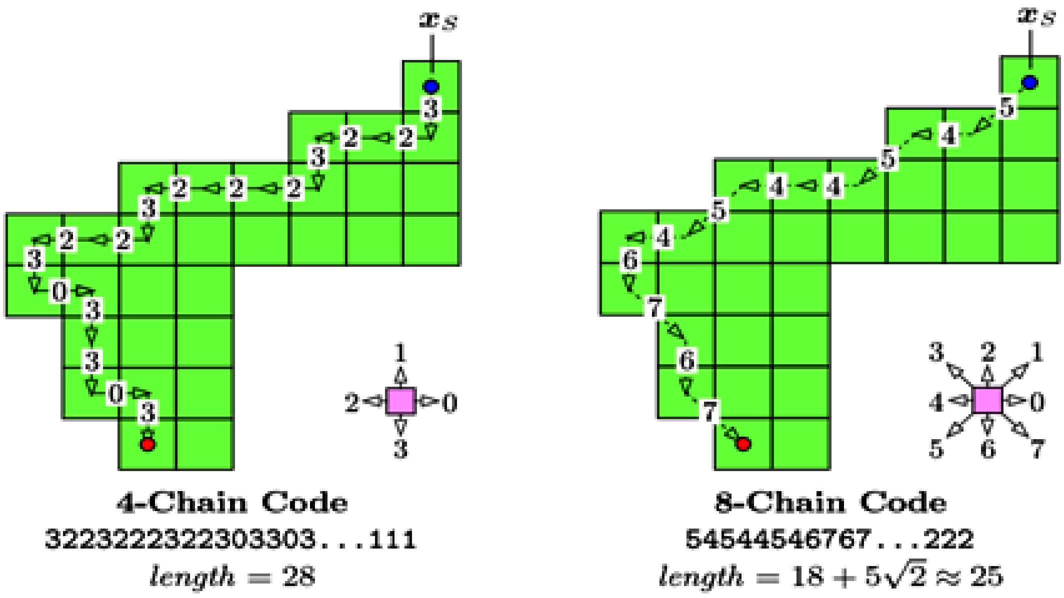

Figure 3.8: 4 and 8 Chain Code Examples (Digital Image Processing 2011)

Region based image retrieval methods firstly apply the segmentation to divide the image into different regions/segments, by setting threshold values according to the desirable results. Moment based methods find the centre point of the region then apply the moment invariant method where Hu derives a set of seven invariant moments that have the desirable characteristic of being invariant under the image rotation, translation and scaling (Chen 2003). Features can be extracted based on the centre point as a starting point which is shown in Figure 3.9. These extracted features are used to recognize the object.

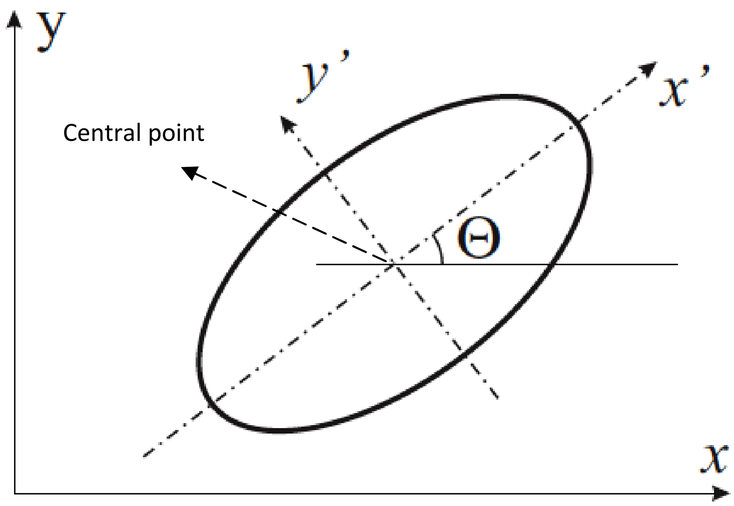

Figure 3.9: The centre point of the region

3.6 Similarity Measures

In the content-based image retrieval system, similarity between two objects or two images can be measured based on the similarity measure. The content-based image retrieval systems produce the search results based on this measurement. Calculating the similarity between image query and image database presents an issue relating to accurate measurements of features that can affect the performance of the content-based image retrieval systems.

Many similarity measure methods have been developed for effective image retrieval purposes based on empirical estimates of the distribution of features in recent years (Long et al. 2003). Some of the well known similarity measures include Euclidean Distance, Histogram Intersection and Fuzzy Heuristics.

Similarity between two images is measured numerically which reflects the strength of connections between them. Similarity is crucial in obtaining relevant results. To obtain better results various researchers use different methods to measure similarity. For example, some researchers used fuzzy measures (Chaira and Ray 2005), histogram intersection (Jeong et al. 2004; Smeulders 2000) and Euclidean Distance (Long et al. 2003). The most important and relevant similarity measure methods are described in the following sections.

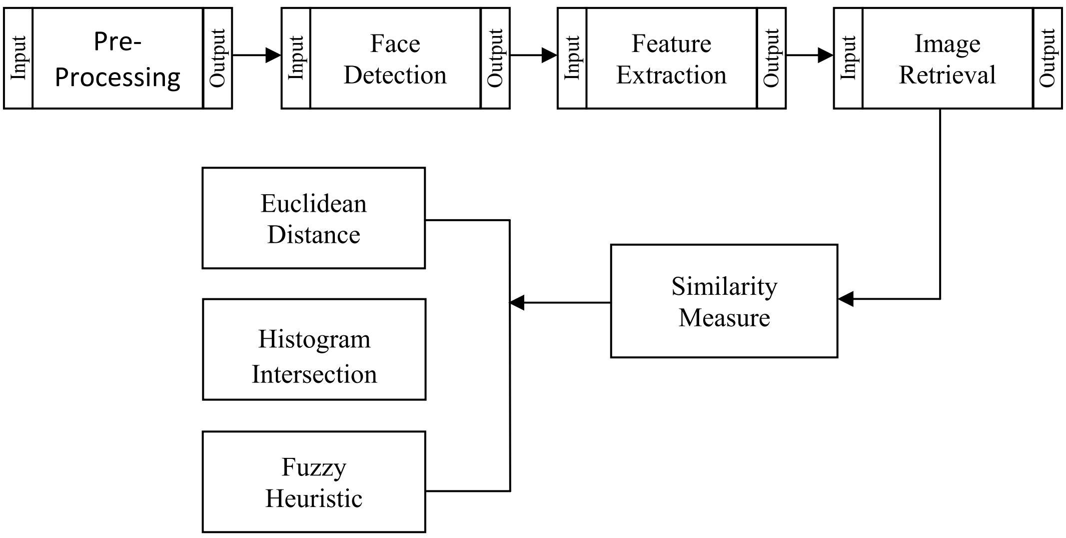

Figure 3.10 : Similarity Measure Methods

3.6.1 Euclidean Distance

The Euclidean distance formula can be used to calculate the similarity between two feature vectors as follows.

$$ED\left(M^{k}, M^{t}\right) = \sqrt{\sum_{i=1}^{n}\left(M_{i}^{k} - M_{i}^{t}\right)^{2}} \qquad (3.20)$$

Where M^k and M^t are image query and image database respectively, *i* is a feature range. Closer distance between image features represents the higher similarity between an image query and image database.

3.6.2 Histogram Intersection

Histogram Intersection is normally used to measure similar values occupied by two histograms. It calculates the histogram bins that are common between two histograms such as query image histogram and database image histogram. The advantage of this method is that it explicitly neglects those features which only appear in one histogram (Siggelkow 2002). It is a simple method that does not require high computation resources, in the number of histogram bins it is linear, where $M : O(M)$

The intersection is related to the L_1-norm

$$\cap\left(h^{(0)}, h^{(1)}\right) = 1 - \frac{L_1(h^{(0)}, h^{(1)})}{2} \qquad (3.21)$$

It can be defined in the following way, as all the histogram entries are summed up to 1 (Siggelkow 2002).

$$\sum_{m=0}^{M-1} h_m^{(0)} + \sum_{m=0}^{M-1} h_m^{(1)} = 2 \qquad 3.22)$$

$$2\sum_{m=0}^{M-1} \min(h_m^{(0)}, h_m^{(1)}) + \sum_{m=0}^{M-1} \left| h_m^{(0)} - h_m^{(1)} \right| = 2 \qquad (3.23)$$

$$2\cap\left(h_m^{(0)}, h_m^{(1)}\right) + L_1\left(h_m^{(0)}, h_m^{(1)}\right) = 2 \qquad (3.24)$$

$$\cap\left(h_m^{(0)}, h_m^{(1)}\right) = 1 - \frac{L_1\left(h_m^{(0)}, h_m^{(1)}\right)}{2} \qquad (3.25)$$

3.6.3 Fuzzy Classification

In 1973, Lotfi Zadeh proposed a method for the analysis of complex system by using human knowledge in fuzzy rules (Jiang et al. 2006). Over the last two decades, fuzzy logic has gain importance increasingly. It has been used for the development of different kind of applications. Fuzzy rules can be defined in the form of conditional statement such as:

IF x is A and y is B THEN z is C

Here the x, y are the input variables and z is a single output variable, where A, B and C are the linguistic labels which are determined by the fuzzy sets on the universe of discourses X, Y and Z respectively.

In fuzzy logic system, the fuzzification, rule evaluation, aggregation of rule and defuzzification are the major steps that are described below (Hanacek et al. 2000; Fuzzy Inference Systems 2011):

- **Fuzzification:**

In fuzzification, the crisp input values (external values) are converted to fuzzy values through the membership functions. In other words we can say that the crisp input values are used to calculate the degree of membership of each input values inside each of its term sets. This procedure produces a set of fuzzy sets.

- **Rule Evaluation**:

In this step the crisp inputs have been fuzzified, where the fuzzy rules (Using If-Then type fuzzy rules convert the fuzzy input to the fuzzy output) are evaluated in order to produce an output for each rule. In this procedure two or more membership values are used to generate one output value. This output value indicates the strength of firing of the rule. It is used to redesign the consequent part of the rule that generates the modified fuzzy sets.

- **Aggregation of Rule:**

In aggregation step all the associated fuzzy sets of the fired rules are merged through fuzzy operators such as AND or OR operators, in order to generate the single fuzzy set for each of output values.

- **Defuzzification:**

The purpose of Defuzzification is to convert the aggregate output of fuzzy set into the crisp number. The most commonly used method for defuzzification is the centroid method, this method can find a point representing the Centre Of Gravity

(COG) of fuzzy set. The sensible estimation can be obtained through computing it over a sample of points.

Fuzzy inference system (FIS) is a process that uses the fuzzy theory of fuzzy sets in order to formulate the mapping of given input to an output. There are two types of Fuzzy Inference Systems (FIS) that are available in literatures. These are Mamdani Fuzzy Inference System (Keshwani 2008) and Sugeno Fuzzy Inference System. Fuzzy Inference System (FIS) is based on three main processes that are defined as follows. Membership functions, Fuzzy logic operator and Fuzzy if then rules.

The commonly used Fuzzy Inference System is known as Mamdani method. This method is one of the first fuzzy systems used to control the combination of a steam engine and boiler (Mamdani and Assilian, 1975). This method is commonly used due to its wide acceptance in capturing expert knowledge. Mamdani FIS allows one to illustrate the expertise in more intuitive, and more human like manner.

The second inference system is Sugeno Fuzzy inference system. It is computationally effective and produces better results in optimization and adaptive techniques. Due to this it is used in control environment problems, especially for nonlinear applications.

3.7 Summary

This chapter has discussed several models and concepts relating to image enhancement, face detection, feature extraction and image retrieval. The objective of this chapter is to get insight from the existing models and theories and form the basis of the proposed approach based on the selection of the methods that would be used as part of the proposed approach.

As discussed in this chapter, there exist several colour models such as RGB colour model, HSI colour model and YCrCb colour model which can be used to improve the perception of the images. Image enhancements methods are discussed in the chapter. Particularly, the focus of this research is on transform-based approaches which will be used as part of the proposed approach. Due to the fact that these approaches are based on point processing techniques, which directly perform operations on the pixel values, they are more efficient and they require less time and resources. These approaches include Gray World, Retinex/White Patch and Contrast Stretching.

Face detection methods are briefly discussed. The proposed research intends to improve the quality of the images by proposing an integrated approach which can be used in liaise with the existing face detection methods.

Feature extraction methods for Content based image retrieval systems have also been discussed which are based on colour features, texture features and shape features. Different colour feature extraction methods such colour histogram, colour moments, and colour coherence have been described in this chapter. In texture feature extraction, the statistical and structural methods have been discussed. In structural texture features extraction, the structural information is obtained through edges or lines or sketch of an image object. In statistical texture, the co-occurrence matrix and Gabor filter are used to extract the texture features such as entropy, contrast, energy and homogeneity. In shape feature extraction, the boundary or edge based and region based methods that can be used to extract the features of shape object have been discussed. The Fourier descriptors and Chain code methods can be used to extract the features from the contour/boundary of an object shape whereas Region-based method namely Hu moments can be used to extract the region of an object.

The most relevant similarity measures such as Euclidean Distance and Histogram Intersection are also discussed. Finally, fuzzy classification is discussed in order to gain insight on how this process is to be applied to the proposed approach to get better results.

Among the above discussed methods for image enhancement, the contrast enhancement and colour balancing methods are proven to be able to produce better results. These methods can improve the quality of surveillance images from different prospective such as contrast, illumination and colour cast. Therefore these methods have been selected to be used as part of the proposed approach. Further discussions on these methods will be carried out in the next chapter.

Similarly, different feature extraction methods are discussed in this chapter, among them the best methods are to be selected for the proposed content based image retrieval approach. Three kinds of feature extraction methods will be used to extract Colour feature, Texture features and Shape feature. For colour features extraction, Colour histogram is used to extract the colour features of an image using four components; three of the components (Red, Green and Blue) are obtained from RGB colour model while the fourth component (Intensity) is generated by combining the Red, Green and Blue components. The histogram method is widely used for visual feature representation due to its many advantages in image retrieval such as its robustness, effectiveness, implementation and computational simplicity. For the purpose of texture feature extraction, the Gabor wavelet algorithm is used. As the recent study shows, Gabor filter can produce better results as compared to the existing texture feature extraction methods. Therefore, the Gabor filter will be used as a part of the proposed approach. Regarding the shape feature extraction, there exist two types of methods: a region based method and a boundary based method. The boundary based method only uses the boundary of an image whereas the region based method uses regions of an image along with its boundary. The region based methods provide more detailed information as compared to boundary based methods. Therefore a region based moment invariant method will be used for shape feature extraction. Similarity measure plays a vital role for retrieving similar images. In this regard a Euclidean distance and a set of Fuzzy rules will be used to measure similarity between a query image and images in a database in order to retrieve and prioritise the results.

The next chapter will discuss the proposed framework consisting of image enhancement for visibility improvement, feature extraction and similarity measures using Fuzzy rules for image retrieval.

CHAPTER 4

A NEW INTEGRATED FRAMEWORK FOR BIOMETRIC SECURITY

4.1 Introduction

This chapter attempts to address a root problem concerning biometric security, in particular with regard to surveillance images from an image enhancement perspective. In order to address the surveillance images problem an integrated framework is proposed in this chapter. The proposed framework consists of three stages which are pre-processing, feature extraction and evaluation. In the first stage an integrated image enhancement approach is proposed to enhance the quality of images in order to use these images for further processing. In the second stage three feature extraction methods are used to extract the image features such as colour features, texture features and shape features. These features are extracted from image database and image query. Then, using Euclidean Distance method these feature values are used to calculate the distance between an image query and images in a database such as shape distance, colour distance and texture distance. Based on these feature distances a set of fuzzy rules are defined in order to prioritise the results. In the final stage, the testing and evaluation of components of the proposed approach are performed using face detection, precision and recall methods. Further evaluation is carried out by comparing the achieved results with those of existing well-known methods.

The rest of the chapter is organised as follows. Section 4.2 presents the new integrated framework and discusses its components. Section 4.3 discusses the image enhancement methods. Section 4.4 discusses face detection. Section 4.5 discusses feature extraction. Section 4.6 presents the feature matching methods for image retrieval. Section 4.7 discusses testing and evaluation. Section 4.8 provides a brief summary of this chapter.

4.2 A New Integrated Framework

This section proposes an integrated framework for biometric security as shown in Figure 4.1. The framework emphasises the use of different image enhancement techniques that can improve face detection, feature extraction and image retrieval of surveillance images for biometric security. The framework consists of three main stages as briefly described below:

- At the first stage, image enhancement techniques namely contrast enhancement and colour balancing methods are applied to improve the visibility of an image which is important for face detection. The integrated image enhancement method is applied to face detection which is further discussed in the evaluation chapter.
- At the second stage, feature extraction methods namely colour feature extraction, texture feature extraction and shape feature extraction methods are used to extract the image features.
- At the third stage, a comparison is made between the extracted colour, texture and shape features of database images with the image query using Euclidean distance and fuzzy measure methods for feature matching and image retrieval.
- In the final stage, the testing and evaluation of components of the proposed approach are performed using face detection, precision and recall methods. Further

evaluation is carried out by comparing the achieved results with the existing well-known methods.

The framework is applied to images produced by surveillance cameras which usually produce low quality images. The main purpose of the new framework is to improve the efficiency and accuracy of image retrieval system for biometric security by improving the quality of surveillance images.

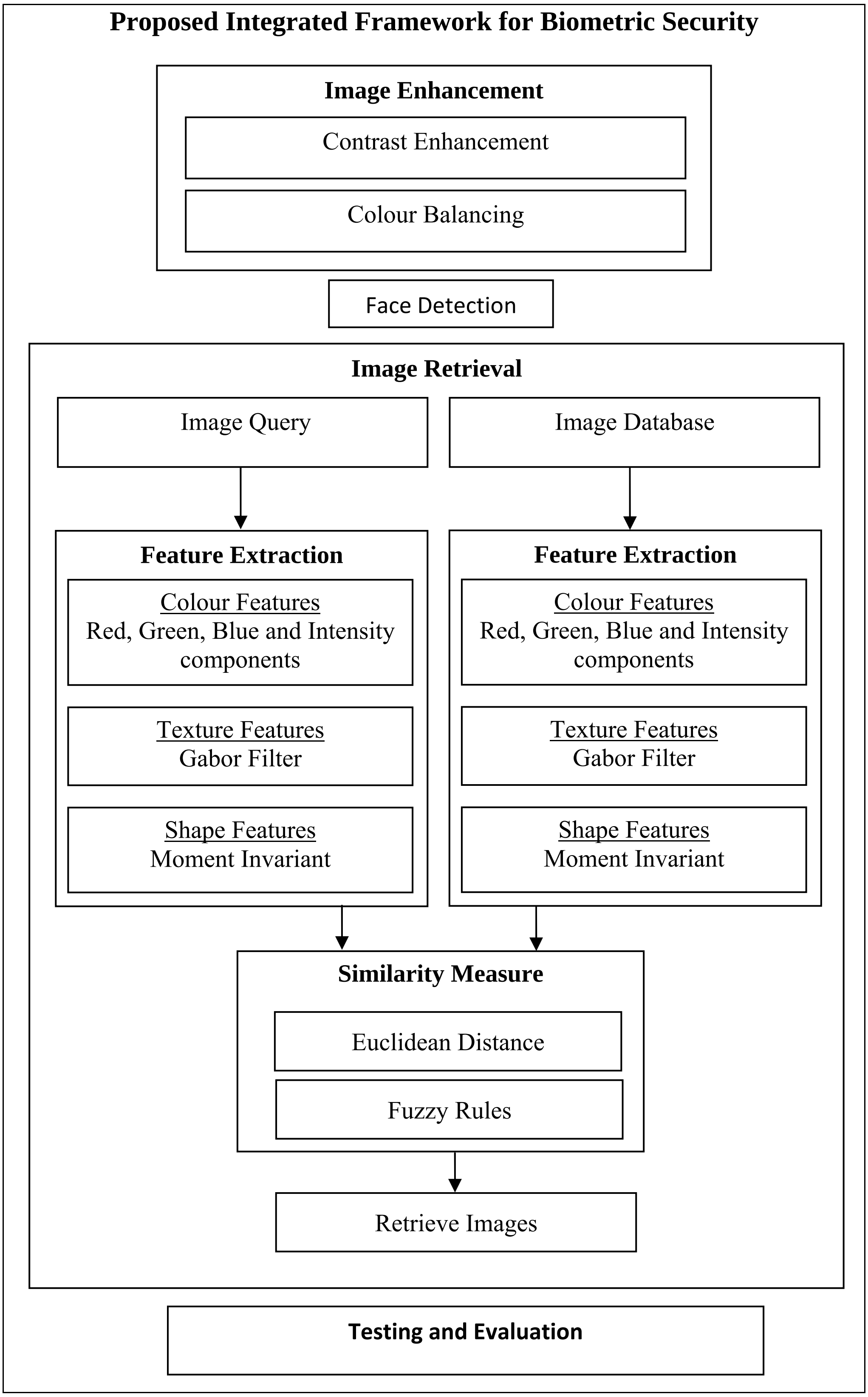

Figure 4.1: A New Integrated Framework for Biometric Security

4.3 Image Enhancement

Surveillance cameras usually produce low quality images. Therefore in the new framework, multiple methods of image enhancement are proposed in order to improve the contrast, make the image balanced and improve the illumination of an image.

In order to improve the visibility of the surveillance images two image enhancement methods namely contrast enhancement and colour balancing methods are applied to:

1. Improve the low contrast surveillance image by using the contrast enhancement method. It makes the surveillance images clearer as compared to the original images. Without applying the contrast enhancement method it is not possible to achieve the clear images.
2. Balance the values of Red, Green and Blue components of an RGB colour image in order to produce a well balanced image and adjust the dominant colour in the rest of an image. A new process will be introduced in order to calculate the colour cast and remove it effectively.

4.4 Face Detection

Face detection can be improved by enhancing the quality of images. Image and feature based methods are normally used for face detection. The new framework takes advantage of both categories of face detection methods. Image based techniques normally rely on machine learning and statistical analysis. These techniques are trained based on the images rather than the abstract level information about the features of face. These techniques include Bayesian Network and Neural Network, as discussed in the previous chapter.

Feature based approaches rely on skin colour or edges or global face knowledge. Skin colour is also commonly used to detect faces. In this method the face detection is achieved by firstly applying colour segmentation methods for image segmentation purposes. These methods segment the image based on their colours that eventually help to detect the face based on their skin colour (Chaves-González et al. 2010).

The enhanced images are used to provide input to the face detection methods in order to detect the faces. The existing face detection methods produce poor results when applied to surveillance images. After the enhancement of surveillance images, these methods can produce better results as discussed in chapter 7.

4.5 Feature Extraction

In image recognition the feature extraction stage plays a vital role. Feature extraction provides the means to get vital information from an image for classification purpose. The classified data or patterns are used to train the system for supervised as well as unsupervised learning. In the unsupervised method, no information is given to the system but the system creates patterns based on its built-in functions. Normally, statistical and syntactic (rule based) methods are used for pattern recognition.

In this stage the features of an image are extracted. Feature extraction is important for object recognition as the whole process of recognition is highly dependent on the features of an image. Thus a suitable method will ensure better results are achieved for an object recognition. The following feature extraction methods are used as part of the new approach.

- Colour feature extraction: Red, Green, Blue and Intensity histograms based methods are used to extract the colour features of images.
- Texture feature extraction: Gabor filter method is used to extract the texture features of images.
- Shape feature extraction: Hu moment invariant method is used to extract the shape feature of images.

These visual features of an image namely colour, texture and shape are automatically extracted from image and do not rely on any human annotation.

4.6 Similarity Measures

The extracted features will then used for feature matching. The features of query image are matched with the images that are stored in the database. The Euclidean distance and fuzzy measure methods are employed to find the most relevant images from the image database based on image query in order to retrieve the most relevant images. Additionally, 14 fuzzy rules, based on the priority that is given to the more reliable features of image, are defined in order to produce most similar images relevant to the image query.

Image recognition and retrieval cannot be improved without improving the quality of images (Wang et al. 2004). Therefore, an important part of the new approach is to use image enhancement techniques to enhance the quality of the images in order to improve the efficiency and accuracy of the biometric security system.

4.7 Testing and Evaluation

This stage will test the efficiency and accuracy of the proposed new approach. This test will be based on the quality of the output images. Because images are enhanced, the rate of face detection will be improved; accurate features will be extracted and eventually image retrieval will be improved.

The results of the first part of the proposed image enhancement approach are to be evaluated using face detection methods. The standard evaluation metrics Precision and Recall will be used to evaluate the second part of the proposed approach. The overall results of the proposed approach will also be compared with the existing approaches in order to demonstrate the effectiveness and accuracy of the proposed approach.

4.8 Summary

In this chapter, an integrated framework for biometric security has been proposed. The integrated framework consists of four stages: image enhancement; feature extraction; similarity measures using Fuzzy rules and testing and evaluation. The framework emphasises the use of different image enhancement techniques that can improve face detection, feature extraction, face recognition and image retrieval for biometric security.

The new integrated image enhancement approach consisting of contrast enhancement and colour balancing methods will be applied to enhance the surveillance images in order to improve face detection. The improvement in face detection using the proposed approach is shown in the evaluation chapter. The proposed integrated image enhancement approach will also be used to enhance the query image so that more features can be made visible for better image retrieval.

The three image features namely colour, texture and shape will be extracted from images in order to measure similarity between a query image and a set of database images. The new content based image retrieval system will then use these three types of visual features: colour, texture and shape to calculate similarity using the Euclidean Distances of each feature between the query image and database image. A set of Fuzzy rules will be employed to prioritise results based on the important features of the image.

Finally, the evaluation of the proposed approach will take place using several methods so that the effectiveness and accuracy of the proposed approach can be demonstrated. Firstly, the proposed integrated image enhancement approach will be applied to detect faces before and after enhancement using the proposed approach. Secondly, the standard methods such as Precision and Recall will be applied to evaluate the content based image retrieval approach. A comparative evaluation will also be carried out to compare the overall results of the proposed approach against the well known existing approaches.

The next chapter will discuss the first part, face detection, of the new approach. It will present an integrated image enhancement approach for face detection.

CHAPTER 5

NEW INTEGRATED IMAGE ENHANCEMENT APPROACH FOR FACE DETECTION

5.1 Introduction

Face detection plays a vital role towards face recognition and image retrieval. Face detection is the first step of face recognition applications; therefore, it is crucial that faces are detected efficiently and most importantly accurately in order to recognise them for security reasons. The performance of a face detection method is highly dependent on the quality of input images (Wang et al. 2004). It is therefore important to apply image enhancement techniques so that the quality of images can be enhanced for better face detection and retrieval. An unclear image does not show full details as CCTV images suffer from low contrast, low brightness, noise, and sometimes the image is dominated by one or more colours that make the image unbalanced. Therefore these factors make surveillance images difficult for recognition purposes. In order to improve the accuracy and efficiency of the biometric system, it is necessary to make the images clearer and sharper to extract the good features of an image.

The rest of the chapter is organised as follows. Section 5.2 discusses an integrated methodology applied to enhance the quality of the surveillance images. This section also discusses the different components of the methodology. Section 5.3 concludes this chapter.

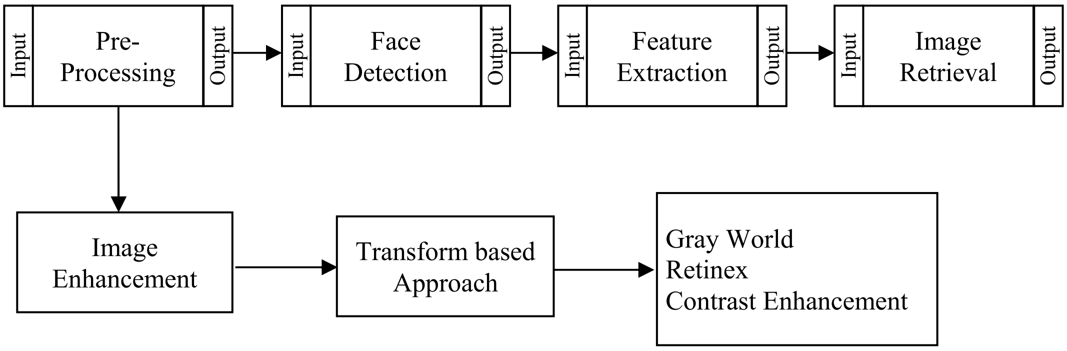

Figure 5.1: Methods used in proposed image enhancement approach

5.2 New Integrated Image Enhancement Approach

This section discusses the new integrated image enhancement approach which can be used to improve the quality of the images so that better face detection can be achieved. The new integrated image enhancement approach is based on the three important methods namely: Gray World, Retinex and Contrast Enhancement methods. Several researchers (Bianco et al. 2010; Chikane and Fuh 2006a, 2006b; Gasparini et al. 2004) integrate Gray World and Retinex methods for colour balancing. Similarly, in the proposed approach colour balancing consists of Gray World and Retinex/White Patch methods.

The proposed approach discussed in this dissertation is complementary to and extends the existing research corpus related to image enhancement (Chikane and Fuh 2006a & 2006b; Gasparini *et al.,* 2004). Before describing the proposed approach, a brief description of the existing image enhancement methods is given below so that a comparison can be made between the existing research methods and the proposed approach. Importantly, it will be shown how the perceived limitation is addressed in the proposed approach.

Briefly, colour balancing method which was proposed by (Gasparini *et al.,* 2004) and white balance method which was proposed by Chikane and Fuh (2006a & 2006b) have used the predefined threshold values. Due to the use of predefined threshold values these methods were able to enhance limited set of images. More details about these methods can be found in section 2.2.3 in chapter 2. The proposed integrated image enhancement approach calculates different kinds of values that are taken directly from the image pixels such as average, maximum, reference points, scale factors and gain factors instead of relying on predefined threshold values. These values are interrelated to each other in order to enhance the affected image accurately. The proposed approach is an adaptive approach because it performs functions on the image pixel values automatically without using any predefined value. Due to these characteristic of the proposed approach, it can enhance every kind of surveillance images whether it is affected by colour cast, colour contrast or brightness. The existing image enhancement approaches are unable to enhance the quality of images when they are affected by heavy colour cast (Gasparini *et al.,* 2004).

Histogram stretching method is applied to enhance the bimodal MRI (Magnetic Resonance Imaging) medical images (Al-Manea and El-Zaart, 2007). It is used to improve the contrast of gray scale images. The drawback of this method is that it is unable to remove the colour cast. On the other hand, the proposed approach is based on contrast enhancement and colour balancing methods which are able to improve the contrast and remove the colour cast.

Bianco et al. (2010) have used several image enhancement methods, such as gray world, white patch (Retinex) and gray edge, in order to improve the quality of images. It enhances the quality of images by improving the visibility of edges. On the other hand, the proposed approach uses the gray world, white patch (Retinex) and contrast enhancement methods in order to improve the visibility of colour images from different angles such as improving the contrast, improving the brightness and most importantly, by removing the colour cast. Thus, using the proposed approach, the whole image can be enhanced instead of only edges.

Another similar approach proposed by Kao et al. (2010) enhances the quality of gray scale images using contrast enhancement and edge enhancement methods. Then, these enhanced images are used to extract the texture features from image. But on the other hand, in the proposed approach contrast enhancement and colour balancing methods are used to improve the visibility of colour images from different angles such as improving the contrast, improving the brightness and most importantly, by removing the colour cast as described above. Then, these enhanced images are used to extract three types of features such as Colour, Texture and Shape for image retrieval.

A detailed systematic methodology, showing how different image enhancements methods are integrated and applied to enhance the surveillance images, is shown in figure 5.2.

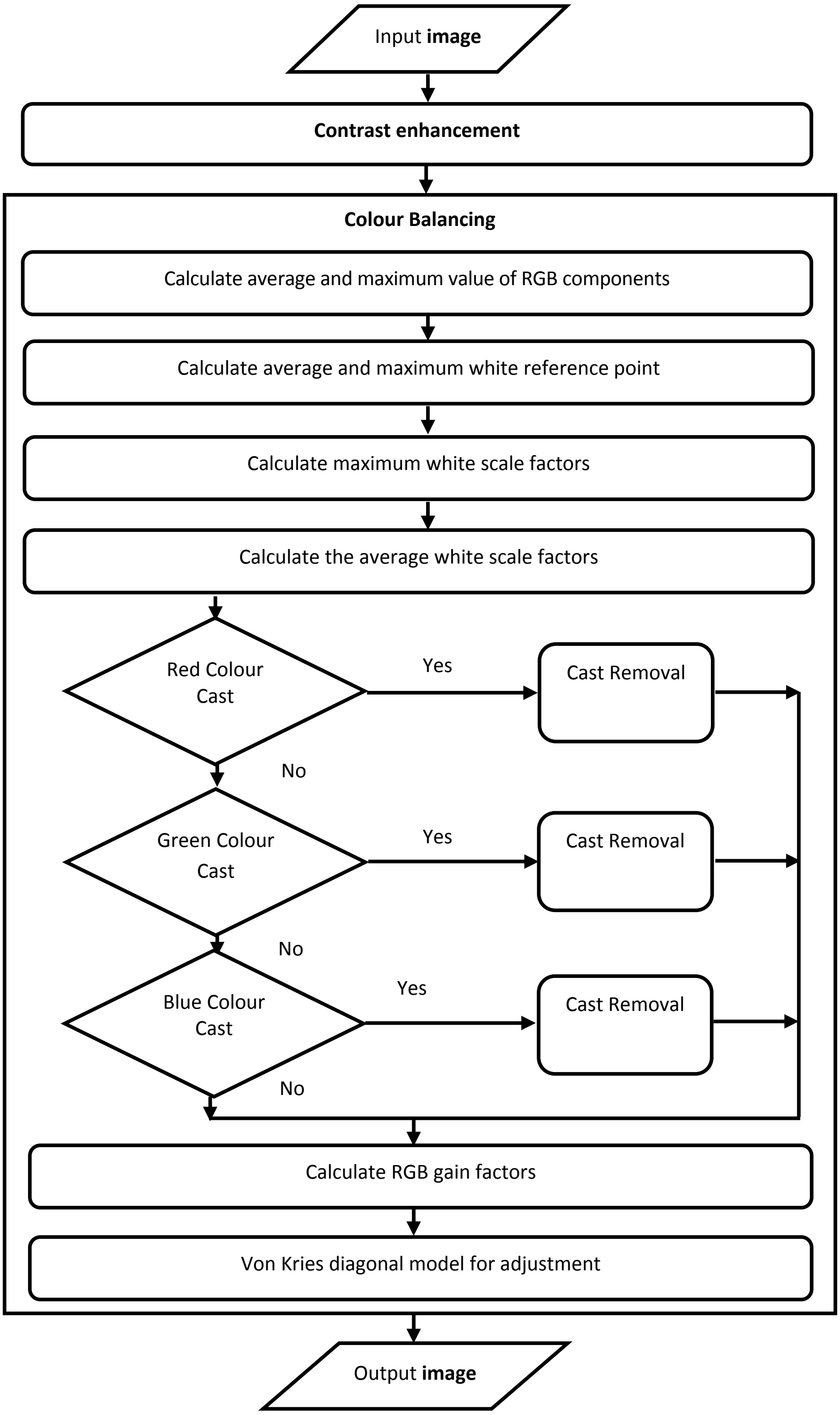

Figure 5.2: New Integrated Image Enhancement Approach

5.2.1 Contrast Enhancement

The first method of the new approach is contrast enhancement which is applied to each Red, Green, and Blue channel of image in order to enhance the contrast of these images. The contrast enhancement method improves the contrast in order to make objects visible so that the colour balancing algorithms can be applied more effectively. It is argued that a low contrast situation can obscure image information, which results in an unclear image which is difficult to understand or see. Due to this fact, the contrast enhancement algorithm is merged with colour balancing algorithm for biometric image enhancement. The following equation has been used for contrast enhancement (Fisher et al. 2003).

$$P_o = (P_i - c)\frac{(b-a)}{(d-c)} + a \tag{5.1}$$

Where P_o is the contrast corrected pixel value; P_i is the considered pixel value; a is the lower limit value which is 0; b is the upper limit value which is 255; c is the minimum pixel value currently present in the image and d is the maximum pixel value currently present in the image. In order to achieve better results, it is proposed that the contrast enhancement algorithm should be applied to every pixel in the whole image.

5.2.2 Colour Balancing

Colour balancing method is applied to enhance the image by removing any dominate colour that occupies the entire image. Colour balancing is an important algorithm that is used to achieve high quality images. After the contrast enhancement algorithm, the colour balancing algorithm is applied to calculate average and maximum white reference points. Based on these reference points, the average and maximum white scale factors are calculated. On the basis of these scale factors, gain factors are calculated. By using gain factors, the quality of the image is improved. Figure 5.2 demonstrates the process flow of the new approach. Details of these steps are given below.

Step 1: Calculate the average and maximum value of RGB components.

$$R_{Avg},\ G_{Avg},\ B_{Avg} \tag{5.2}$$

$$R_{\text{Max}},\ G_{\text{Max}},\ B_{\text{Max}} \tag{5.3}$$

Step 2: The matrix operation below is used to convert RGB to the YCrCb colour model (see equation 5.4). These are easier and faster to calculate as compared to other colour models (Schweng and Detlef, 2006). The Y component is luminance. Cr, Cb are the chrominance components which represent colours. Luminance describes the range from black to white and certain amount of luminance is essential for human eyes to make a color pixel visible. In our proposed method we only used luminance channel.

$$\begin{cases} Y = (\ 0.299 \times R) + (0.587 \times G) + (0.114 \times B) \\ \mathbf{C}r = (\ 0.701 \times R) - (0.587 \times G) - (0.114 \times B) \\ \mathbf{C}b = (-0.299 \times R) - (0.587 \times G) + (0.886 \times B) \end{cases} \tag{5.4}$$

Y luminance values are used with average and maximum value of each RGB component in order to calculate the maximum white reference point and average white reference point as shown in equations (5.5 & 5.6).

$$Y_{MaxWhite} = (0.299 \times R_{Max}) + (0.587 \times G_{Max}) + (0.114 \times B_{Max}) \tag{5.5}$$

$$Y_{AvgWhite} = (0.299 \times R_{Avg}) + (0.587 \times G_{Avg}) + (0.114 \times B_{Avg}) \quad (5.6)$$

To calculate the reference white, the top 10% of the pixel values are used (Weng et al. 2005). Chikane and Fuh (2006a and 2006b) have calculated the reference value using average values based on the range average to bright pixel value. In the new colour balancing algorithm, both average and maximum values are used to calculate two separate white reference points as shown in (5.5 & 5.6). These reference points of average and maximum are used to calculate the scales factors.

Step 3: In this step, the maximum white scale factor of each colour component is calculated according to the maximum white reference point using equations (5.3) and (5.5) as written in equations (5.7, 5.8 & 5.9).

$$R_{MaxWhiteScaleFactor} = Y_{MaxWhite} / R_{Max} \quad (5.7)$$

$$G_{MaxWhiteScaleFactor} = Y_{MaxWhite} / G_{Max} \quad (5.8)$$

$$B_{MaxWhiteScaleFactor} = Y_{MaxWhite} / B_{Max} \quad (5.9)$$

Step 4: Here, the new approach is used to calculate the average white scale factor to maintain the whole image brightness at the same level because the human eye is more sensitive to brightness feature rather than colour feature. According to the average white reference point, the average white scale factor is calculated using equations (5.2) and (5.6) as written in equations (5.10, 5.11, and 5.12).

$$R_{AvgWhiteScaleFactor} = Y_{AvgWhite} / R_{Avg} \quad (5.10)$$

$$G_{AvgWhiteScaleFactor} = Y_{AvgWhite} / G_{Avg} \tag{5.11}$$

$$B_{AvgWhiteScaleFactor} = Y_{AvgWhite} / B_{Avg} \tag{5.12}$$

Step 5: A new method for adjustment is proposed on the base of colour cast. More precisely, the approach is applied to make the maximum white scale factor as zero using the colour component with the highest average white scale factor. The ratio is calculated by dividing the other two colour components with designated maximum white scale factor. The Red, Green and Blue colour casts are found using equations (5.13, 5.15 & 5.17). The zero scale factor is set by default in all these else statements. These equations are derived based on a decision making observation. It is argued that such observation should be used in order to find colour cast of an image.

Step 5.1: The Red colour cast is found based on average white scale factors and correction is carried out by calculating the Red, Green and Blue factors as written below in (5.14):

$$if\begin{pmatrix} R_{AvgWhiteScaleFactor} > G_{AvgWhiteScaleFactor} \ \&\& \\ R_{AvgWhiteScaleFactor} > B_{AvgWhiteScaleFactor} \end{pmatrix} \tag{5.13}$$

$$\begin{cases} R_{Factor} = 0 \\ G_{Factor} = \dfrac{G_{MaxWhiteScaleFactor}}{R_{MaxWhiteScaleFactor}} \\ B_{Factor} = \dfrac{B_{MaxWhiteScaleFactor}}{R_{MaxWhiteScaleFactor}} \end{cases} \tag{5.14}$$

Step 5.2: The Green colour cast is found based on average white scale factors and correction is carried out by calculating the Red, Green and Blue factors as written below in (5.16):

$$if\begin{pmatrix} G_{AvgWhiteScaleFactor} > R_{AvgWhiteScaleFactor} \ \&\& \\ G_{AvgWhiteScaleFactor} > B_{AvgWhiteScaleFactor} \end{pmatrix} \tag{5.15}$$

$$\begin{cases} R_{Factor} = \dfrac{R_{MaxWhiteScaleFactor}}{G_{MaxWhiteScaleFactor}} \\ G_{Factor} = 0 \\ B_{Factor} = \dfrac{B_{MaxWhiteScaleFactor}}{G_{MaxWhiteScaleFactor}} \end{cases} \tag{5.16}$$

Step 5.3: The Blue colour cast is found based on average white scale factors and correction is carried out by calculating the Red, Green and Blue factors as written below in (5.18):

$$if\begin{pmatrix} B_{AvgWhiteScaleFactor} > G_{AvgWhiteScaleFactor} \ \&\& \\ B_{AvgWhiteScaleFactor} > R_{AvgWhiteScaleFactor} \end{pmatrix} \tag{5.17}$$

$$\begin{cases} R_{Factor} = \dfrac{R_{MaxWhiteScaleFactor}}{B_{MaxWhiteScaleFactor}} \\ G_{Factor} = \dfrac{G_{MaxWhiteScaleFactor}}{B_{MaxWhiteScaleFactor}} \\ B_{Factor} = 0 \end{cases} \tag{5.18}$$

In order to calculate the colour cast, average values are used due to the fact that majority pixels fall in this range, such as (equations 5.13, 5.15 & 5.17). In the case of using the maximum value, a single outlying pixel having a very high value can badly affect the whole image which will eventually lead to unrepresentative scaling. Regarding the calculation of ratio (5.14, 5.16 & 5.18), only the maximum value of any pixel affects the image, therefore the maximum value is used to calculate the ratio. If red colour cast is higher, the red values are used as constant and the other two colours are adjusted. Using this maximum values, the over saturation problem has been addressed in the new approach. Furthermore, by using the maximum values as divisor, lower values can be obtained. This will solve the over saturation problem and will help to adjust illumination of the image at the same level.

Step 6: Here the gain factors are calculated.

$$R_{GainFactor} = \left[\left((R_{Factor} + G_{Factor} + B_{Factor}) / 3 \right) \times \left(R_{AvgWhiteScaleFactor} \times R_{MaxWhiteScaleFactor} \right) \right] \quad (5.19)$$

$$G_{GainFactor} = \left[\left((R_{Factor} + G_{Factor} + B_{Factor}) / 3 \right) \times \left(G_{AvgWhiteScaleFactor} \times G_{MaxWhiteScaleFactor} \right) \right] \quad (5.20)$$

$$B_{GainFactor} = \left[\left((R_{Factor} + G_{Factor} + B_{Factor}) / 3 \right) \times \left(B_{AvgWhiteScaleFactor} \times B_{MaxWhiteScaleFactor} \right) \right] \quad (5.21)$$

Step 7: According to the Von Kries hypothesis (see section 3.3.2), the pixel value of every pixel in the whole image is adjusted.

$$R' = R_{GainFactor} \times R \tag{5.22}$$

$$G' = G_{GainFactor} \times G \tag{5.23}$$

$$B' = B_{GainFactor} \times B \tag{5.24}$$

Where R, G and B are original pixel values in the image and R′, G′ and B′ are the adjusted pixel values.

5.3 Summary

In this chapter, the first stage of the new framework is discussed in relation to image enhancement techniques. The new integrated image enhancement approach is based on contrast enhancement and colour balancing methods. Contrast enhancement method improves the contrast of the image. This process makes the surveillance images clearer as compared to the original images. Without applying the contrast correction method it is not possible to achieve the clear images.

Contrast enhancement is applied to each Red, Green, and Blue channel of image in order to enhance the contrast of these images. After the contrast enhancement algorithm, the colour balancing algorithm is applied to calculate average and maximum white reference points. Based on these reference points, the average and maximum white scale factors are calculated. On the basis of these scale factors, gain factors are calculated. By using gain factors, the quality of the image is improved.

Most of the time surveillance images have colour cast that can be Blue/Red/Green. Therefore, three different kinds of decision making process have been used to find out the colour cast. In order to calculate the colour cast, average values are used due to the fact that most of the pixels fall in this range. In this situation, the maximum value should not be used because the single outlying pixel with high value can badly affect the image.

The results achieved by applying the new integrated image enhancement approach are discussed in chapter 7. The results will be shown based on 'enhancement condition' and 'without enhancement condition' for comparison purposes. The 'enhancement condition' will show the results where the enhanced images were used and the 'without enhancement condition' will show where the original images were used for experimental purposes. The next chapter discusses a new content-based image retrieval system.

CHAPTER 6

NEW CONTENT-BASED IMAGE RETRIEVAL SYSTEM

6.1 Introduction

The previous chapter has demonstrated the potential of the new image enhancement approach for face detection. In this chapter, a new content-based image retrieval system is discussed for biometric security, which is based on colour, texture and shape features, it also employs a set of fuzzy heuristics. The new system is based on the three algorithms: colour histogram, texture and moment invariants. The use of these three algorithms ensures that the new image retrieval system produce results which are highly relevant to the content of query image, by taking into account the three distinct features of the image and similarity metrics based on Euclidean measure. Colour histogram is used to extract the colour features of an image. Gabor filter is used to extract the texture features, whereas the moment invariant is used to extract the shape features of an image.

The rest of the chapter is organised as follows. Section 6.2 briefly discusses content based image retrieval. Section 6.3 discusses the new content based image retrieval system by explaining its components. Section 6.4 discusses similarity measure methods. Section 6.5 provides the summary of this chapter.

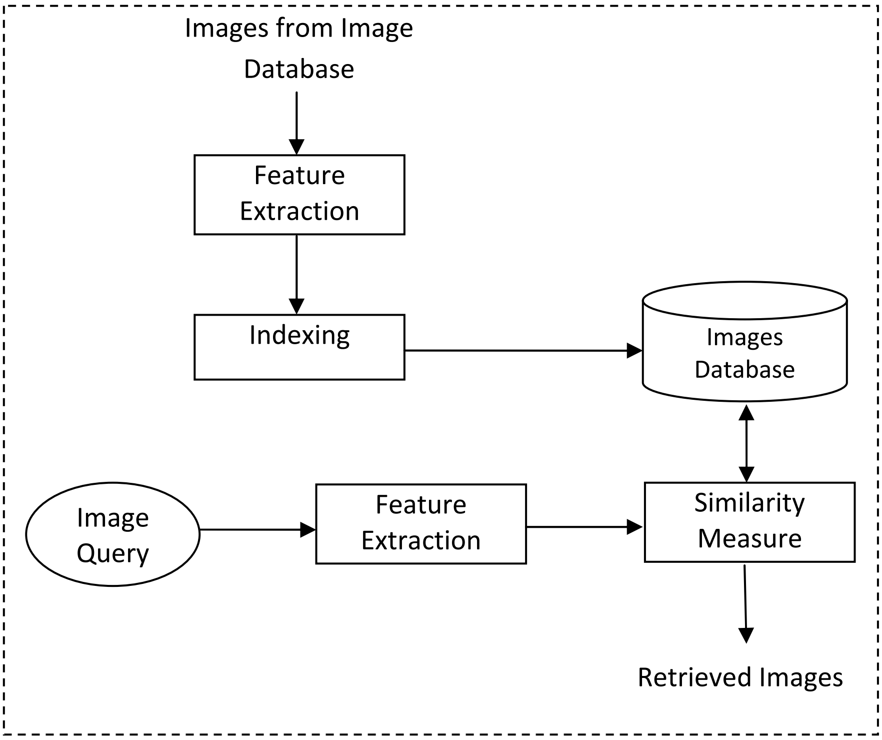

Figure 6.1: A typical content-based image retrieval system

6.2 Content-based Image Retrieval

This section provides a brief overview of content-based image retrieval systems. In a typical content-based image retrieval approach, a user submits an image query which is then used by the image retrieval system to extract visual features from images. The visual features may include shape, colour or texture depending upon the type of image retrieval system being used. These features are examined in order to search and retrieve similar images from an image database. The similarity of visual features between query image and each image in a database is calculated based on their distance by comparing the feature vectors of two images. The image retrieval system displays images, as the result of an image query, that have the closest similarity according to the predefined threshold value in the system. The predefined threshold value is usually set in order to restrict the number of results that the content-based image retrieval system displays. A general content-based image retrieval system is shown in figure 6.1.

There exists a significant amount of literature showing problems relating to text-based query, for example, search experience and domain expertise can affect system's performance (Ericsson and Lehmann, 1996). Similarly, an ill-defined problem or query can produce poor results as compared to a well-defined problem.

Another stream of research related to relevance feedback is also affected by a number of contextual factors such as, interaction time (Lee et al. 2008), user's subjective perception of relevance (Krug 2006; Spink and Losee 1996) and environmental settings (Lopatovska and Arapakis 2011; Oulasvirta et al. 2009). Relevance feedback is based on the knowledge of how relevant the particular piece of information (document or image) is to the user and how its content can be reused in order to find documents or images that are similar. Documents or images that are similar to the relevant content have a very high probability of relevance. In contest to these approaches (text-based query and relevance feedback), content-based approaches produce better results (ElAlami 2011; Huang 2003; Jhanwar 2004; Lin et al. 2009) based on the visual contents of the image query. In other words, content-based retrieval systems produce better results as the features of an image query search for similar features (of images in the database).

Content-based approaches are still under investigation. Different researchers have proposed various algorithms in order to address the problem of image retrieval using content-based approaches. Mostly, their approaches rely on one algorithm and ignore the existence of others (AlGarni and Hamiane 2008; Cinque et al. 2001; Kekre and Thepade 2008; Krishnamoorthi and devi 2012; Lei et al. 1999; Pun and Wong 2011; Vadivel 2005).

Approaches based on one specific algorithm (e.g., colour, texture or shape) can work effectively only on specific types of images. When different types of images are input to these systems their performance is degraded. For example, approaches based on colour histogram take into account only the visual contents relating to colours and ignores shape and texture. Similarly, approaches based on shape perform reasonably well when dealing with the shape of images without taking into account colour histogram and texture. The disadvantage with these approaches is that two totally different images can be shown as a result of a query, for example, even if their shape is the same.

All these approaches (colour based, shape-based or texture-based) can perform well when applied to a specific type of data-set. They produce poor results across the datasets or when different datasets are used. It is hypothesized that by integrating these three distinct features of the image better results across data-sets will be produced. Particularly, this approach would be beneficial in the case of biometric image retrieval, as the images are taken in different light conditions and also from different angles.

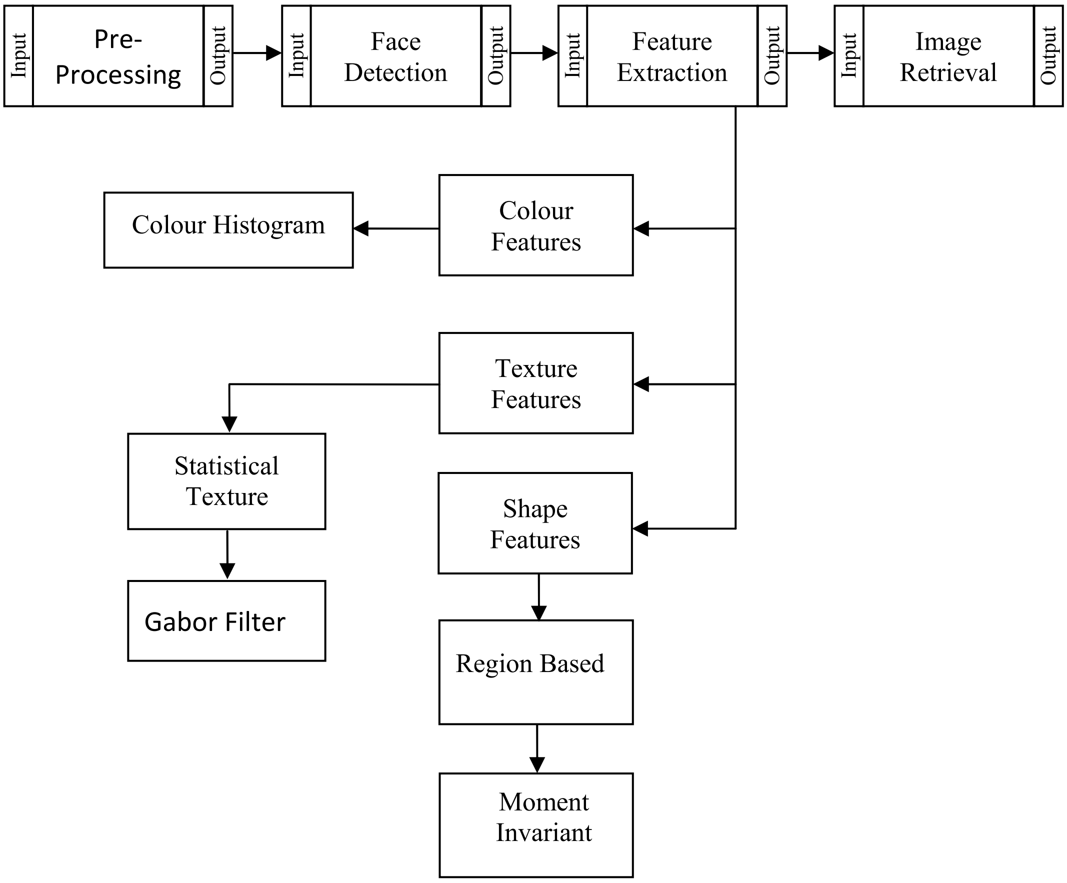

Figure 6.2: Methods used in the new system for feature extraction

In the content-based image retrieval system, searching and retrieval is carried out based on the visual contents of an image instead of the text attributes such as tags and meta-data. The important visual contents include colour feature, texture feature and shape feature. Amongst these features, shape is considered the best feature (AlGarni and Hamiane 2008; Premaratne and Nguyen 2008; Rizon et al. 2006; Premaratne and Safaei 2009; Zhang et al. 2009) due to its reliability on geometric measurement. Features such as colour and texture can be affected by the quality of an image. Therefore, our new system, takes into account all possible distinct features, such as colour, shape and texture, for searching for similar images based on the Euclidean measure. It is based on the three well-known algorithms: colour histogram, texture and moment invariants. The use of these three algorithms ensures that the new system produces highly relevant results for user's query. Importantly, fuzzy heuristics are employed to assess the relevance of the retrieved images.

6.3 New Content-based Image Retrieval System

This section, discusses a new content-based image retrieval system for biometric security, which is based on colour, texture and shape features, controlled by fuzzy heuristics. The new system is based on the three well-known algorithms: colour histogram, texture and moment invariants. The objective of using these three algorithms is to develop a new integrated image retrieval system capable of producing better results for biometric security. The new system ensures that the retrieved images are highly relevant to the query image. For better performance, searching is carried out based on the three distinct features of the image. Colour histogram is used to extract the colour features of an image. Gabor filter is used to extract the texture features, whereas the moment invariant is used to extract the shape features of an image, as briefly described in table 6.1.

When a user inputs an image query, the image retrieval system extracts features based on colour, shape and texture by applying relevant algorithms as discussed in the subsequent sections. The extracted features are stored in a feature vector. Following that, a similarity measure based on Euclidean distance and a set of fuzzy rules is applied to produce results relevant to the given image query as shown in figure 6.3. Details of these algorithms are given in the subsequent sections. The advantages of the new content-based system are as follows:

- Visual features of an image such as colour, texture and shape information are automatically extracted from it;

- The similarity of images is measured based on the feature distances between query and database images;
- Low level visual features are directly extracted from the image and do not rely on any human annotation;
- The image query removes the difficulty of describing the feature of an image in words when similar images are searched.
-

Table 6.1: Components of the new system

No.	Type	Method	Description
1	Colour	Colour histogram	Used to extract the colour features.
2	Texture	Gabor Filter	Used to extract texture features.
3	Shape	Moment Invariant based on Hu	Used to extract the shape features.
3	Similarity	Euclidean measure	Used to calculate the distance between the query image and the database images.
4	Controller	Fuzzy rule based	Used to control the results based on fuzzy heuristics.

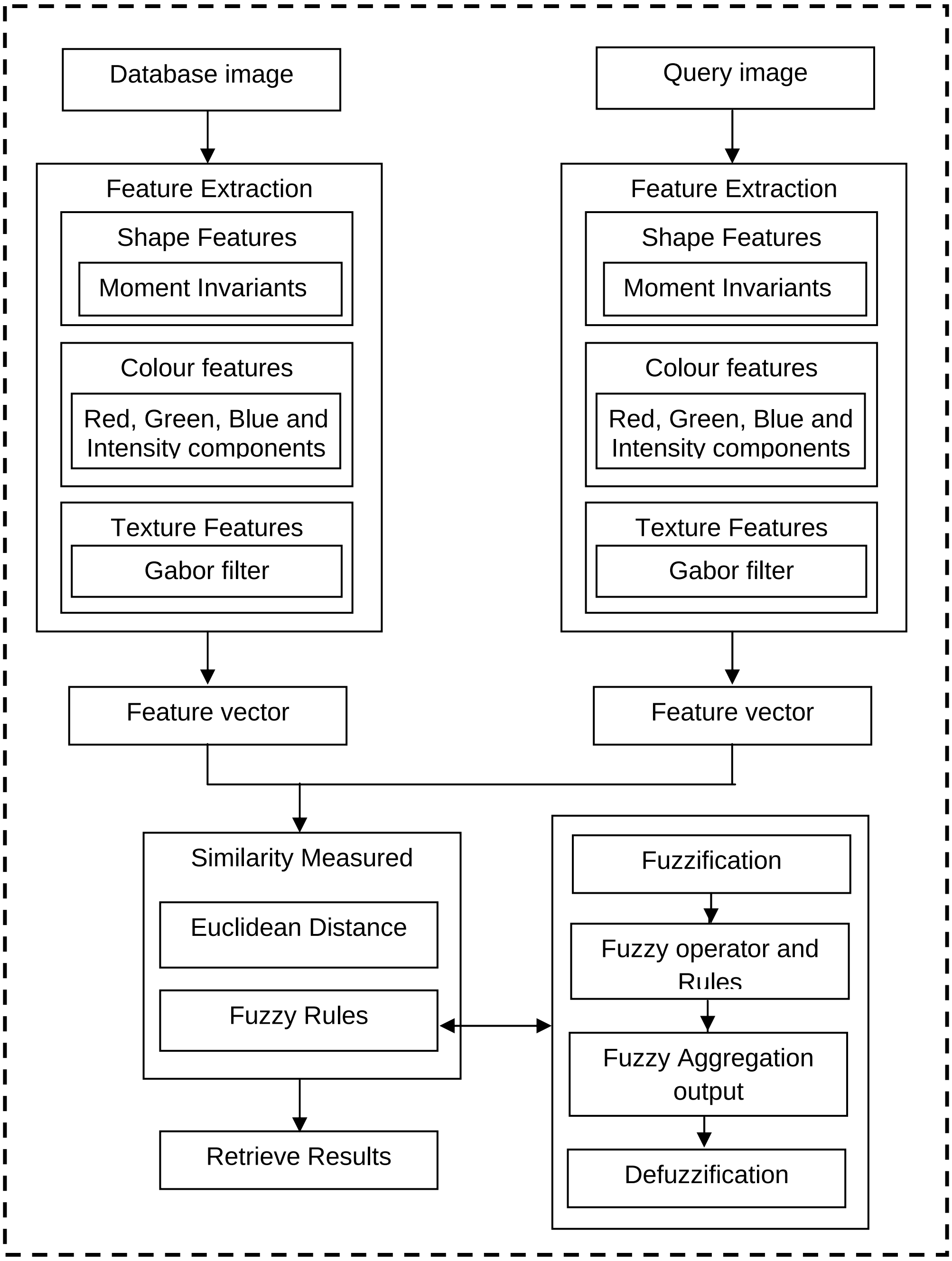

Figure 6.3: New Content-Based Image Retrieval System

Before the description of the proposed method, the most relevant image retrieval approaches are briefly described so that new features of the proposed approach can be highlighted, especially those that address the limitations of the existing approaches. These existing approaches were based on one or two feature extraction methods such as colour and or texture (ElAlami 2011, Huang 2003, Jhanwar 2004 and Lin et al. 2009). More details of these methods can be found in section 2.3.

ElAlami: This approach is based on colour and texture features extraction methods. In order to refine the retrieved results, a set of data mining rules is used (ElAlami 2011). The shape features are very important to be considered for image retrieval purpose due to the fact that shape is not easily affected by environmental factors but this approach has not considered this feature. However, due to the integration of two methods they have received better results as compared to other existing approaches (Huang 2003, Jhanwar 2004 and Lin et al. 2009).

Lin: This approach is based on colour and texture feature extraction methods used in order to retrieve most relevant images from the database (Lin et al. 2009). Their results are comparable with ElAlami (2011) as they also used the same methods.

Huang: This approach combined two methods: gradient vector and wavelet decomposition in order to extract the texture features for image retrieval purpose (Huang 2003). This approach has comparatively achieved less performance than Jhanware and Lin due to the fact that the approach is based on only texture features.

Jhanwar: In this approach the researchers extracted the texture features using Motif Co-occurrence Matrix method for image retrieval (Jhanwar 2004). Their main focus was on extracting texture features while ignoring the colour and shape features. As compared to ElAlami method in which two features were used, Jhanwar's method has achieved lower results.

These existing methods are based on one or two feature extraction methods; therefore they are limited in their scope. We are of the view that the usage of three feature extraction methods along with fuzzy rules will produce better results. Therefore, the proposed approach uses three feature extraction methods: colour feature, texture feature and shape feature controlled by fuzzy rules. By combining three feature extraction methods along with fuzzy rules we believe that better results can be achieved as compared to existing approaches.

6.3.1 Colour Features

Colour histogram is used to extract the colour features of an image using four components; three of the components (Red, Green and Blue) are obtained from RGB colour model while the fourth component (Intensity) is generated by combining the Red, Green and Blue components. The colour histogram provides meaningful information for extracting the features of images, as it is robust against object distortion and scaling of the object (Acharya and Ray 2005). Additionally, high effectiveness, simplicity, low storage requirements and real time application possibility makes it the best among others (Jeong, et al. 2004).

A digital image is commonly seen as a 2D mapping $I : \mathrm{u} \rightarrow v$ from $M \times N$ pixels $\mathrm{u} = [\mathrm{x}, yj]^T$ to values v (where $\mathrm{x} = 1, 2, . . ., M$ and $y = 1, 2, . . . , N$ corresponds to y-axis and x-axis respectively). Often the values v are discrete intensity values in the range [0−255], which shows that $I(\mathrm{x})$ is a single component of an image which could be Red, Green, Blue or Intensity. In order to design a descriptor of an image its histogram is calculated. An image histogram can be generated as follows:

$$h_b = \sum_{x=1}^{M} \sum_{y=1}^{N} \delta_b(x, y), \qquad \forall_b = 0,1,2,....B \tag{6.1}$$

Where $\delta_b(x, y) = 1$ if the value *v* at pixel location [x, *y*] falls in bin *b*, and $\delta_b(x, y) = 0$ otherwise and B is the number of bins in histogram. Similarities between different histograms $h_b \ \ and \ \ h'_b$ can be calculated using different methods such as Euclidean distance and histogram intersection as a similarity measure.

Every pixel in an image is basically represented as a point in the colour model such as RGB. This colour point is represented by three values that hold the information of colour. The image is represented by its histogram. The colour histogram helps to find the images which contained similar colour distribution. It is achieved by measuring the similarities through computing the distance between the two histograms.

6.3.2 Texture Features

The second element of the new system is the texture feature. For this purpose, the Gabor wavelet algorithm is used. Texture representation based on the Gabor wavelet is described in this section. Wavelets are extensively used in image processing applications such as image compression, image enhancement, image reconstruction and image analysis. The wavelet transformation provides a multi-scale decomposition of image data (Wu et al. 2010).

The two-dimensional Gabor filter is a group of wavelets. Many researchers have used the Gabor wavelet filter to extract texture features from an image (Manjunathi and Ma 1996; Do and Vetterli 2002). The Gabor filter is normally used to capture energy at a certain scale and at a certain orientation. Scale and orientation are two most important and useful features that are used for texture analysis. Therefore, in our new system, we have used the Gabor method to extract texture features of an image that are considered very important for image retrieval purposes. The Gabor filter is also known as scale and rotation invariant (Han and Ma 2007).

A 2D Gabor function consists of a sinusoidal plane wave of some orientation and frequency, modulated by a 2D Gaussian. The Gabor filter in spatial domain is given below (Idrissa and Acheroy 2002; Han and Ma 2007).

$$g,\lambda,\theta,\Psi,\sigma,\gamma(x,y) = \exp\left(-\frac{x'^2+\gamma^2 y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda}+\Psi\right) \quad (6.2)$$

Where
$$x' = x\cos(\theta) + y\sin(\theta)$$
$$y' = y\cos(\theta) - x\sin(\theta)$$

In the above equation, wavelength of cosine factor is represented by λ; θ represents the orientation of the normal to parallel stripes of a Gabor function in the degree; the phase offset in degree is represented by Ψ ; the spatial aspect ratio which specifies the elliptically of the support of the Gabor function is represented by γ ; and σ is the standard deviation of the Gaussian that determines the linear size of the receptive field. When an image is processed by Gabor filter; the output is the convolution of the image I(x, y) with the Gabor function g(x, y) which is

$$r(x,y) = I(x,y) * g(x,y) \quad (6.3)$$

Where * represents the 2D convolution, the process can be performed at various orientation and scale; and prepared filter bank (Choudhary et al. 2010). In order to generate the filter bank, different scale and orientations parameters can help to cover the entire spatial frequency space to capture mostly texture information with filter design.

After applying Gabor filters on the image by orientation and scale, we are able to obtain an array of magnitudes

$$E(m,n) = \sum_{x} \sum_{y} \left| G_{mn}(x,y) \right|, \tag{6.4}$$

m=0,1,…S-1 ; n=0,1,…. O-1

Where m and n specify the scale and orientation of the wavelet respectively, S is the number of scales and O is the number of orientations. The magnitudes represent the energy content at different orientation and scale of image. The main purpose of texture-based retrieval is to find images or regions with similar texture. The following mean μ_{mn} and standard deviation σ_{mn} of the magnitude of the transformed coefficients are used to represent the texture feature of the region:

$$\mu_{mn} = E(m,n) \big/ M \times N \tag{6.5}$$

$$\sigma_{mn} = \sqrt{\sum_{x} \sum_{y} \left(\left| G_{mn}(x,y) \right| - \mu_{mn} \right)^2 \Big/ M \times N} \tag{6.6}$$

The feature vector that represents the texture features is created using mean μ_{mn} and standard deviation σ_{mn} as feature components and these components are saved into two feature vectors, and then these two vectors are combined in order to make the single feature vector that will be treated as an image texture descriptor.

6.3.3 Shape Features

The third main element of the proposed system is the shape feature. In the new system, the Hu moment invariant algorithm is used for shape features. The Hu moment invariants algorithm is known as one of the most successful techniques for extracting image features for object recognition applications such as hand gestures (Premaratne and Nguyen 2007), objects (Rizon et al. 2006), face expression (Zhu et al. 2002) and shoe prints (AlGarni and Hamiane 2008). It is a widely used algorithm for image classification (Premaratne and Safaei 2009; Zhang et al. 2009).

Surveillance images are mostly not captured accurately and therefore objects in images are neither always visible nor straight forward in terms of location, orientation and size. Therefore the moment invariants algorithm is selected to be used as an important part of the proposed approach because the moment invariants algorithm is invariant to location, orientation and size. Many existing image retrieval systems perform pre-processing steps manually that include adjustment of image size (i.e. 128 x 128) (Khan et al. 2011) and image alignment, this method can help to achieve this automatically.

In order to provide the descriptions of shape features which are independent of location, orientation and size, the 2D moment of order $(p + q)$ of a digital image $f(x, y)$ is defined as

$$m_{p,q} = \sum_{x} \sum_{y} x^p y^q f(x, y) \qquad (6.7)$$

For *p,q = 0, 1, 2* where the summation are over the values of the spatial coordinate x and y spanning the image. The corresponding central moment is defined as

$$\mu_{pq} = \sum_{x} \sum_{y} (x-\bar{x})^{p} \quad (y-\bar{y})^{q} \quad f(x,y) \qquad (6.8)$$

$$Where \quad \bar{x} = {m_{1,0}}/{m_{0,0}} \quad , \quad \bar{y} = {m_{0,1}}/{m_{0,0}} \quad and \quad \bar{x}, \quad \bar{y} \quad \text{is called the centre of the region.}$$

Hence the central moments of order up to 3 can be computed as

$$\left.\begin{aligned}
\mu_{0,0} &= m_{0,0} \\
\mu_{1,0} &= 0 \\
\mu_{0,1} &= 0 \\
\mu_{1,1} &= m_{1,1} - \bar{y} m_{1,0} \\
\mu_{2,0} &= m_{2,0} - \bar{x}^{2} m_{1,0} \\
\mu_{0,2} &= m_{0,2} - \bar{y} m_{0,1} \\
\mu_{3,0} &= m_{3,0} - 3\bar{x} m_{2,0} + 2 m_{1,0} \bar{x}^{2} \\
\mu_{2,1} &= m_{2,1} - 2\bar{x} m_{1,1} - \bar{y} m_{2,0} + 2\bar{x}^{2} m_{0,1} \\
\mu_{1,2} &= m_{1,2} - 2\bar{y} m_{1,1} - \bar{x} m_{0,2} + 2\bar{y}^{2} m_{1,0} \\
\mu_{0,3} &= m_{0,3} - 3\bar{y} m_{0,2} + 2\bar{y}^{2} m_{0,1}
\end{aligned}\right\} \qquad (6.9)$$

The normalized central moment of order *(p + q)* is defined as

$$\eta_{p,q} = {\mu_{p,q}}/{\mu_{0,0}^{\gamma}} \qquad (6.10)$$

For *p, q = 0, 1, 2*…where $\gamma = \left[{(p+q)}/{2} \right] + 1$

For $p + q = 2,3$…. A set of seven 2D moment invariants can be derived from second and third central moments as written below. Where $\phi_1 \quad to \quad \phi_6$ moments are scaling, rotation and translation invariants and the ϕ_7 moment is skew invariant which enables it to differentiate the mirror images. The $\phi_1 \quad to \quad \phi_7$ moments, written below, are used to calculate the feature vectors (AlGarni and Hamiane 2008):

$$\left.\begin{aligned}
&\phi_1 = \mu_{2,0} + \mu_{0,2} \\
&\phi_2 = (\mu_{2,0} + \mu_{0,2})^2 + (4\mu_{1,1})^2 \\
&\phi_3 = (\mu_{3,0} + 3\mu_{1,2})^2 + (3\mu_{2,1} - \mu_{0,3})^2 \\
&\phi_4 = (\mu_{3,0} + \mu_{1,2})^2 + (\mu_{2,1} - \mu_{0,3})^2 \\
&\phi_5 = (\mu_{3,0} + 3\mu_{1,2}) + (\mu_{3,0} + \mu_{1,2}) \left[(\mu_{3,0} + \mu_{1,2})^2 - 3(\mu_{2,1} + \mu_{0,3})^2 \right] \\
&\qquad + (3\mu_{2,1} + \mu_{0,3})(\mu_{2,1} + \mu_{0,3}) \left[3(\mu_{3,0} + \mu_{1,2})^2 - (\mu_{2,1} + \mu_{0,3})^2 \right] \\
&\phi_6 = (\mu_{2,0} - \mu_{0,2}) \left[(\mu_{3,0} + \mu_{1,2})^2 - (\mu_{2,1} + \mu_{0,3})^2 \right] + 4\mu_{1,1}(\mu_{3,0} + \mu_{1,2})(\mu_{2,1} + \mu_{0,3}) \\
&\phi_7 = (3\mu_{2,1} - \mu_{0,3})(\mu_{3,0} - \mu_{1,2}) \left[(\mu_{3,0} + \mu_{1,2})^2 - 3(\mu_{2,1} + \mu_{0,3})^2 \right] \\
&\qquad - (\mu_{3,0} - 3\mu_{0,3})(\mu_{2,1} + \mu_{0,3}) \left[3(\mu_{3,0} + \mu_{1,2})^2 - (\mu_{2,1} + \mu_{0,3})^2 \right]
\end{aligned}\right\} \qquad (6.11)$$

6.4 Fuzzy Similarity Measure

In order to measure the similarity between a query image and a set of database images the system uses three types of visual features namely colour, texture and shape that can be used to determine an overall image similarity. This can be achieved by calculating the Euclidean Distances of each feature between the query image and database images. These are defined as Shape Distance (DS), Colour Distance (DC) and Texture Distance (DT) that have been retrieved using Moment Invariants, Histogram of images (Red, Green, Blue and Intensity) and Gabor Wavelet. The Euclidean distance is used to calculate the distance between two feature vectors of a query image and database images as give below:

$$ED\left(M^{Q}, M^{I}\right) = \sqrt{\sum_{j=1}^{n}\left(M_{j}^{Q} - M_{j}^{I}\right)^{2}} \qquad (6.12)$$

Where M^Q and M^I are query image and database image respectively, j is a feature range. The range of values to check the similarity between a query image and database images is set from 0 to 1. The features distance, of both query image and database image, closer to zero shows high similarity between each other. On the other hand, low similarity is measured if the feature distance of both the query image and a database image is closer to one.

In this research, the main interest has been to prioritise the effect each input feature (DS, DC, DT) has on the overall image similarity based on expert knowledge or data. For example, the shape features cannot be easily affected by external factors, but on the other hand, colour features can be easily affected and can dominate the image, such as background colour. Therefore, it is important to design a set of fuzzy rules to prioritise the search results. This prioritisation of image features has been achieved in the new system by using fuzzy If-Then rules as part of a Fuzzy Logic system (FLS) for modelling image similarity as shown in figure 6.5. FLSs have been applied to a range of application areas in similarity measure such as retrieval of information and images (Chaira and Ray 2005;

Viitaniemi and Laaksonen 2007). FLSs provide means for the handling of real world data imprecision through the use of linguistic quantifiers such as ‘low’ or ‘High’ (Mendel 2001). FLSs represent a methodology for computing with words in which linguistic quantifiers describing fuzzy sets are combined with human readable If-Then rules (Mendel 2001) which are used to show patterns of association between the input attributes and an output decision or state.

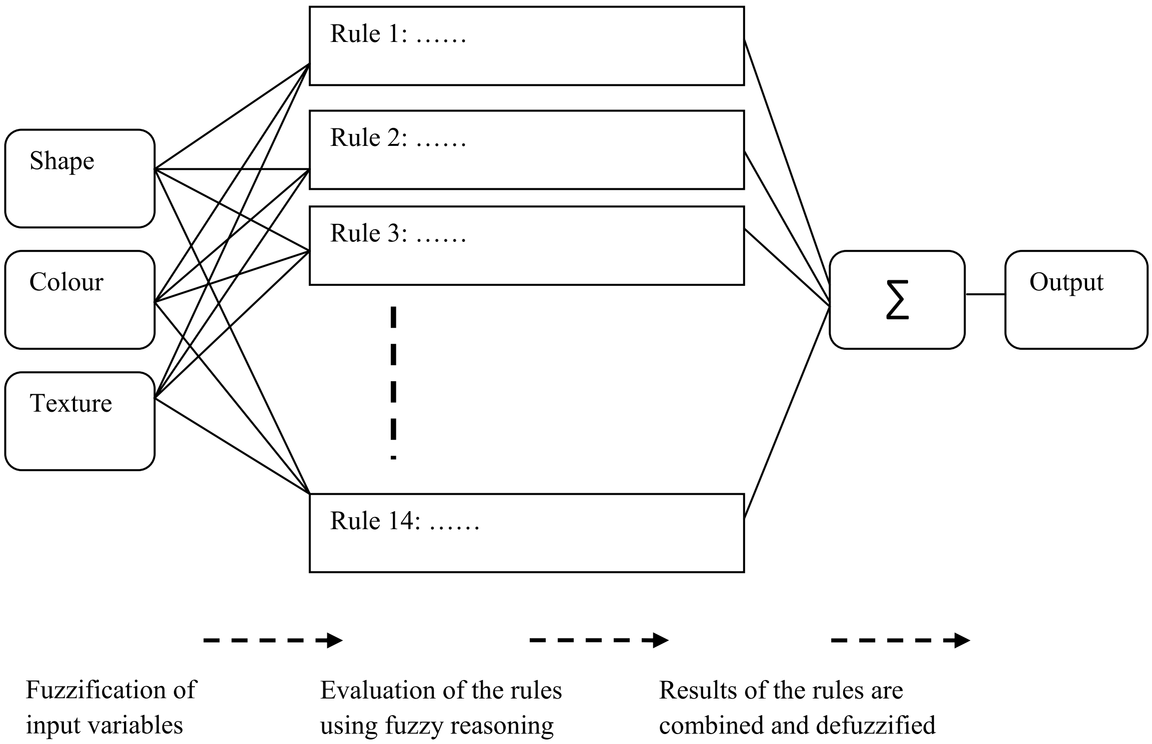

Figure 6.4: Fuzzy System Architecture

The fuzzy logic system, consists of four steps these are: fuzzifier, fuzzy inference and defuzzificer. They are described below (Mendel 2001) and shown in Figure 6.5.

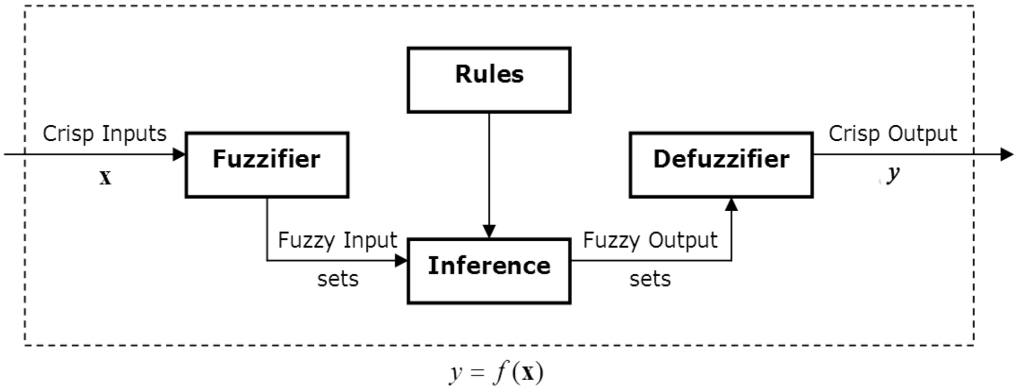

Figure 6.5: Diagram of Type-1 FLS

6.4.1 Fuzzification:

In fuzzification, the crisp input values (external values) are converted to fuzzy values through the membership functions. In other words, we can say that the crisp input values are used to calculate the degree of membership of each input values inside each of its term sets. This procedure produces a set of fuzzy sets.

Suppose a query image is *Q* and an image from the image database is *I*. The shape distance *DS* (*SQ*, *SI*), color distance *DC* (*CQ*,*CI*) and texture distance *DT(TQ,TI)* between image *Q* and *I* are three inputs of the fuzzy logic-based image retrieval system.

Three fuzzy sets namely “High”, “Medium” and “Low” represented using triangular Membership Functions (MFs) are used to describe these input features: *DS, DC* and *DT* in the system. Output of the fuzzy system Sim is the overall similarity of two images based on different combinations of color shape and texture distance. The output is described by three fuzzy sets: “high similar”, “medium similar” and “low similar”, which are also represented using triangular MFs.

6.4.2 Fuzzy Inference

In this step the crisp inputs have been fuzzified, where the fuzzy rules (using If-Then type fuzzy rules to convert the fuzzy input to the fuzzy output) are evaluated in order to produce an output for each rule. In this procedure, three membership values are used to generate one output value. This output value indicates the strength of firing of the rule. It is used to redesign the consequent part of the rule that generates the modified fuzzy sets. In aggregation, all the associated fuzzy sets of the fired rules are merged through fuzzy operators such as AND operator, in order to generate the single fuzzy set for each of output values.

The Mamdani fuzzy inference method is used to perform fuzzy rules in the proposed new system (Keshwani 2008) as shown in figure 6.6. In this figure, the three visual features are shown in the left side, in the middle the fuzzy rules which are created based on these three inputs are shown and finally on the right hand side of this figure the output in the form of similarity is shown.

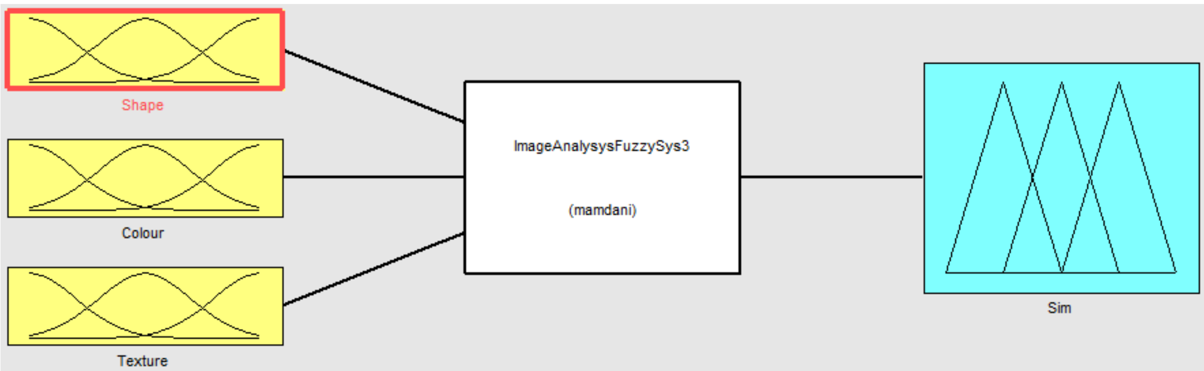

Figure 6.6: Similarity calculated by Mamdani fuzzy inference system based on Shape, Colour and Texture features

6.4.3 Defuzzification:

The purpose of Defuzzification is to convert the aggregated output of fuzzy set into a crisp number. The most commonly used method for defuzzification is the centroid method. This method can find a point representing the centre of the modified output fuzzy set.

6.4.4 Fuzzy Rules

In order to prioritise the effect of each input feature, fuzzy rules are defined in the form of conditional statement such as:

IF x is A and y is B THEN z is C

Here the x, y are the input variables and z is a single output variable, where A, B and C are the linguistic labels which are determined by the fuzzy sets on the universe of discourses X, Y and Z respectively.

A set of fuzzy rules is employed to measure similarity between the query image and the database images in order to retrieve and display relevant or similar results to a user query. There are three types of preferences that are taken into account while checking the similarity between images. These preferences are based on expert knowledge. First, priority is given to the shape features, as the shape of an image is not easily affected by external factors, and also it is invariant to the rotation, translation and orientation of images. Second, priority is given to the colour features, as these features are invariant to the rotation and translation of images. Third, priority is given to the texture features. Using these criteria a set of fuzzy rules are created and applied to a data set as discussed in the previous chapter. The application of Fuzzy rules can achieve better results by modelling these preferences while handling uncertain variations in image data to accurately derive an output similarity of an image.

Table 6.2, shows fourteen Fuzzy rules which were determined based on three image features such as colour, texture and shape. In the table, DS indicates shape features distance which is calculated between query and database image. DC shows colour features distance which is calculated between query and database image. DT shows texture features distance which was calculated between query and database image while Sim represents image similarity.

Table 6.2: Fuzzy rules measuring similarity by three feature distance values

	If	**DS**	**And**	**DC**	**And**	**DT**	**Then**	**Sim**
1		Low		Low		Low		High
2		Low		Low		Medium		High
3		Low		Low		High		Medium
4		Low		Medium		Low		Medium
5		Low		High		Low		Medium
6		Medium		Low		Low		High
7		High		Low		Low		Medium
8		Low		Medium		Medium		Medium
9		Low		High		High		Low

10		Medium		Low		Medium		Medium
11		High		Low		High		Low
12		Medium		Medium		Low		Medium
13		High		High		Low		Low
14		Medium		Medium		Medium		Low

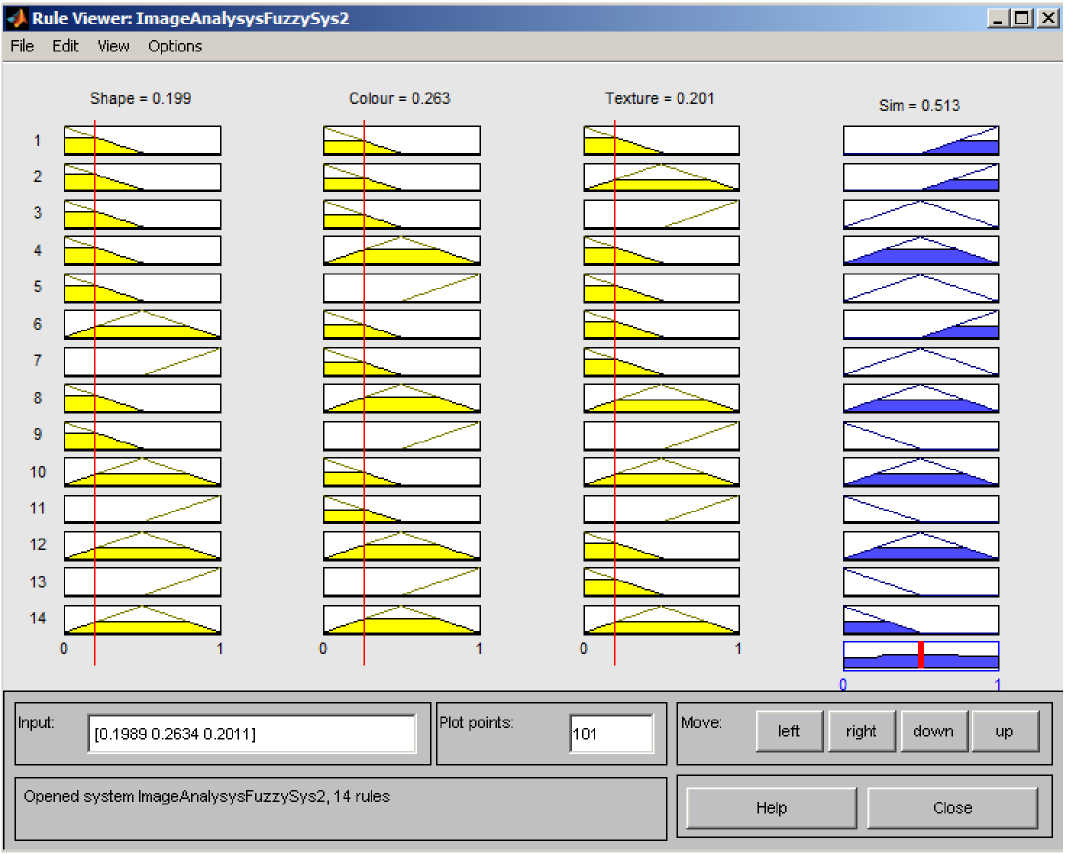

Figure 6.7: Fuzzy Rule Representation

The fuzzy rule representation, as shown in Figure 6.7, shows the relevant input and output membership functions for each rule involving Shape, Colour and Texture values. The output membership function for each input value is shown in blue. These values are aggregated and shown in the bottom right membership function representing the fuzzified result. For the input values 0.19, 0.26, 0.2 of shape, colour and texture respectively rules are fired and the aggregated membership function is shown in the bottom of the figures above. The default defuzzification process is the centroid method and the red line indicates the centroid and its output.

6.5 Summary

Following the proposed framework, a new image enhancement approach was proposed in the previous chapter consisting of contrast enhancement and colour balancing. This approach is then used for image enhancement in order to prepare images for better image retrieval. This chapter has discussed a new content-based image retrieval system for biometric security, which is based on colour, texture and shape features, controlled by fuzzy heuristics. The new system is based on the three well-known algorithms: colour histogram, Gabor filter and Hu moment invariants. The use of these three algorithms will ensure that the new image retrieval system produces results which are highly relevant to the content of the image query, by taking into account the three distinct features of the image and similarity metrics based on Euclidean measure. The Colour Histogram is used to extract the colour features of an image. The Gabor filter is used to extract the texture features and the Hu moment invariant is used to extract the shape features of an image. Three different types of visual features are stored in the feature vector. Following that, a similarity measure based on Euclidean distance and a set of fuzzy rules is applied in order to produce results which are most relevant to the given image query.

The next chapter will discuss results achieved using the proposed image enhancement and content-based image retrieval approach. The integrated image enhancement approach is applied to face detection. The standard evaluation methods such as Precision and Recall are used to evaluate the effectiveness of the new content based image retrieval system. Results using the new system are compared with existing well-known methods.

CHAPTER 7

RESULTS AND EVALUATION

7.1 Introduction

This chapter presents the evaluation results of the proposed new approach. As the approach presented in this thesis is an integration of several methods and involves several stages, three evaluation measures have been applied to evaluate the proposed new approach thoroughly as shown in Figure 7.1. Several researchers also emphasis the use of multiple methods for evaluation in order to ensure the quality of the proposed approach. This chapter is divided into three sections.

In the first section, the integrated image enhancement approach as a pre-processing method is evaluated using three types of face detection methods. These are skin colour, feature and image based methods. These face detection methods are applied to the images before and after enhancement by the proposed approach. Furthermore, the histogram method is used to evaluate the image enhancement approach. Following that, the second component of the proposed approach namely content based image retrieval is evaluated using the standard evaluation metrics which are Precision and Recall. Thirdly, the content based image retrieval system for biometric security is compared with three well known existing approaches.

The evaluation results show that the proposed approach has achieved better results as compared to the existing approaches. More precisely, more faces were detected when the images were enhanced by using the proposed integrated image enhancement approach at the pre-processing stage. Similarly, the evaluation metrics Precision and Recall show that better results are achieved using the proposed content based image retrieval systems. In the proposed content based image retrieval system different cases were used showing the similar images were retrieved in each case. This chapter also shows that better Precision and Recall were achieved using the proposed content based image retrieval system as compared to the existing well known methods. The accuracy of these results are also shown in this chapter. This demonstrates that the proposed approach has achieved significantly better accuracy as compared to the existing approaches.

The rest of the chapter is organised as follows. Section 7.2 discusses the results achieved using three types of face detection methods (skin colour based face detection, feature based face detection and image based face detection). Section 7.3 discusses the histogram method. Section 7.4 discusses the contented based image retrieval method. Section 7.5 carries out a comparative evaluation by comparing results of the new system with well-known approaches. Section 7.6 summaries the chapter.

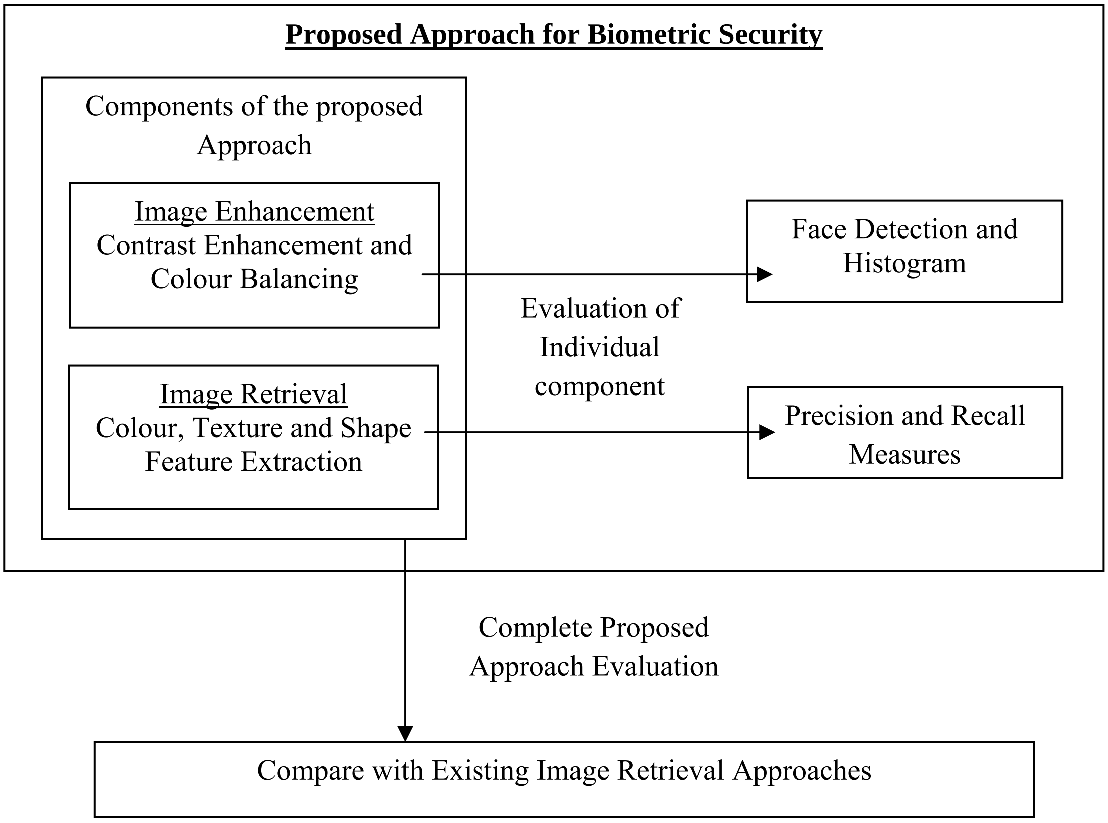

Figure 7.1: Evaluation of the Proposed Approach

7.2 Face Detection

In chapter five the image enhancement methods of contrast enhancement and colour balancing were proposed to improve the visibility of the image so that more faces can be detected. In order to evaluate the performance of the new integrated image enhancement approach, surveillance images were processed for face detection using three existing well known face detection methods namely skin colour based face detection, feature based face detection and image based face detection. The selection of these methods is carried out due to fact that they were proposed recently and they have achieved good results. Therefore in order to evaluate the performance of the new approach these methods (skin colour based, feature based and image based) are used.

These three methods are based on different types of image characteristics. For example, the skin colour based face detection method uses the colour information of an image; the feature based face detection method relies on image features characteristics while the image based face detection method is based on the Neural Network and Gabor Filter. The usage of these three different types of methods ensures that the new integrated image enhancement approach is thoroughly evaluated.

In our experiments, the face detection methods were applied before and after enhancement of images using the new approach. On each occasion significant improvements in face detection were achieved after enhancing the images using the new approach. These results demonstrate the effectiveness of the new approach and show its potential in the area of biometric security.

The subsequent subsections are organised as follows. Section 7.2.1 discusses the results achieved using skin colour based face detection algorithms. Section 7.2.2 shows the results achieved using feature based face detection methods. Section 7.2.3 shows the results achieved using image based face detection methods. Section 7.6 concludes this chapter.

7.2 .1 Skin Colour Based Face Detection

In this stage, a skin colour based face detection method is selected. It detects the face objects based on their skin colour. The face detection method is applied to original images and the images enhanced using the new approach. The results in figure 7.2 show that the rate of face detection has been increased by using the new image enhancement approach. It can be seen in figures 7.3, 7.4 and 7.5 that the face detection methods have not detected any face when original images were used. On the other hand, faces were detected when the new image enhancement approach was used. It is important to note that the same face detection methods were used for both the original and the enhanced images.

The figures 7.2, 7.3 and 7.4 were taken by CCTV cameras and downloaded from websites. In figure 7.2, one person is entering into a shop; in figure 7.3, one person is on an escalator and in figure 7.4 a person is walking in a main street.

Figs 7.2, 7.3 and 7.4 have been removed as they show identifiable people. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Another category contains images which were affected by weather are used for experimental purposes in order to evaluate the new proposed approach thoroughly (figures 7.5, 7.6, and 7.7). These three images were captured when it was raining or snowing. As can be seen in figure 7.5 that the quality of the image was affected by snow, and a skin colour based face detection method is unable to detect any face from the affected image. On the other hand, faces were detected when the new image enhancement approach was applied. It is important to note that the same face detection method was applied on original image as well as on the enhanced image. One wrong object was also detected by face detection method due to the fact that the detected object is similar to face colour and shape.

As mentioned above, Images taken during rain were also used to test the performance of the new approach (figure 7.6). In this image the face of a person is not clear due to heavy rain. Therefore the face detection method was not able to detect a face from the original image. But by enhancing the same image through the new approach, the face has been detected from the image (figure 7.6).

Another image affected by weather is used to evaluate the performance of the new approach. In this image heavy snow can be observed therefore the person has covered most of his face and only little area of his face is uncovered. Due to the heavy snow, that little area of face is difficult to detect using skin colour based face detection method. But on other hand the face was detected accurately when the image was enhanced by the new approach as can be seen in figure 7.7.

Figs 7.5, 7.6 and 7.7 have been removed due to identifiable people in the images. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Input/Original Image

Enhanced by new Approach

Skin colour based face detection method is applied (no detection)

Skin colour based face detection method is applied (true detection)

Figure 7.6: Skin colour based face detection method before and after using the new integrated image enhancement approach (person walking during rain)

Input/Original Image

Enhanced by new Approach

Skin colour based face detection method is applied (no detection)

Skin colour based face detection method is applied (true detection)

Figure 7.7: Skin colour based face detection method before and after using the new integrated image enhancement approach (person walking during snow)

7.2.2 Feature Based Face Detection

In this stage, a feature based face detection method known as "fdlibmex" is used for face detection. The method is considered computationally fast and robust (Yap et. al., 2009). As can be seen in figures 7.8, 7.9 and 7.10 the face detection method was not able to detect the face when the image was not clear. In fact, the underlying algorithm of this face detection method also uses a built-in image enhancement method.

The face detection method was applied to the original images and the enhanced images using the new approach. The results showed that the rate of face detection was increased by using the new image enhancement approach.

It can be seen in figures 7.8, 7.9 and 7.10 that the face detection method did not detect any face when original images were used even though the face detection method uses a built-in image enhancement method. By processing the image second time using the built-in image enhancement method, it detected a face and two false objects (4th row of figure 7.8). On the other hand, a face was detected using the proposed image enhancement approach. This is important to note that the same face detection methods were used for both, the original and the enhanced images.

Figs 7.8, 7.9 and 7.10 have been removed due to identifitbale people in the images. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Input/Original Image

Enhanced by new Approach

- Feature based face detection method is applied (no detection).
- First output is used as a second input

First output (true detection)

Second output (true and false detection)

Figure 7.8: Feature based face detection method before and after using the new integrated image enhancement approach (person is on an accelerator)

Input/Original Image

Enhanced by new Approach

- Feature based face detection method is applied (no detection).
- First output is used as a second input

First output (true detection)

Second output (no detected)

Figure 7.9: Feature based face detection method before and after using the new integrated image enhancement approach (person walking in a street)

Input/Original Image | Enhanced by new Approach

Feature based face detection is applied (no detection) | Feature based face detection is applied (True detection)

Figure 7.10: Feature based face detection method before and after using the new integrated image enhancement approach (person is entering into a shop)

7.2.3 Image Based Face Detection

In this stage of our experiments, a recently proposed method was selected which is based on the Gabor feature extraction and the Neural Network for face detection (Sahoolizadeh et al. 2008). This method was selected because it is use of the best method for face detection. A recent study shows that Gabor filters produce good results for feature extraction whereas the Neural Network method is one of the best well known learning methods.

This method firstly has to be trained using available data set in order to produce better results. The main drawbacks of this method are high computational cost and it only accepts smaller images (27x18 pixels). This method was not able to detect all the faces as shown in figure 7.11; only three faces were detected, while the new approach has detected all faces (figure 7.11) in the image.

7.3 Histogram

An image histogram represents a graph that can be used to evaluate the quality of an image by comparing the values of an image before and after enhancement. However, there are a few other factors that need to be taken into account in order to conduct an evaluation. Several researchers have used the histogram as an analytical tool in order to evaluate the performance of their methods (Rizzi et al. 2003).

This evaluation has taken into account the following guidelines which are derived from the existing literature. “The wider histogram represents a more visually appealing image” (Image Analysis 1999). In order to achieve that, the histogram should be stretched to the minimum (0) and maximum (255) value level. It can be noted in figures 7.2 to 7.11; that the histograms generated by the new approach were stretched well to both minimum (0) and maximum (255) sides, whereas the histograms of the original images were not fully stretched.

Input/Original Image Enhanced by new Approach

Fig 7.11 has been removed due to identifiable faces in the images. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Three face detected All the faces detected

Figure 7.11: Image based face detection method before and after using the new integrated image enhancement approach (group photo)

7.4 Content based Image Retrieval System

The previous section has demonstrated the potential of the new image enhancement approach for face detection. In this section, a new content-based image retrieval system is discussed for biometric security, which is based on colour, texture and shape features, it also employs a set of fuzzy heuristics. The image retrieval system is based on the three algorithms: colour histogram, texture and moment invariants as described in section 6.3 and shown in figure 6.3. The use of these three algorithms ensures that the new image retrieval system produces results which are highly relevant to the content of an image query, by taking into account the three distinct features of the image and similarity metrics based on Euclidean measure. Colour histogram is used to extract the colour features of an image. Gabor filter is used to extract the texture features, whereas the moment invariant is used to extract the shape features of an image.

7.4.1 Dataset

In order to assess the performance of the new system, the same dataset that was used by previous researchers (ElAlami 2011; Huang 2003; Jhanwar 2004; Lin et al. 2009) was used in our experiments. In addition to this, another 14 different datasets containing 140 biometric images were added to the dataset. In total there were 1140 images in the database that was used for search and retrieval purposes based on image query.

The objective of this diverse collection was to evaluate the new system thoroughly on different data sets so that the effectiveness and usefulness of the new system can be demonstrated. The different categories of the images were labelled according to the type of images each data set contained as shown in table 7.1.

Overall 24 categories of images were used in our experiments, where 14 categories of the images belong to the biometric and contained 140 images. The remaining 1000 images were general images. Each category of the general images contained 100 images such as African people, Horse, Buses, Flowers, Building, Dinosaur, Mountain and Food. Although these general images are not related directly to the topic of the research, they help to validate the performance of the new system in different environments. Importantly, the goal was to investigate whether the performance of the new system can be affected by the large number of images or search space. Our results show that the new system is able to search for similar images and retrieve them effectively from a huge data-set of images (see figures 7.12 to 7.32).

In our experiments, we have used some surveillance images that were available. It was not possible to obtain a complete data set of surveillance images due to privacy and security reasons. However, attempts were made to get the available surveillance images for testing and evaluation purposes. The images used for evaluation have similar characteristic to surveillance images, for example shape of those images. Surveillance images have shape problems because of moving objects. Secondly, they have colour and texture problems due to environmental issues. These problems are contained in the images which were used to test and evaluate the proposed approach. The proposed approach was thoroughly evaluated from each of the three angles: shape, colour and texture.

Table 7.1: Image data set used for evaluation

Main Category	Number of Images	Sub-Category	Description of images
Human Whole Body Images	30	A-Elevator	Person on the elevator -with various image appearance -different scale, orientation and transplantation
		B-Shop	Person in the shop -with various image appearance -different scale, orientation and transplantation
		C-Street	Person in the street -with various image appearance -different scale, orientation and transplantation
Face Images with Background Objects	40	L-Blue & Background Objects	Face images with different poses -along with some background objects -different orientation
		H-Back Objects	Face images with different poses -along with some background objects -different scale, orientation and transplantation
		G-Back Objects	Face images with different poses -along with some background objects

		D-Dark Light	Face images in dark light -with different expression -with different scale, orientation and transplantation
Face Images in Grayscale	20	E-Grayscale	Face grayscale images -with different face expression -with different scale, orientation and transplantation
		I-Black Background	Face images with black background -from different angle and with various expression -different scale and orientation
Face Images with Plan Background	30	F- Plan Back	Face images -with plan background -images taken with different angles and expression -different scale, orientation and transplantation
		K-Brown	Face images in dark light -with different expression
		J-Plan Back	Face images -with plan background

			-images taken with different angles and expression -different scale and orientation
Shape Images	30	M-Motor Bike	Motor bike images -different types of bike -different scale, orientation and transplantation
		N-Airplane	Airplane images -different types of airplane -with different orientation
		O-Star	shape images -different types of shapes
Face images few background objects	20	P-face images	Face images - images taken with different expression -different orientation
		Q- face images	Face images -with and without moustache -few images taken from different angles
People	100	African people	-single and group of people photos
Beach images	100	Beach images	Beach images with and without people
Building images	100	Building images	Different building images taken from different angles

Bus images	100	Bus images	Different kinds of bus images -double decker buses -images are taken from different angles
Dinosaur images	100	Dinosaur images	Different types of dinosaur pictures
Animal images	100	Elephant images	Different kinds of elephant images -from different angles - single and group of elephant photos
Flower images	100	Flower images	Various types of flower images
Animal images	100	Horses images	Single and multiple horse photos
Mountain images	100	Mountain images	Various types of mountain pictures
Food images	100	Food images	Varity of food dishes

7.4.2 Results and Evaluation

In order to evaluate the effectiveness of the new system, two standard methods such as Precision and Recall were used. These are the most common measurements used for the evaluation of information and image retrieval systems (Viitaniemi and Laaksonen 2007). The Precision and Recall are defined below (Viitaniemi and Laaksonen 2007):

$$\text{Precision} = I_N / R \quad (7.1)$$

$$\text{Recall} = I_N / T \quad (7.2)$$

Where I_N is the number of images retrieved that are most relevant to the image query. T is the total number of images in the database that are similar to the image query. R is the total number of images retrieved. Different researchers use different threshold values to apply such metrics (Liu 2010). We used R=10 and T=20 to 40 to assess the performance of the new system. Although different data sets were annotated and labelled separately based on the relevance among them, a search and retrieval process was performed on all the data sets (total 1140 images) in the database as a result of a user query.

In our experiments, seven different types of cases were used to evaluate the proposed approach. The main objective is to evaluate the proposed approach from all possible perspectives: colour feature, texture feature and shape feature in order to ensure the effectiveness and usefulness of the proposed approach. In this thesis seven representative cases are included as shown in table 7.2 and discussed below.

Table 7.2: Summary of seven evaluation cases

Case	Evaluation
1	Image enhancement methods were evaluated A category (whole body images) B category (detected face used to retrieve whole body images)
2	Shape features were evaluated by focusing on image direction
3	Colour features were evaluated using dark brown light images
4	Texture features were evaluated using gray and black images A category (gray scale images) B category (black background images)
5	Colour and shape features were evaluated
6	Colour features were evaluated using images affected by dominant colour A category of images where the blue colour is dominant B category of images where the brown and green colour is dominant

7	Colour and texture features were evaluated

Case one: Evaluation of image enhancement methods

A category of images

The image showing a person on the escalator was used as an image query as shown in figure 7.12. As the image query was enhanced by the proposed integrated image enhancement approach. Based on the given image query the most relevant images were retrieved, out of 1140 images in the database. All the retrieved images belonged to the same person. The enhanced query image has been able to retrieve all similar images. Due to visible features of the enhanced image, it has been possible to match the exact features of the image query with database images. It indicates that using image query enhanced by the proposed integrated image enhancement method has retrieved more relevant images. Therefore, in this case of our experiment it can be concluded that after enhancing the image query more relevant images can be retrieved. On the other hand, it would be impossible to retrieve all relevant images if unclear image query is used.

The new system relies on colour feature, texture feature and shape feature. Therefore, it is able to retrieve all relevant results regardless of their visibility, size, orientation and format of the image. The Precision and Recall value based on the retrieved images is shown in figure 7.13. The Precision value was 1 and the Recall was 0.33. The Precision value 1 shows that all relevant images were retrieved based on the image query. The Recall value shows that there were other related images belong to the same category however new system accurately retrieved the same person images from 30 similar images in the database based on image query.

One image from fig 7.12 has been removed as it shows an identifiable person. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.12: Query image (at top) and results obtained

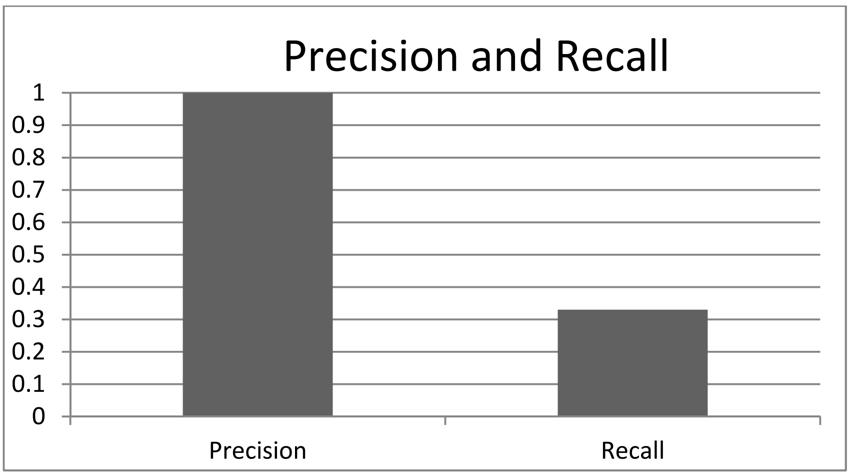

Figure 7.13: Precision and Recall values of the figure 7.12

B category of images

Another category of images in which a person entered into a shop was used as an image query. In this experiment only face of the person was used in the image query (see figure 7.14). Based on the image query, nine out of ten most relevant images were retrieved by the new system. Even though the retrieved images were of different sizes and shapes to the image query but the person is the same in all images therefore the new system intelligently retrieved all those images based on the enhanced image query regardless of their sizes and orientation. This is an important feature of the new system. The new system is able to search for relevant results without taking into account size and orientation of the image. The Precision and the Recall of the retrieved images is also shown in figure 7.15. The Precision value was 0.9 which shows that 90% accuracy was achieved. The Recall values show that the ten most accurate images were retrieved out of 30 similar images by searching 1140 images in the database as shown in table 7.1.

Some images have been removed from fig 7.14 as they show identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.14: Query image (at top) and results obtained

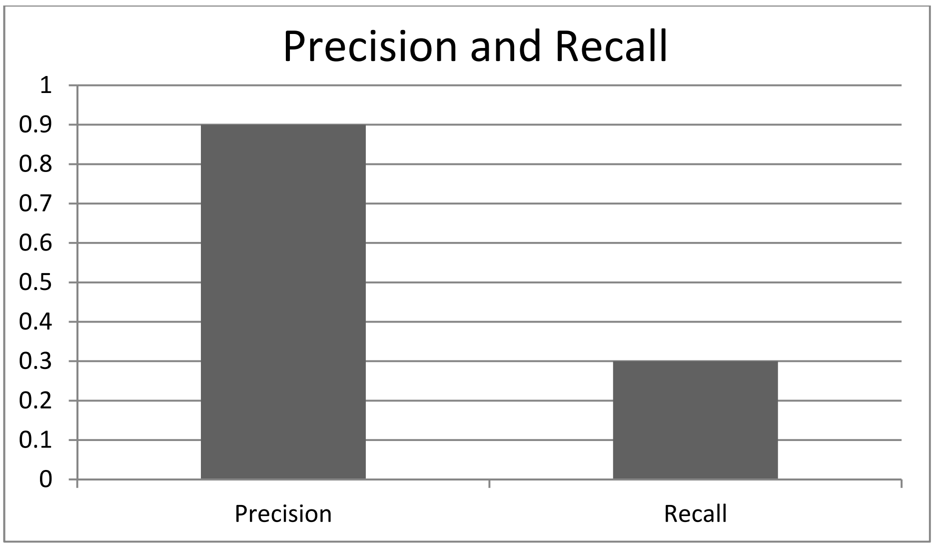

Figure 7.15: Precision and Recall values of the figure 7.14

Case two: Evaluation of shape features by focusing on image orientation

In the third image query the image captured in dark light and from different angles was used as an image query in order to retrieve the relevant images. Based on the image query, seven relevant images were retrieved. In this image query, three other images were also displayed which were of a different person but having similar angle to the image query (see figure 7.16). The Precision and Recall of the retrieved images is shown in figure 7.17. The Precision value is 0.7 which is slightly lower than the other queries as briefly described above and the Recall is 0.175. The Precision value shows that 70% results were achieved by retrieving 7 images which were exactly of the same person. The Recall values show that the most accurate images were retrieved out of 40 similar images by searching 1140 images in the database as shown in table 7.1. In this case, it is clear that the shape feature has been dominated.

Fig 7.16 has been removed as the images show identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.16: Query image (at top) and results obtained

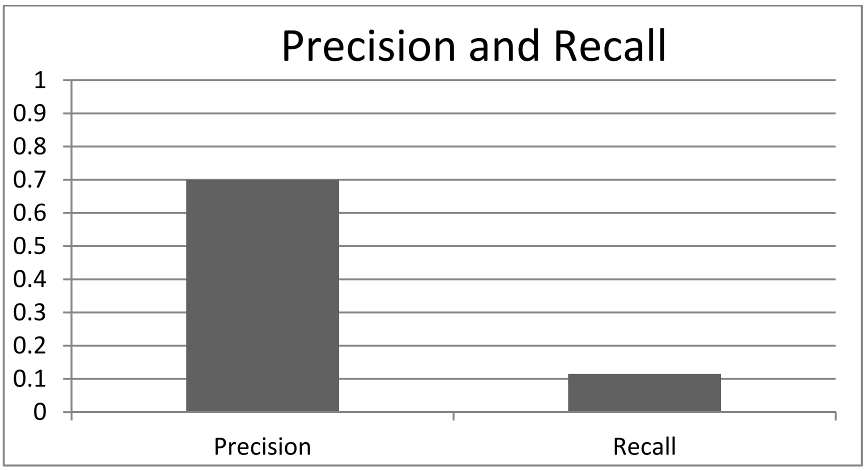

Figure 7.17: Precision and Recall values of the figure 7.16

Case three: Evaluation of colour features using dark brown light images

In order to evaluate the new system thoroughly different light condition images were also used as shown in figure 7.18. An image query shows an image captured in dark brown background light. The images belong to this person but were different in image visibility and orientation. The new system retrieved eight highly relevant images belonging to the same person. The other two images were not of the same person but had some characteristics such as visibility that were the same. However, due to their irrelevance, they were shown at the bottom of the displayed results. The Precision and Recall are shown in figure 7.19. The Precision value is 0.8 and Recall value is 0.266 in this query. The Precision value shows that 80% accurate results were achieved in this query. The Recall value shows that the most relevant images were retrieved out of 30 similar images by searching 1140 images in the database as shown in table 7.1. In this example, colour features were evaluated as image query and mostly retrieved images were similar in colour appearance. The colour feature extraction process is completely dependent on the image histogram. Therefore, the images which can generate similar histogram can be retrieved through the similar query based on image histogram. If a query image is similar in terms of histogram to a database image then there is a high probability of retrieving those similar histogram based images. This example ensures that colour feature of content based image retrieval has been evaluated effectively.

Fig 7.18 has been removed as the images show identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.18: Query image (at top) and results obtained

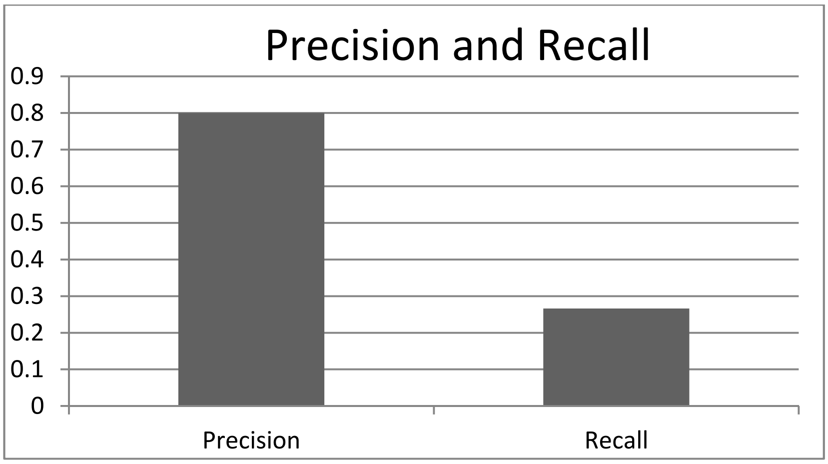

Figure 7.19: Precision and Recall values of the figure 7.18

Case four: Evaluation of texture and shape features

A category of images

In this case of experiment texture and shape features of the proposed content based image retrieval system are tested. Based on the image query nine similar images are retrieved, because these retrieved images are similar in terms of texture and shape features to the image query. The new content based image retrieval system accurately retrieves the images that contained similar texture and shape features. Due to the fact that one irrelevant image also contained similar texture and shape to the image query, the image was also retrieved.

The performance of the new content based image retrieval system was evaluated by using various types of images that have different face expressions. In this image query, a grayscale image was used which was captured from 45 degrees (see in figure 7.20). As a result of an image query, nine relevant images were retrieved. The retrieved images are different in poses, face expression, image appearance and image size but the new system accurately retrieved the images that belong to the same person. But these retrieved images were similar in texture and shape to the query image. Therefore these images were retrieved as a result of the image query.   One irrelevant image was also retrieved along with the nine relevant images. The irrelevant image also had the 45 degrees angle same to the image query. The Precision and Recall of these results are shown in figure 7.21, according to which the Precision value is 0.9 and Recall value is 0.45. Using this image query 90% results were achieved from many similar category of images.

Fig 7.20 has been removed as it shows identifiable eprsons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.20: Query image (at top) and results obtained

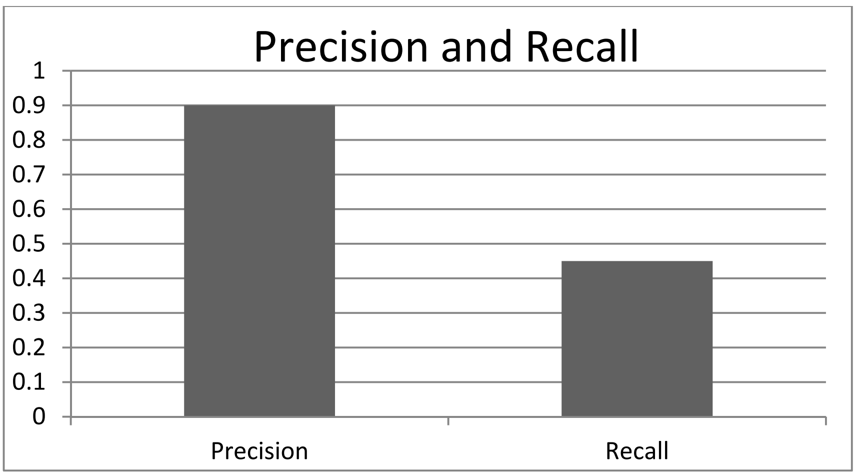

Figure 7.21: Precision and Recall values of the figure 7.20

B category of images

In this case of our experiment the texture and shape feature were evaluated. In another query, an image of a girl was used as an image query as shown in figure 7.22. All the images of this person were taken from different sides, along with different face expressions. Landscape image was used as an image query that helped to search and displayed the top 10 most relevant images from the database. As can be seen in figure 7.22, 8 images were of the same person but the last two retrieved images did not belong to the same person. These 8 images contained similar texture and shape features to the image query. Due to similar texture and shape features these images were retrieved. On the other hand two irrelevant images were also retrieved at the end of retrieved results. The Precision and the Recall rate of achieved results are displayed in figure 7.23. In this query, the Precision value was 0.8 and the Recall value was 0.40. The Precision value shows that 80 % accurate results were achieved. The Recall values show that the most accurate images were retrieved out of 20 similar images by searching 1140 images in the database.

Fig 7.22 has been removed as it shows identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.22: Query image (at top) and results obtained

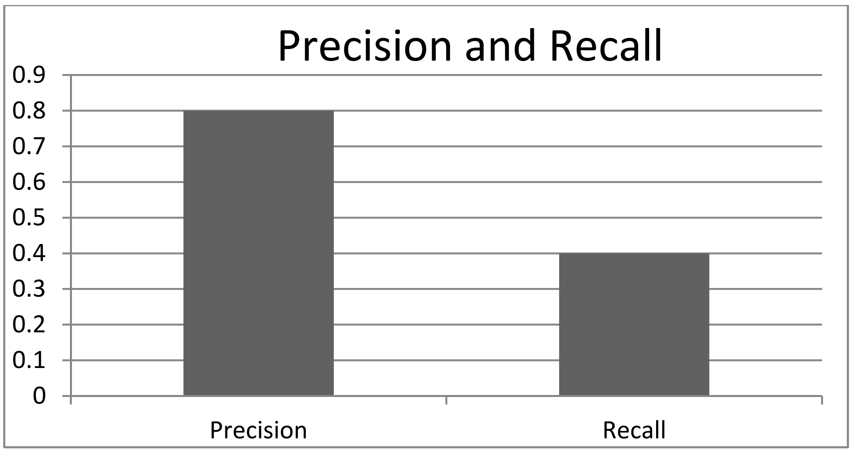

Figure 7.23: Precision and Recall values of the figure 7.22

Case five: Evaluation of shape and colour features

In this case, shape and colour features are evaluated. Another category contained images with different face expressions such as happy face, sad face, angry face and by closing one eye face. In this case, an image query was given to the new system in order to search and display the images relevant to the image of the person being sought. Regardless of the orientation and face expression of the image of the person being sought, the new system was able to retrieve all the images of the same person accurately. The results are shown in figure 7.24. The Precision and the Recall are shown in figure 7.25. The Precision value is 1.0 and Recall value is 0.5 in this query. 100% accurate results were achieved in this query. The Recall values show that the same person images were retrieved out of 20 similar images by searching 1140 images in the database as shown in table 7.1.

Fig 7.24 has been removed as it shows identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.24: Query image (at top) and results obtained

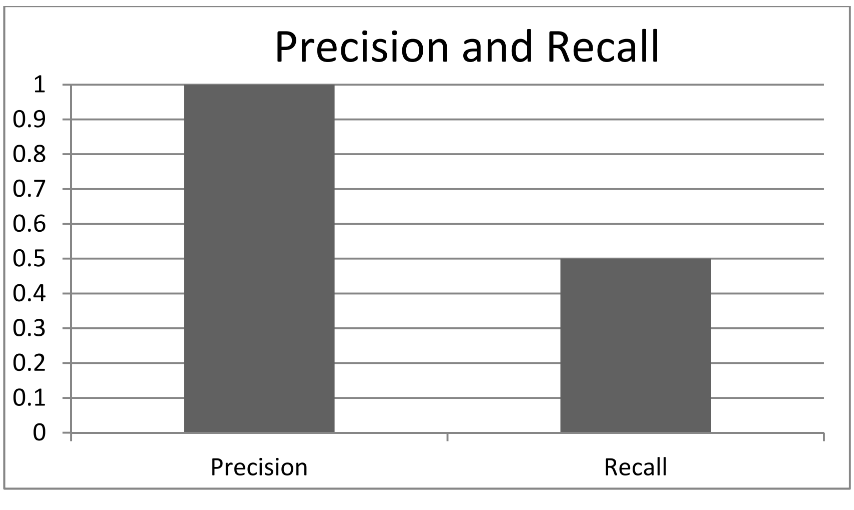

Figure 7.25: Precision and Recall values of the figure 7.24

Case six: Evaluation of colour features using images which are affected by dominant colour

A category of images where the blue colour is dominated:

Another category of images which were affected by colour cast were also used to test the performance of the new system. An image having blue colour cast and background objects was used as an image query as shown in figure 7.26. As can be seen in figure 7.26 the new system was able to retrieve the six most relevant images. These six images are of the same person. Four irrelevant images were also retrieved due to the fact that these four images also contain background objects as appeared in the image query. Even though these images are different in terms of person as well as background objects but these images still contain background objects. Second reason for the retrieval of these irrelevant images is that these images were captured in the same way as the query image was captured. It can be noticed that a person's appearance in irrelevant images is also similar to the image query.

The Precision and Recall are shown in figure 7.27. The Precision value is 0.6 and Recall value is 0.15 in this query. The Precision value shows that 60 % results were achieved. The Recall value shows that the most relevant images were retrieved out of 40 similar images by searching 1140 images in the database as shown in table 7.1.

Fig 7.26 has been removed as it shows identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.26: Query image (at top) and results obtained

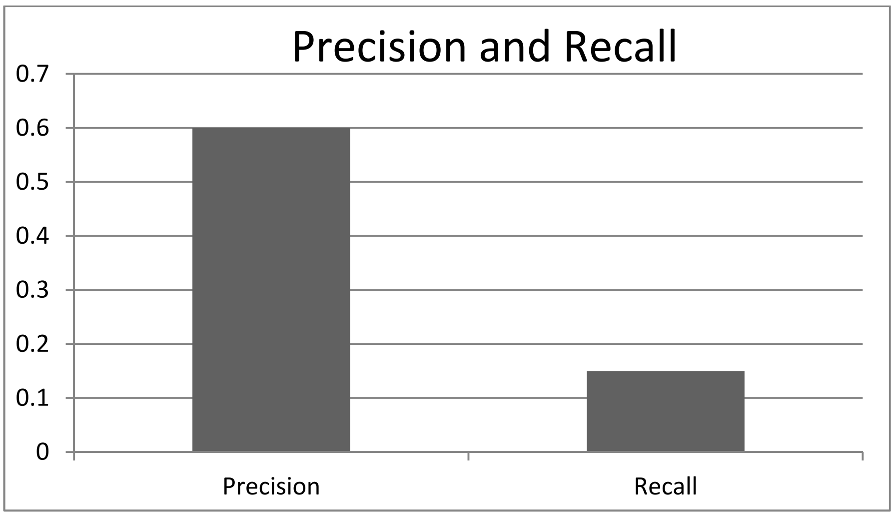

Figure 7.27: Precision and Recall values of the figure 7.26

B category of image where brown and green colours are dominated

An image in black background with stair objects is used as an image query (figure 7.28). In response to this image query, six images of the same person were retrieved, although the retrieved images contained background objects. The four irrelevant images having some similar characteristics were also retrieved as they were the closet in the database to the image query from the same pose and background perspectives. Background perspective means that both query and retrieved images contained similar background objects. Therefore irrelevant images were retrieved. The Precision and Recall are shown in figure 7.29. The Precision value is 0.6 and Recall value is 0.15 in this query. The Precision value shows that 60 % results were achieved. The Recall value shows that the most relevant images were retrieved out of 40 similar images by searching 1140 images in the database as shown in table 7.1.

Fig 7.28 has been removed due to identifiable persons. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.28: Query image (at top) and results obtained

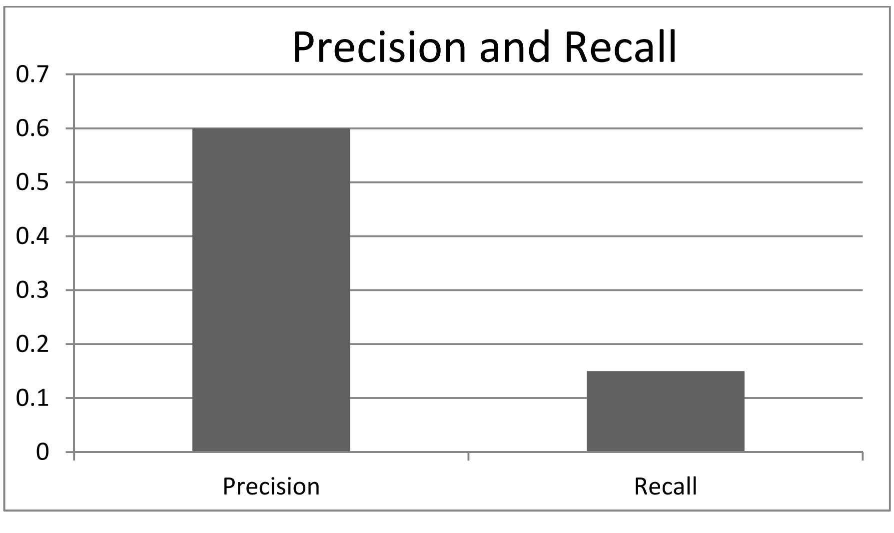

Figure 7.29: Precision and Recall values of the figure 7.28

Case seven: Evaluation of colour and texture features

An image query was used to evaluate the performance of the new system from colour and texture perspective as shown in figure 7.30. The selection of this category of images was made based on several features such as face images with and without moustache, images with different poses, different type of dresses and different backgrounds. The image in which the person had moustache was used as an image query. Based on the image query eight most relevant images were retrieved from a huge number of images in the database. Two irrelevant images containing the same orientation to the image query were retrieved. The Precision and Recall are shown in figure 7.31. The Precision value is 0.8 and Recall value is 0.4 in this query. 80% accurate results were achieved in this query. The Recall value shows that the most relevant images were retrieved out of 20 similar images by searching 1140 images in the database as shown in table 7.1.

Fig 7.30 has been removed due to third party copyright. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University

Figure 7.30: Query image (at top) and results obtained

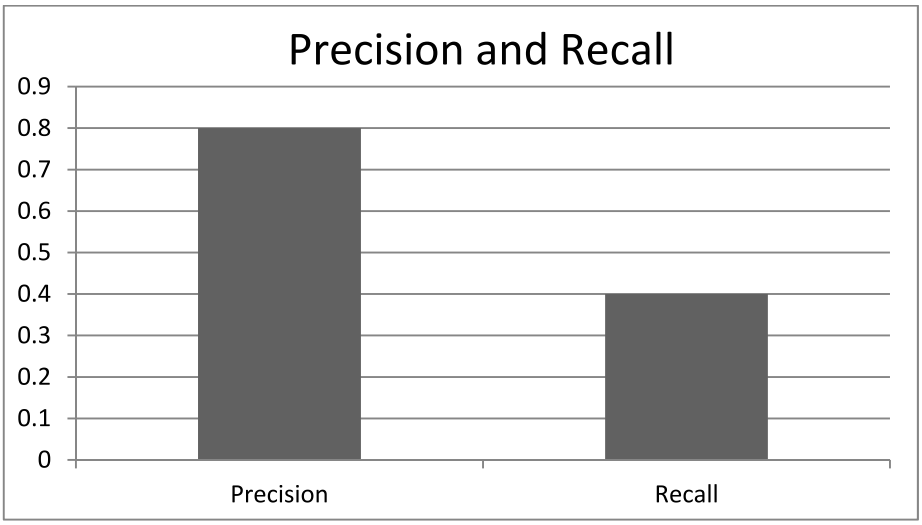

Figure 7.31: Precision and Recall values of the figure 7.30

Table 7.3 shows each data-set category and its Precision and Recall values achieved through results discussed in above cases in brief. The results shown in graphical form in figure 7.32 shows Precision and Recall values calculated based on 14 different types of queries. In the graph, the verticle values range from 0 to 1 shows the Precision and Recall. The Precision is shown in blue while the Recall is shown in red. The horizontal values range from 1 to 14 shows the number of queries which are used in the experiment for evaluation purpose. Average Precision and Recall values are also calculated and shown in figure 7.33. The average Precision value is 0.8 and the average Recall value is 0.29. In the next section, the results are compared with the well-known existing approaches.

Table 7.3: Images retrieval results with Precision and Recall

Category	Precision	Recall
A-Elevator	1.0	0.33
B-Shop	0.9	0.3
C-Street	0.9	0.3
L- Blue & Background Objects	0.6	0.15
H-Background Objects	0.7	0.175
G-Plan Back	0.6	0.15
D-Dark Light	0.7	0.175
E-Greyscale	0.9	0.45
I-Black Background	0.8	0.4
F-Plan Back	0.8	0.26
K-Brown	0.8	0.266
J-Plan Back	0.7	0.23
P-Expression	1.0	0.5
Q- Appearance	0.8	0.4

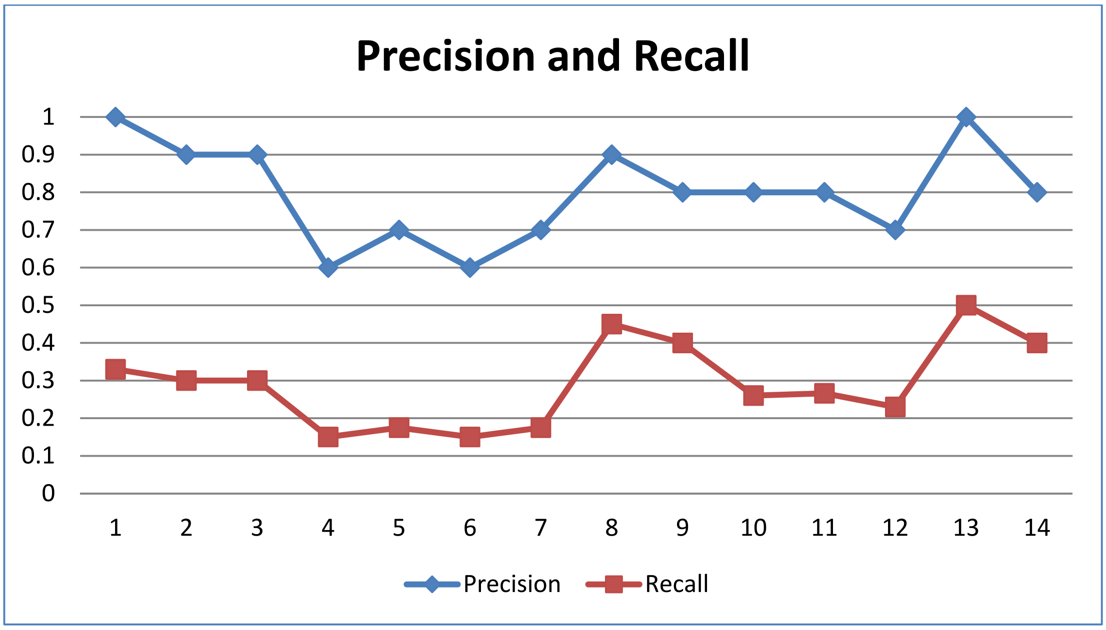

Figure 7.32: Precision and Recall on the obtained results using New System

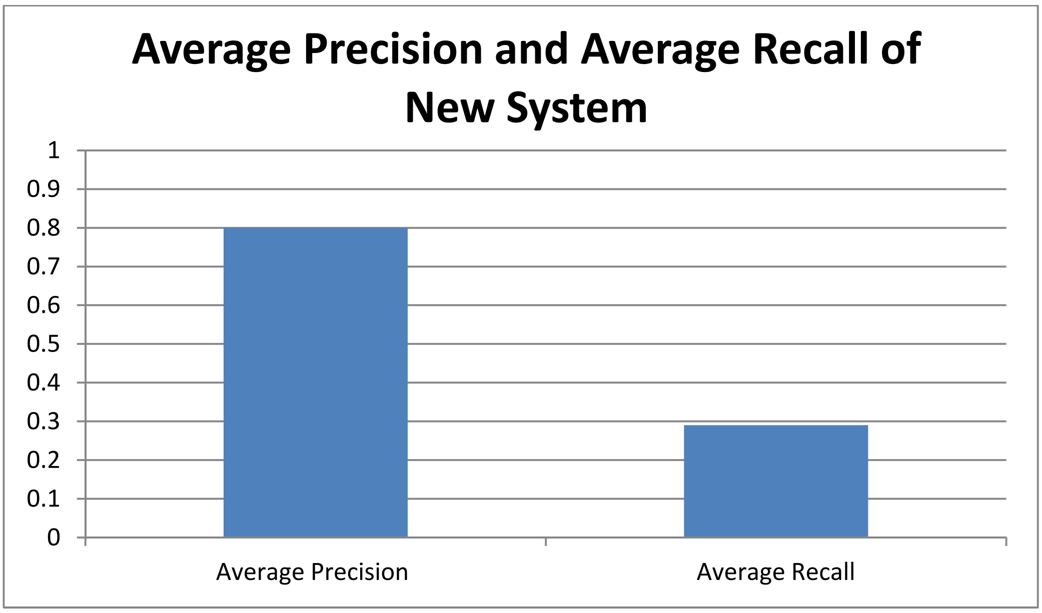

Figure 7.33: Average Precision and Average Recall of New System

7.5 Comparative Evaluation

In the previous section the evaluation results using standard metrics such as Precision and Recall are discussed. In this section we compare the achieved results by proposed system with four existing well-known approaches in order to demonstrate the effectiveness of the new content-based image retrieval system. These well known-approaches (ElAlami 2011, Huang 2003, Jhanwar 2004 and Lin et al. 2009) are listed in table 7.4 along with the type of features used by these approaches. They are also discussed briefly in this section. In addition, the evaluation is carried out based on Average Precision and Average Recall values as well as through accuracy measure.

Table 7.4: Comparison of content based image retrieval approaches

Methods	Texture Features	Colour Features	Shape Features	Additional method
Huang 2003	√	X	X	
Jhanwar 2004	√	X	X	
Lin et al. 2009	√	√	X	
ElAlami 2011	√	√	X	Data mining rules
Proposed Approach	√	√	√	Fuzzy rules

ElAlami: This approach is based on colour and texture features extraction method. In order to refine the retrieved results a set of data mining rules are used (ElAlami 2011).

Huang: This approach combined two methods. Gradient vector and wavelet decomposition in order to extract the texture features for image retrieval (Huang 2003).

Jhanwar: This approach extracted the texture features using Motif Co-occurrence Matrix method for image retrieval (Jhanwar 2004).

Lin: This approach is based on colour and texture feature extraction methods which are used to retrieve the most relevant images from the database (Lin et al. 2009).

In order to compare the results of the proposed image retrieval system with the latest literature. The same dataset as described in section 7.4.1 was adopted which was used by the existing researchers, but in our experiments we have also added another 14 different categories of images. These different categories of images are related to the biometric images. Further details on the above methods have been described in the literate review in chapter 2 (section 2.3).

Compared to the well-known approaches (ElAlami 2011; Huang 2003; Jhanwar 2004; Lin et al. 2009) based on the average Precision and average Recall, the new system achieved the best results as can be seen in figure 7.34. In the literature, accuracy is measured based on the average of precision and recall (Sharma 2011). The accuracy of the new system was calculated based on the following equation.

$$\text{Accuracy} = (\text{Precision} + \text{Recall}) / 2 \qquad (7.3)$$

Even though in some cases where the accuracy was affected, the new system has achieved better overall results as compared to the existing approaches. The proposed approach has produced better results as compared to the existing research approaches. The accuracy of the proposed approach was compared with existing four well-known approaches (ElAlami 2011, Huang 2003, Jhanwar 2004 and Lin et al. 2009)) as shown in figure 7.35.

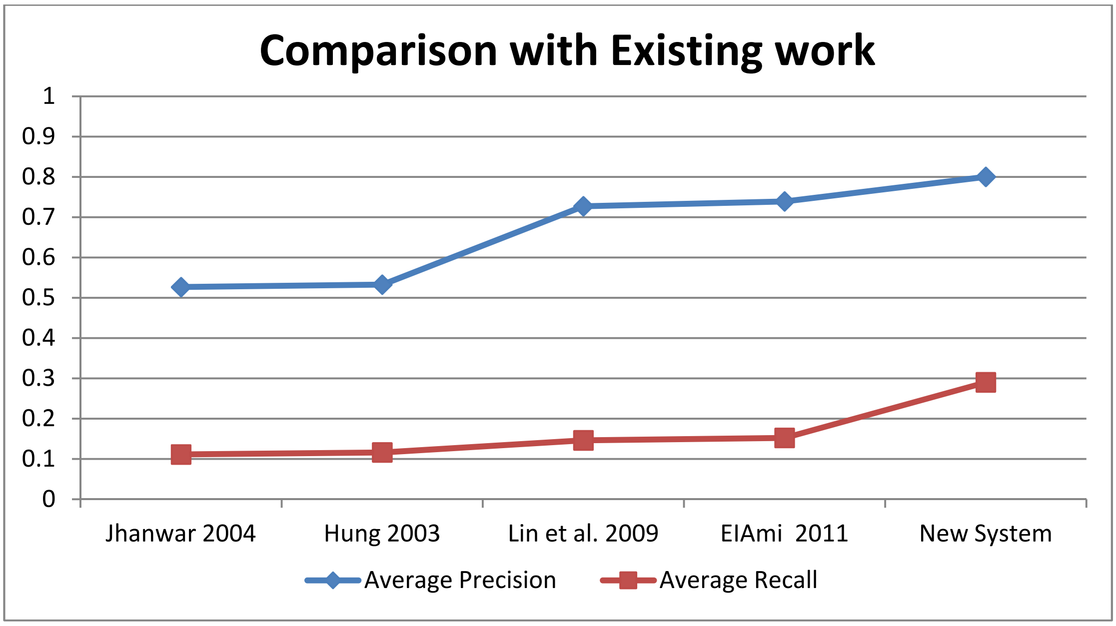

Figure 7.34: Results comparison using existing methods and new system

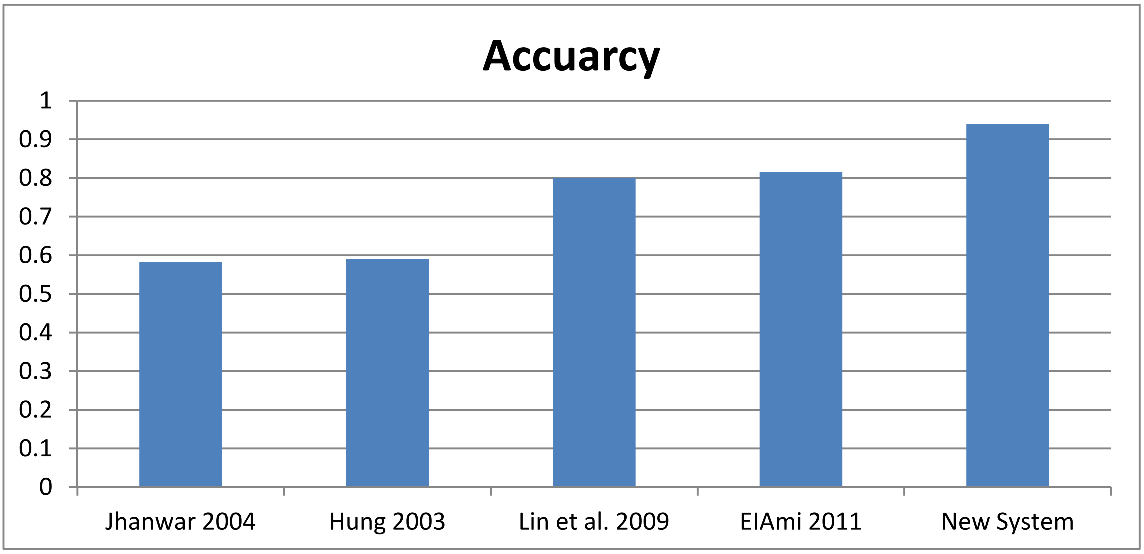

Figure 7.35: Accuracy comparison using existing methods and new system

7.6 Summary

This chapter was divided into three parts; in the first two parts individual components of the proposed approach were evaluated. In the third part the overall comparative evaluation of the proposed approach was carried out against with existing well known approaches.

First part of this chapter has presented the evaluation results achieved by applying the new integrated image enhancement approach for biometric security. The new approach is based on the integration of contrast enhancement and enhanced colour balancing methods. In order to evaluate the performance of the new approach three face detection methods (skin colour based, feature based, image based) were applied to surveillance images before and after enhancement using the proposed approach. On each occasion, significant improvement in face detection was achieved after enhancing the images using the new approach. Secondly, the histogram method was used before and after enhancement of the images. The results also showed that after applying the new approach to the biometric security images, well spread histograms were achieved which also indicated that the images are well enhanced.

In the second part of this chapter content based image retrieval system was evaluated. The integrated image enhancement approach was used to enhance the image's visibility and as result of this pre-processing phase, the image features became more obvious in the image. These obvious features help the feature extraction methods to extract more detailed information of these features. It is known that a clear image provides more information as compared to an unclear image. These extracted features play an important role in image retrieval system as the whole process of image retrieval relies on the image features. If the image query has more detailed features, there exists a better chance of retrieving the images which are closest to the query image. Therefore, the proposed system is able to retrieve more relevant images to the query image because in the proposed image retrieval system the enhanced images were used as an image query.

The evaluation is carried out using the standard Precision and Recall measures. We used seven different cases to evaluate the proposed content based image retrieval system. In these cases of evaluation image enhancement method, colour feature, texture features and shape features were used. In each case, the proposed approach has achieved better results. Further evaluation is carried out by comparing the achieved results with the existing approaches. The presented results show that the proposed approach produce better results as compared to the existing methods.

The next chapter conclude this thesis by summarising the work discussed in this thesis and providing future directions.

CHAPTER 8

CONCLUSION AND FUTURE WORK

8.1 Introduction

This chapter discusses the contribution that this thesis has made to existing knowledge. It also discusses the strengths and limitations of the proposed approach and outlines some points for future research.

The chapter is organised as follows. Section 8.2 discusses the contribution of this thesis. Section 8.3 discusses the strengths and perceived limitations of the new integrated image enhancement approach and the new content based image retrieval system. Section 8.4 outlines some points for future work.

8.2 Main Contributions

This thesis has made a number of contributions in the area of biometric security, particularly with regard to surveillance images. The quality of images has been enhanced by applying an integrated image enhancement approach so that more features can be extracted and eventually more similar images can be retrieved. The contributions are discussed in more details below.

8.2.1 New Integrated Image Enhancement Approach

A new integrated approach is proposed for image enhancement. The new integrated approach addresses the problem related to the quality of surveillance images produced by surveillance cameras which are installed in public places to monitor human activities. Surveillance images are mostly affected by low contrast, low brightness and colour cast due to many reasons such as the capturing devices and environmental factors.

In order to develop the new integrated image enhancement approach, two methods are integrated namely the contrast enhancement method and the colour balancing method. The contrast enhancement method is used to improve the contrast, while the colour balancing method helps to achieve colour balancing. Importantly, in the colour balancing method, a new process for colour cast adjustment is introduced which relies on statistical calculation. It adjusts the colour cast and maintains the luminance of the whole image at the same level.

More precisely, the approach is applied so as to make sure the maximum white scale factor does not go below zero using the colour component with the highest average white scale factor. The ratio is calculated by dividing the other two colour components with designated maximum white scale factor. The Red, Green and Blue colour casts are found using “IF ELSE” decision making statements (see equations: 5.13, 5.15 & 5.17). The zero scale factor is set by default in all these else statements. These equations are derived based on a decision making observation. It is argued that such observation should be used in order to find the colour cast of an image.

In order to calculate the colour cast, average values are used due to the fact that majority of pixels fall in this range (see equations 5.13, 5.15 & 5.17). In the case of using the maximum value, a single outlying pixel having a very high value can badly affect the whole image which will eventually lead to unrepresentative scaling. Regarding the calculation of a ratio (see equations: 5.14, 5.16 & 5.18), only the maximum value of any pixel affects the image, therefore the maximum value is used to calculate the ratio. If red colour cast is higher, the red values are used as constant and the other two colours are adjusted. Using these maximum values, the over saturation problem has been addressed in the new approach. Furthermore, by using the maximum values as divisors, lower values can be obtained. This solves the over saturation problem and helps to adjust illumination of the image at the same level.

8.2.1.1 Evaluation of New Integrated Image Enhancement Approach

In order to evaluate the performance of the new integrated image enhancement approach, surveillance images were processed for face detection using three existing well known face detection methods namely skin colour based face detection, feature based face detection and image based face detection. The selection of these methods is carried out due to fact that they were proposed recently and they have achieved good results.

The second purpose of using these methods is that they are based on different types of image characteristics. For example, the skin colour based face detection method uses the colour information of an image; the feature based face detection method relies on image features characteristics while the image based face detection method is based on the Neural Network and Gabor Filter. The usage of these three different types of methods ensures that the new integrated image enhancement approach is thoroughly evaluated.

In our experiments, the face detection methods were applied before and after enhancement of images using the new approach. On each occasion significant improvements in face detection were achieved after enhancing the images using the new approach. These results demonstrate the effectiveness of the new approach and show its potential in the area of biometric security.

8.2.2 New Content Based Image Retrieval System

The new content-based image retrieval system is based on colour, texture and shape features. It also employs a set of fuzzy heuristics in order to prioritise the results based on the predefined criteria. The new system is based on the three well-known algorithms: colour, texture and shape. The use of these three algorithms ensures that the new image retrieval system produces results which are highly relevant to the content of an image query, by taking into account the three distinct features of an image and using a similarity metrics based on the Euclidean measure.

Colour histogram is used to extract the colour features of an image using four components; three of the components (Red, Green and Blue) are obtained from RGB colour model while the fourth component (Intensity) is generated by combining the Red, Green and Blue components.

Secondly, the Gabor filter is used to extract the texture features of an image. Precisely, the magnitudes represent the energy content at different orientation and scale of image. The main purpose of texture-based retrieval is to find images or regions with similar texture. Therefore, in the new system the mean and the standard deviation of the magnitude of the transformed coefficients are used to represent the texture feature of the region.

Thirdly, the Hu moment invariant is used to extract the shape features of an image. Due to the fact that Surveillance images are mostly not captured accurately, the images are neither always visible nor have the appropriate orientation or the size of objects. Therefore the Hu moment invariants algorithm is selected to be used as an important part of the proposed system because the moment invariants algorithm is invariant to location, orientation and size. It finds the centre of a region, and then seven Hu moments are derived to extract the feature of an image.

The similarity between query image and database images is calculated using the Euclidean distance algorithm. Finally, fuzzy rules are defined based on feature priorities and then these rules are driven using the Mamdani fuzzy inference method.

8.2.2.1 Evaluation of New Content Based Image Retrieval System

The evaluation of the new content based image retrieval system is carried out using the standard Precision and Recall measures, and the results are compared with well known methods. In total, 1140 images containing 24 different categories were used in order to evaluate the performance of the new content based image retrieval system. The results presented show that the new system produces better results as compared to the existing methods. Furthermore, accuracy metrics are applied in order to compare the new system against the existing approaches, and results show that the new system has achieved a higher rate of accuracy as compared to existing methods.

8.3 Strengths and Limitations

8.3.1 An Integrated Image Enhancement Approach

Evaluation of the new integrated image enhancement approach shows that the new approach has performed well on images which were affected by low contrast and colour cast. It can effectively improve the image visibility by enhancing the contrast and adjusting the colour cast of an image. The new approach performs several functions such as calculating average and maximum values and calculating the scale and gain factors of the whole image. Applying such functions to the whole image makes the image enhancement process very fast. A potential advantage of the new approach is that it can be used to enhance the quality of videos in real-time.

One of the limitations of the proposed integrated image enhancement approach is that it is unable to enhance the black and white images because it is proposed to enhance the quality of colour images because nowadays surveillance cameras produce mostly colour images and the proposed approach is tested on colour images and found to be more accurate and effective as compared to the existing approaches. Secondly, the images which are affected by distortion cannot be enhanced by the proposed integrated image enhancement approach. Thirdly, the proposed approach cannot enhance the images of low resolution. However, the proposed approach can effectively address the problems related to contrast, brightness and colour cast. Therefore, it is out of scope of proposed approach to improve the resolution of images. Another important aspect of the proposed approach that may be perceived as a limitation is that if surveillance images are captured in extreme deep dark or extreme deep bright conditions, they cannot be improved using the proposed integrated image enhancement approach in order to make the objects visible due to the fact that objects are not normally well captured in the image.

8.3.2 Content Based Image Retrieval System

Although there exist several approaches relating to image retrieval, they mostly rely on text query and user feedback. This is the first comprehensive approach that has been proposed based on the integration of several methods. The strength of the new system is demonstrated by evaluating the results and comparing the new system with the existing available solutions. The new system has achieved better average Precision and average Recall values as compared to well-know methods. An aspect of the new content-based retrieval system that can be perceived as its limitation is the limited number of fuzzy heuristics that were employed to prioritise the results. A few of the results showed that the shape feature has been slightly dominant as in those cases where irrelevant images are retrieved. The irrelevant images are similar in shape to the image query.

Another limitation of the proposed content based image retrieval system is that if images contain background objects then there is a high probability of retrieving irrelevant images. This limitation can be minimized by focusing on the face objects rather than the full images. This will help to eliminate the irrelevant background features related to shape or colour or texture or combination of these features. Currently this part is not fully integrated with the content based image retrieval system. Another aspect of the proposed content based image retrieval system that may be perceived as a limitation is that if images are affected by dominant colour such as red/green/blue, then there is a high probability of retrieving similar images which also contain the similar dominant colour. The features of the query image should be visible enough to make successful feature extraction in order to match these features with database images to retrieve most similar images.

8.4 Future Work

Working on this thesis has generated several interesting ideas which can help to improve the proposed approaches and also to apply the approaches to different domains such as health and drilling applications.

8.4.1 An Integrated Image Enhancement Approach

- One way to improve the quality of images is to use the local enhancement process. In this process the image is divided into different regions or blocks. For example an image is converted to 16x16 blocks/regions and then each block/region is considered separately to calculate the values in order to enhance the image by removing colour cast or improving their contrast. Through this procedure images of good quality can be produced as each block of image is accommodated individually according to their requirements. By calculating the values of each block the problem relating to that block can be addressed accurately in that limited region/block. The main drawback of using this approach is that it will require longer time to enhance a single image of 310 X 293 pixels.
- In future the problem of high computational cost of local enhancement process, as briefly described above, can be addressed through parallel processing. Processing the individual block in parallel will boost the processing time. It will also make the application to be used for real time video enhancement.

- Another future direction that can be taken from this work is to apply Artificial Intelligence algorithms to enhance the quality of images. That can be carried out by enhancing a sample image. Then the sample image can be used as a reference image in order to enhance the rest of the similar images. This reference image can be used to train the system for better results.

8.4.2 Content Based Image Retrieval System

The new content based image retrieval system extracts the feature of an image by using three different types of methods namely Colour Histogram, Gabor Filter and Hu Moment Invariant. The similarity between images is checked through Euclidean distance and fuzzy rules. Future directions can be taken from these methods as explained below:

Colour Histogram

- In the proposed method Red, Green, Blue and Intensity histograms have been used to obtain the colour features of an image. A future direction that can be taken is by using different colour models such as HSI (Hue, Saturation and Intensity) colour model that provides more colour values. This long range of values can help to get more accurate colour features of an image. By combining colour features along with texture and shape features the accuracy of the system can be improved.
- Another direction can be to extract the objects of an image query in order to generate the histogram. The histograms of objects of the image query can then be used to match the similar objects in the database for better accuracy.

Gabor Filter

- Using more Gabor filter functions can help to obtain more information from the image. For example, by increasing the scale and orientation values more image information can be gathered.

Moment Invariant

- The Hu moment invariant algorithm is based on seven moments, and these seven moments help to get the object's information. More movements in this method can be introduced in order to get more information about the objects. This information will eventually help to improve the accuracy of the image retrieval system.

Fuzzy Rules

- Future work will also include the refinement of the existing rules based on the achieved results. New fuzzy heuristics will be developed in order to improve the accuracy of the retrieved results.

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