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An efficient image retrieval scheme for colour enhancement of embedded and distributed surveillance images

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ABSTRACT

From the past few years, the size of the data grows exponentially with respect to volume, velocity, and dimensionality due to wide spread use of embedded and distributed surveillance cameras for security reasons. In this paper, we have proposed an integrated approach for biometric-based image retrieval and processing which addresses the two issues. The first issue is related to the poor visibility of the images produced by the embedded and distributed surveillance cameras, and the second issue is concerned with the effective image retrieval based on the user query. This paper addresses the first issue by proposing an integrated image enhancement approach 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 adjusts the colour cast and maintains the luminance of the image. The integrated image enhancement approach is applied to the enhancement of low quality images produced by surveillance cameras. The paper addresses the second issue relating to image retrieval by proposing a content-based image retrieval approach. The approach is based on the three features extraction methods namely colour, texture and shape. 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 results show the proposed approaches perform better than the well-known existing approaches.

1. Introduction

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 [1-7]. 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.

1.1. Motivation

The main problem with surveillance images is that they are of low quality [6]. This makes the detection and recognition of

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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 [8]; use of low resolution cameras [9]; and environmental factors [10]. The environmental factors include rainfall, fog and snow [11,10,12]. These factors obscure object details and create noise which badly affects the performance of object detection and the recognition process [13]. It is therefore crucial to enhance the quality of surveillance images in order to use them for face detection, recognition and retrieval purposes [7,14]. Moreover, with an increase in the size of the data with respect to the size, volume, and dimensionality, it is quite difficult to process the captured images using a single unified technique. Hence, there is a requirement of efficient techniques which not only divide the problem in to smaller subproblems, but also deal with the growing size of the data from all aspects of size, volume and dimensionality.

In most of the existing systems, face detection is the most challenging task as faces are to be detected from the input image before they can be further processed, recognised or retrieved. In 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 [15]. 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 image retrieval and enhancement has not been fully addressed. Therefore, this area of research is lacking from two aspects: image detection and image retrieval.

1.2. Organization

The rest of the paper is structured as follows. Section 2 discusses the literature review of the paper. Section 3 describes the proposed integrated framework in this paper. Moreover, the detailed methodology and results obtained are also discussed in this Section. Section 4 provides the conclusion of the proposed approach.

2. Literature review

This section reviews current literature concerning biometric security. As this paper 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. This section is divided into two sections: Image Enhancement Approaches and Image Retrieval Approaches as described in subsections.

2.1. Image enhancement approaches

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 [1; 3; 6; 7) 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.

In order to address the problem of low quality of images produced by surveillance cameras, Mudigoudar et al., have developed an application, based on a gradient method, to enhance the low resolution of surveillance images and videos [6]. A gradient method is used to record the sequence of images at sub-pixel 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 [1]. Another similar approach is proposed by Wang et al., to address the face recognition problem through Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA) [7].

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., have proposed a method to restore the colours in highly illuminated images [3]. 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 [3].

An integrated method for face recognition has been proposed [16]. The integration is based on three issues such as: The problem of low illumination is addressed by applying the local contrast enhancement method. Secondly, the selection of feature extraction is carried out using adaptive feature extraction method. Thirdly, support vector machine based technique is used for classification. The limitation of this method is that in extreme conditions it does not perform well [17].

An et al. [2] 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, they have achieved high quality results.

Kim et al., have proposed a biometric method which is based on two levels [5]. 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 two levels of methodology 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 [18]. 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 [19].

Bianco et al., have used several image enhancement methods, (such as grey world, white patch, gray edge), to improve the quality of images [20]. 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.

2.2. Image retrieval approaches

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 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 statistical methods such as Euclidean Distance.

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 [16,21–24].

IBM has introduced several versions of the QBIC system which are widely used for image retrieval purpose. Using the QBIC system, users are able to search the image by identifying certain characteristics of the image. Latest versions of QBIC use a regional segmentation function to segment the image into different regions. The main disadvantage of this system is that it is sensitive to the variation of illumination. Another system known as SIMPlicity is used to segment the image into regions/blocks and to extract features from each block [25]. 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 [25,26].

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 [24–27]. The problem with this approach is that it reduces or increases the regions as a result of imperfect and unsupervised segmentation.

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 [28,29].

Moment invariants method is used for object identification [30]. More precisely the moment invariant method is used for facial expression such as anger, disgust, happiness and surprise. Rizon et al., have used moment invariant and HMM (Hidden Markov Models) for image recognition purposes [30]. 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 [31]. The approach is only applied to a limited dataset and half of the image dataset is used to train the system.

Huang and Dai have proposed an Image retrieval system based on texture features [32]. 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 [33].

Jhanwar et al., proposed an image retrieval system which is based on the concept of Motif co-occurrence matrix (MCM) [34]. 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 [35]. The limitation of this method is that when images contain multiple regions (towards horizontal and vertical) then their method is unable to produce good results.

Lin et al., have proposed a content-based image retrieval application based on colour and texture feature [36]. 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 proposed a content-based image retrieval system [37]. 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.

3. Proposed integrated framework

This section proposes an integrated framework for biometric security as shown in Fig. 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 two stages as briefly described below:

- At the first stage, image enhancement techniques namely contrast enhancement and colour balancing are applied to improve the visibility of an image. Thereafter different face detection

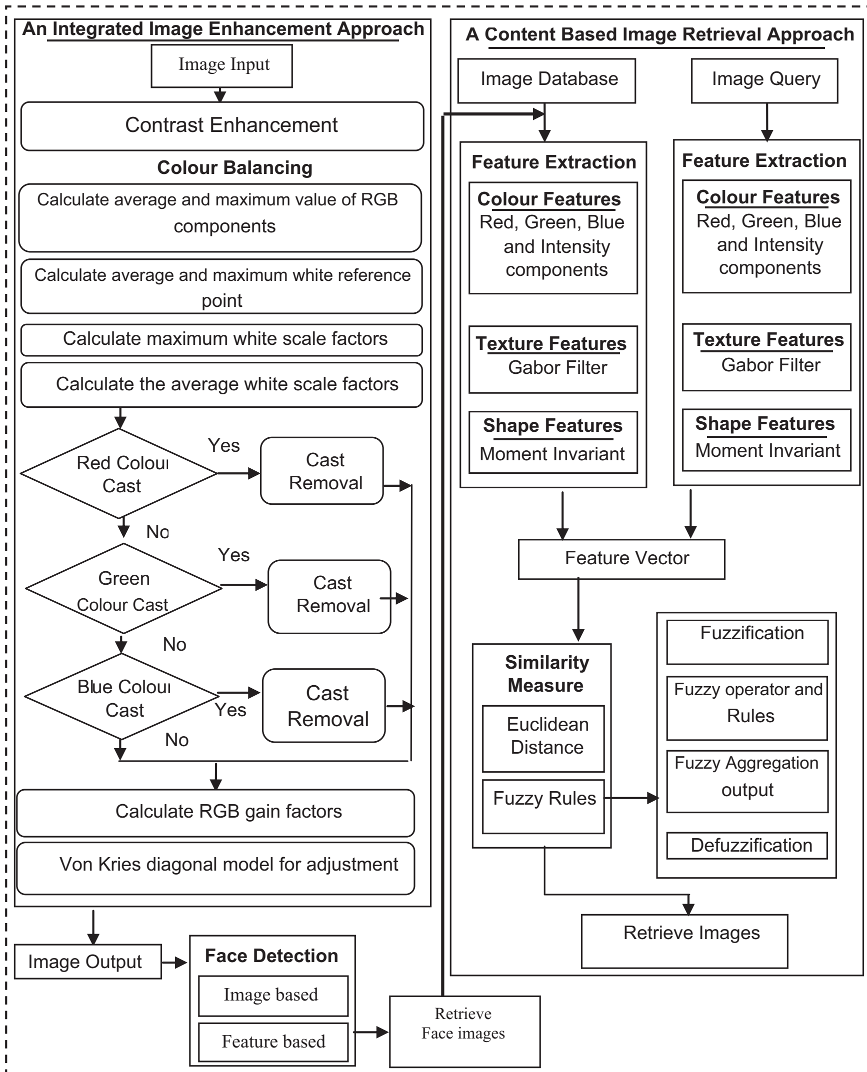

Fig. 1. An integrated framework for biometric security.

methods are applied to the images which are enhanced by the proposed image enhancement approach.

- 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. Furthermore 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.

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

3.1. *An integrated image enhancement approach*

3.1.1. *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 [38]

$$P_o = (P_i - c)\frac{(b-a)}{(d-c)} + a \tag{1}$$

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.

3.1.2. *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. Fig. 1 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

$$R_{Avg},\ G_{Avg},\ B_{Avg} \tag{2}$$

$$R_{Max},\ G_{Max},\ B_{Max} \tag{3}$$

Step 2: The matrix operation below is used to convert RGB to the YCrCb colour model (see Eq. (4). These are easier and faster to calculate as compared to other colour models [39]. 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 colour pixel visible. In our proposed method we only used luminance channel

$$\begin{cases} Y = (0.299 \times R) + (0.587 \times G) + (0.114 \times B) \\ \mathbf{Cr} = (0.701 \times R) - (0.587 \times G) - (0.114 \times B) \\ \mathbf{Cb} = (-0.299 \times R) - (0.587 \times G) + (0.886 \times B) \end{cases} \tag{4}$$

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 Eqs. (5) and (6)

$$Y_{MaxWhite} = (0.299 \times R_{Max}) + (0.587 \times G_{Max}) + (0.114 \times B_{Max}) \tag{5}$$

$$Y_{AvgWhite} = (0.299 \times R_{Avg}) + (0.587 \times G_{Avg}) + (0.114 \times B_{Avg}) \tag{6}$$

To calculate the reference white, the top 10% of the pixel values are used [40]. Chikane and Fuh have calculated the reference value using average values based on the range average to bright pixel value [41,42]. In the new colour balancing algorithm, both average and maximum values are used to calculate two separate white reference points as shown in (5) and (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 Eqs. (3) and (5) as written in Eqs. (7), (8) and (9)

$$R_{Max\ White\ Scale\ Factor} = Y_{Max\ White}/R_{Max} \tag{7}$$

$$G_{Max\ White\ Scale\ Factor} = Y_{Max\ White}/G_{Max} \tag{8}$$

$$B_{Max\ White\ Scale\ Factor} = Y_{MaxWhite}/B_{Max} \tag{9}$$

Step 4: Here, the proposed 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 Eqs. (2) and (6) as written in Eqs. (10), (11) and (12)

$$R_{Avg\ White\ Scale\ Factor} = Y_{Avg\ White}/R_{Avg} \tag{10}$$

$$G_{Avg\ White\ Scale\ Factor} = Y_{Avg\ White}/G_{Avg} \tag{11}$$

$$B_{Avg\ White\ Scale\ Factor} = {}_{Avg\ White}/B_{Avg} \tag{12}$$

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 Eqs. (13), (15) and (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 (14):

$$if \begin{pmatrix} R_{Avg\ White\ Scale\ Factor} > G_{Avg\ White\ Scale\ Factor}\ \&\& \\ R_{Avg\ White\ Scale\ Factor} > B_{Avg\ White\ Scale\ Factor} \end{pmatrix} \tag{13}$$

$$\begin{cases} R_{Factor} = 0 \\ G_{Factor} = \dfrac{G_{MaxWhiteScaleFactor}}{R_{MaxWhiteScaleFactor}} \\ B_{Factor} = \dfrac{B_{MaxWhiteScaleFactor}}{R_{MaxWhiteScaleFactor}} \end{cases} \tag{14}$$

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 (16):

$$if \begin{pmatrix} G_{AvgWhiteScaleFactor} > R_{AvgWhiteScaleFactor}\ \&\& \\ G_{AvgWhiteScaleFactor} > B_{AvgWhiteScaleFactor} \end{pmatrix} \tag{15}$$

$$\begin{cases} R_{Factor} = \dfrac{R_{MaxWhiteScaleFactor}}{G_{MaxWhiteScaleFactor}} \\ G_{Factor} = 0 \\ B_{Factor} = \dfrac{B_{MaxWhiteScaleFactor}}{G_{MaxWhiteScaleFactor}} \end{cases} \tag{16}$$

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 (18):

$$if \begin{pmatrix} B_{AvgWhiteScaleFactor} > G_{AvgWhiteScaleFactor}\ \&\& \\ B_{AvgWhiteScaleFactor} > R_{AvgWhiteScaleFactor} \end{pmatrix} \tag{17}$$

$$\begin{cases} R_{Factor} = \dfrac{R_{Max\ White\ Scale\ Factor}}{B_{Max\ White\ Scale\ Factor}} \\ G_{Factor} = \dfrac{G_{Max\ White\ Scale\ Factor}}{B_{Max\ White\ Scale\ Factor}} \\ B_{Factor} = 0 \end{cases} \tag{18}$$

In order to calculate the colour cast, average values are used due to the fact that majority pixels fall in this range, such as Eqs. (13), (15) and (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 (14), (16) and (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.

$$R_{Gain\ Factor} = \left[\left(R_{Factor} + G_{Factor} + B_{Factor}/3 \right) \times \left(R_{Avg\ White\ Scale\ Factor} \times R_{Max\ White\ Scale\ Factor} \right) \right] \quad (19)$$

$$G_{Gain\ Factor} = \left[\left(R_{Factor} + G_{Factor} + B_{Factor}/3 \right) \times \left(G_{Avg\ White\ Scale\ Factor} \times G_{Max\ White\ Scale\ Factor} \right) \right] \quad (20)$$

$$B_{Gain\ Factor} = \left[\left(R_{Factor} + G_{Factor} + B_{Factor}/3 \right) \times \left(B_{Avg\ White\ Scale\ Factor} \times B_{Max\ White\ Scale\ Factor} \right) \right] \quad (21)$$

Step 7: According to the Von Kries hypothesis, the pixel value of every pixel in the whole image is adjusted

$$R' = R_{Gain\ Factor} \times R \quad (22)$$

$$G' = G_{Gain\ Factor} \times G \quad (23)$$

$$B' = B_{Gain\ Factor} \times B \quad (24)$$

where R, G and B are original pixel values in the image and R', G' and B' are the adjusted pixel values.

In this section, the first stage of the proposed integrated framework is discussed in relation to image enhancement techniques. The integrated image enhancement approach is applied to improve the visibility of the image which is important for face detection. Two methods, contrast enhancement and colour balancing are applied for this purpose.

The results achieved by applying the proposed integrated image enhancement approach are discussed in the following section. 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.

3.1.3. Face detection results

In the previous section 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 proposed 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 proposed approach. On each occasion significant improvements in face detection were achieved after enhancing the images using the proposed approach. These results demonstrate the effectiveness of the proposed approach and show its potential in the area of biometric security.

3.1.3.1. 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 proposed

Fig. 2. Skin colour based face detection method before and after using the proposed integrated image enhancement approach (A-person is entering into a shop) and (B-person is on an accelerator).

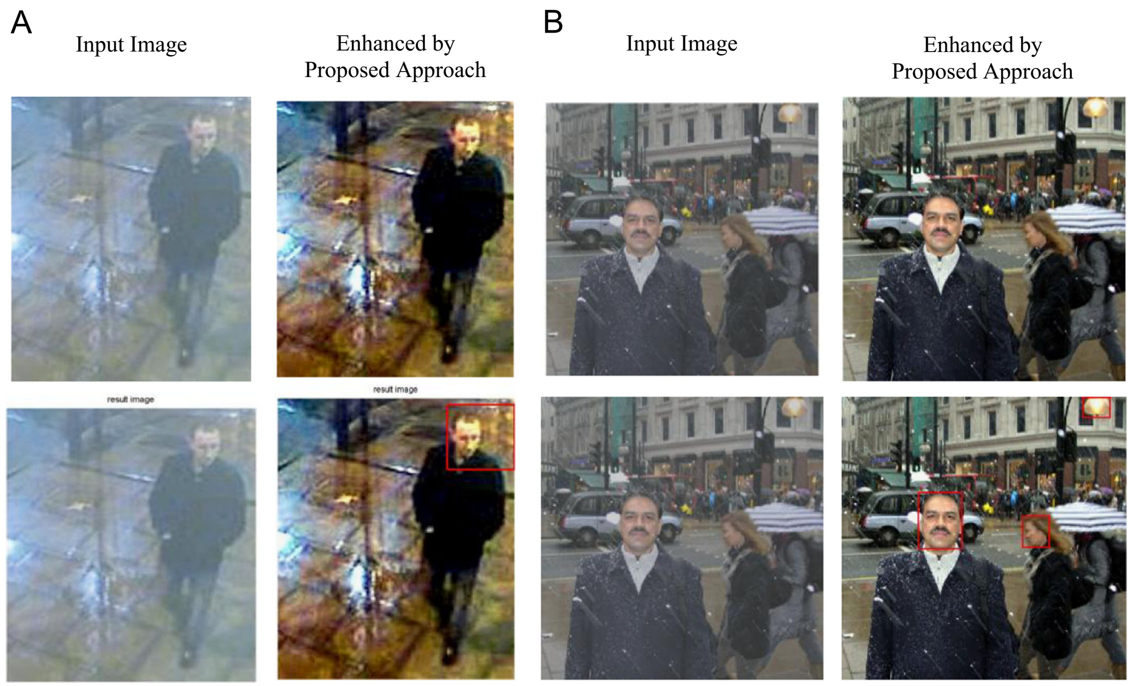

Fig. 3. Skin colour based face detection method before and after using the new integrated image enhancement approach (A-person walking in a street) and (B-pciture captured during snow).

Fig. 4. Skin colour based face detection method before and after using the proposed integrated image enhancement approach (A-person walking during rain) and (B-person walking during snow).

approach. The results in Figs. 2A, B and 3A show that the rate of face detection has been increased by using the proposed image enhancement approach. It can be seen in these figures that the face detection methods have not detected any face when original images were used. On the other hand, faces were detected when the proposed 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.

Figs. 2A, B and 3A are taken by CCTV cameras and downloaded from websites. In Fig. 2A, one person is entering into a shop; in Fig. 2B, one person is on an accelerator and in Fig. 3A a person is walking in a main street.

Another category contains images which were affected by weather used for experimental purposes in order to evaluate the proposed approach thoroughly (Figs. 3B, 4A and B). These three images were captured when it was raining or snowing. As can be seen in Fig. 3B 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 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 proposed approach (Fig. 4A). 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 proposed approach, the face has been detected from the image (Fig. 4A).

Another image affected by weather is used to evaluate the performance of the proposed 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 Fig. 4B.

3.1.3.2. 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 [43]. As can be seen in Figs. 5A, 5B and 6A 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 proposed approach. The results showed that the rate of face detection was increased by using the proposed image enhancement approach.

It can be seen in Figs. 5A, B and 6A 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 (3rd row of Fig. 5A). On the other hand, a face was detected using the proposed image enhancement approach.

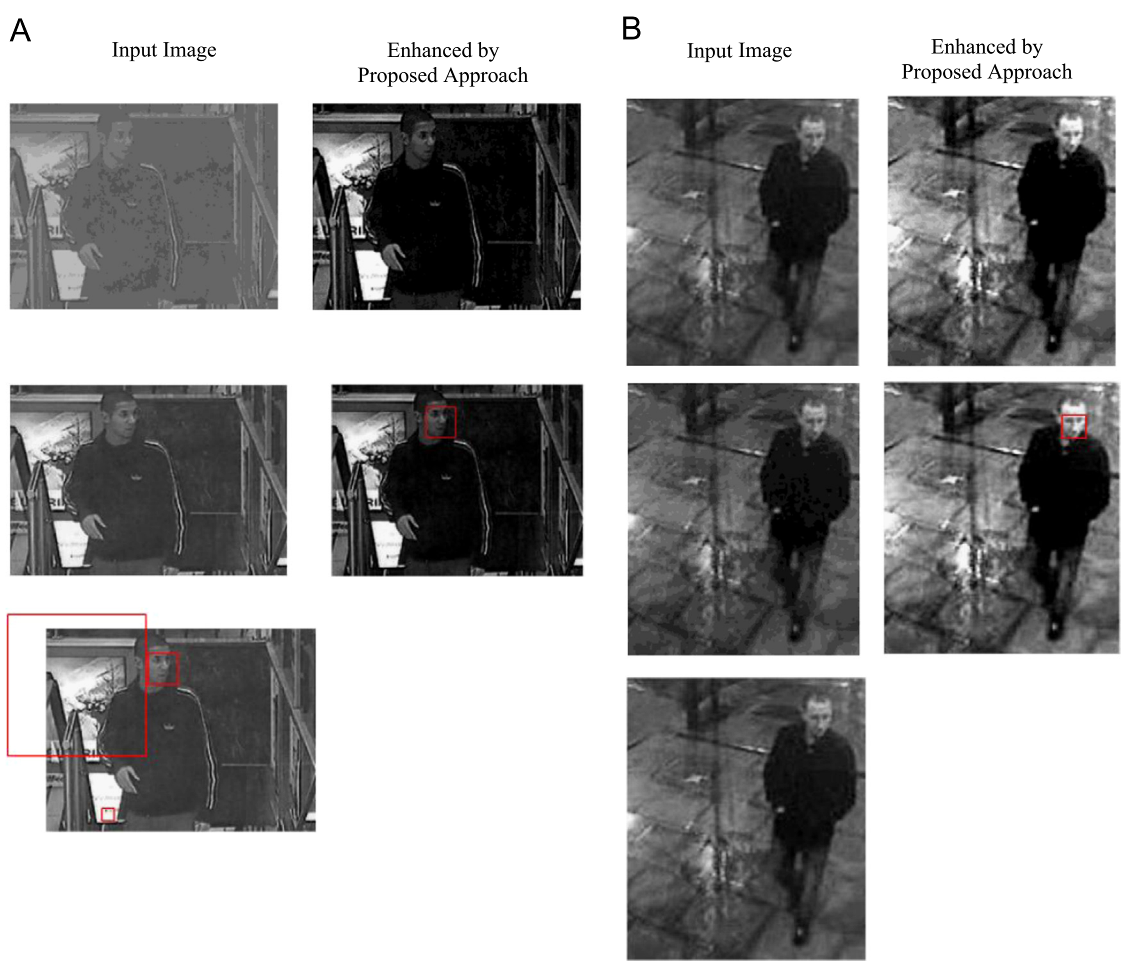

Fig. 5. Feature based face detection method before and after using the proposed integrated image enhancement approach (A-person is on an accelerator) and (B-person walking in a street).

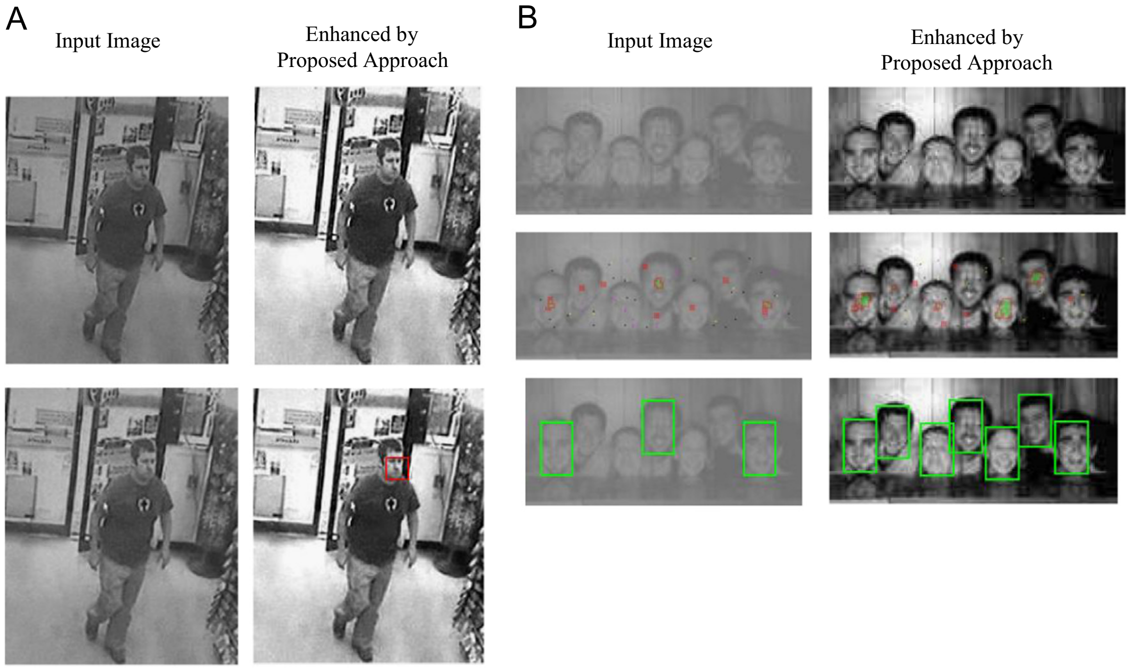

Fig. 6. Feature based face detection method (A) and Image based face detection method (B) before and after using the proposed integrated image enhancement approach [A-person is entering into a shop; B-group photo].

This is important to note that the same face detection methods were used for both, the original and the enhanced images.

3.1.3.3. 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 [44]. 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 Fig. 6B; only three faces were detected, while the proposed approach has detected all faces (Fig. 6B) in the image.

3.2. A content-based image retrieval approach

The previous section has demonstrated the potential of the integrated image enhancement approach for face detection. In this section, a content-based image retrieval approach is discussed for biometric security, which is based on colour, texture and shape features, it also employs a set of fuzzy heuristics. It is based on the three algorithms: colour histogram, texture and moment invariants as shown in Fig. 1. The use of these three algorithms ensures that the proposed image retrieval approach 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.

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.

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 [45]. 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 [46,76], user's subjective perception of relevance [35,47,76] and environmental settings [48,49,76]. 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 [46,77]. In contest to these approaches (text-based query and relevance feedback), content-based approaches produce better results [32,34,36,37] 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 [50–54].

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 dataset. 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.

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 [50,55,30,56,57] due to its reliability on geometric measurement. Features such as colour and texture can be affected by the quality of an image. Therefore, our proposed approach, 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 proposed approach produces highly relevant results for user's query. Importantly, fuzzy heuristics are employed to assess the relevance of the retrieved images.

3.2.1. Proposed content-based image retrieval approach

This section, discusses a proposed content-based image retrieval approach for biometric security, which is based on colour, texture and shape features, controlled by fuzzy heuristics. It is based on the three well-known algorithms: colour histogram, texture and moment invariants. The objective of using these three algorithms is to develop an integrated image retrieval approach capable of producing better results for biometric security. The propose approach 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.

When a user inputs an image query, the image retrieval approach 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 Fig. 7. Details of these algorithms are given in the subsequent sections. The advantages of the proposed content-based image retrieval 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;

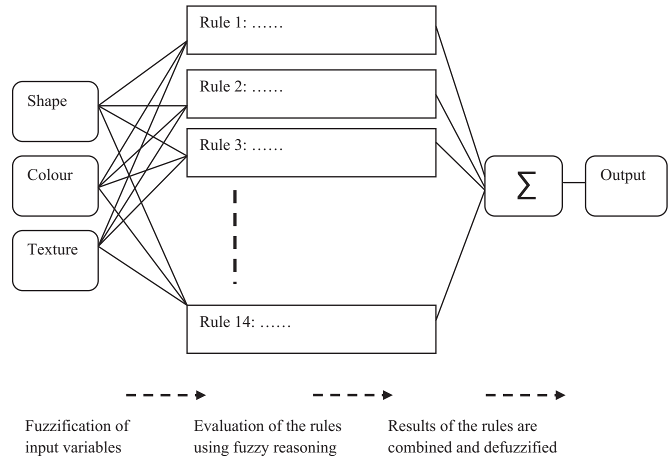

Fig. 7. Fuzzy system architecture.

- The image query removes the difficulty of describing the feature of an image in words when similar images are searched.

3.2.2. Colour features

For the colour feature, we integrate two types of histogram based methods using a colour image histogram and an intensity image histogram. For the colour image we use the RGB colour model that is based on the Red, Green and Blue components. The histogram method is widely used for visual feature representation due to many advantages in image retrieval such as its robustness, effectiveness, implementation and computational simplicity.

A digital image is commonly seen as a 2D mapping $I : \mathbf{x} \to v$ from $M \times N$ pixels $\mathbf{x} = [i, j]T$ to values v (where $i = 1, 2, \ldots, M$ and $j = 1, 2, \ldots, N$ corresponds to y-axis and x-axis respectively). Often the values v are discrete intensity values in the range [0–255]. In order to design a descriptor of an image its histogram is calculated. An image histogram can be generated as follows:

$$h_b = \sum_{i=1}^{M} \sum_{j=1}^{N} \delta_b(i, j), \quad \forall_b = \quad 0, 1, 2, ... \tag{25}$$

where $\delta_b(i, j) = 1$ if the v at pixel location $[i, j]$ falls in b, and $\delta_b(i, j) = 0$ otherwise. 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.

3.2.3. Texture features

The second element of the proposed approach 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 [58].

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 [59,60]. 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 proposed approach, 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 [61].

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 [61,62]

$$g, \lambda, \theta, \Psi, \sigma, \gamma(x, y) = \exp\left(-\frac{x'^2 + \gamma^2 y'^2}{2\sigma^2}\right)\cos\left(2\pi\frac{x'}{\lambda} + \Psi\right) \quad (26)$$

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

$$r(x, y) = I(x, y) * g(x, y) \quad (27)$$

where * represents the 2D convolution, the process can be performed at various orientation and scale; and prepared filter bank [63]. 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

$$E(m, n) = \sum_x \sum_y |G_{mn}(x, y)|, \quad (28)$$

M=0,1,…M-1 ; n=0,1,….N-1

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:

$$\mu_{mn} = E(m, n)/_{P \times Q} \quad (29)$$

$$\sigma_{mn} = \sqrt{\sum_x \sum_y \left(|G_{mn}(x, y)| - \mu_{MN}\right)^2 /_{P \times Q}} \quad (30)$$

Where M represents the scale and N represents the orientation. 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.

3.2.4. Shape features

The third main element of the proposed system is the shape feature. In the proposed approach, 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 [55], objects [30], face expression [31] and shoe prints [50]. It is a widely used algorithm for image classification [56]. The moment invariants algorithm drives a number of self-trait properties from the image of an object.

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. 128x128) [64] 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

$$m_{p,q} = \sum_x \sum_y x^p y^q f(x, y) \quad (31)$$

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

$$\mu_{pq} = \sum_x \sum_y (x - \bar{x})^p (y - \bar{y})^q f(x, y) \quad (32)$$

Where

$\bar{x} = m_{10}/m_{00}$, $\bar{y} = m_{01}/m_{00}$ *and* $\bar{x}, \bar{y}$ is called the centre of the region.

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

$$\eta_{p,q} = \mu_{p,q}/\mu_{0,0}^{\gamma} \quad (33)$$

For p, q = 0, 1, 2…where $\gamma = [(p + q)/_2] + 1$

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 ϕ_1 *to* ϕ_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 ϕ_1 *to* ϕ_7 moments, written below, are used to calculate the feature vectors [50]:

$$\left.\begin{array}{l}
\varphi_1 = \mu_{20} + \mu_{02} \\
\varphi_2 = (\mu_{20} + \mu_{02})^2 + (4\mu_{11})^2 \\
\varphi_3 = (\mu_{30} + 3\mu_{12})^2 + (3\mu_{21} - \mu_{03})^2 \\
\varphi_4 = (\mu_{30} + \mu_{12})^2 + (\mu_{21} - \mu_{03})^2 \\
\varphi_5 = (\mu_{30} + 3\mu_{12}) \\
\quad + (\mu_{30} + \mu_{12})[(\mu_{30} + \mu_{12})^2 - 3(\mu_{21} + \mu_{03})^2] \\
\quad + (3\mu_{21} + \mu_{03})(\mu_{21} + \mu_{03}) \\
\quad [3(\mu_{30} + \mu_{12})^2 - (\mu_{21} + \mu_{03})^2] \\
\varphi_6 = (\mu_{20} - \mu_{02})[(\mu_{30} + \mu_{12})^2 - (\mu_{21} + \mu_{03})^2] \\
\quad + 4\mu_{11}(\mu_{30} + \mu_{12})(\mu_{21} + \mu_{03}) \\
\varphi_7 = (3\mu_{21} - \mu_{03})(\mu_{30} - \mu_{12}) \\
\quad [(\mu_{30} + \mu_{12})^2 - 3(\mu_{21} + \mu_{03})^2] \\
\quad - (\mu_{30} - 3\mu_{03})(\mu_{21} + \mu_{03}) \\
\quad [3(\mu_{30} + \mu_{12})^2 - (\mu_{21} + \mu_{03})^2]
\end{array}\right\} \quad (34)$$

3.2.5. Similarity measure

3.2.5.1. Euclidean distance. The similarity between two images that reflects the strength of connections between them is measured numerically. Similarity is crucial in obtaining relevant results. To obtain relevant results various researchers use different methods to measure similarity. For example, some researchers used fuzzy measures [65], histogram intersection [66,67] and Euclidean distance [68]. Mostly in the area of image retrieval Euclidean distance is used for similarity measurement due to its efficiency and effectiveness [69–71]. Therefore the proposed approach uses Euclidean distance to calculate the similarity between two feature vectors as follows

$$ED\left(M^k, M^t\right) = \sqrt{\sum_{i=1}^{n}\left(M_i^k - M_i^t\right)^2} \quad (35)$$

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

3.2.5.2. Fuzzy similarity measure. A set of fuzzy heuristics 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. First, priority is given to the shape features, as shape of an image is not easily affected by external factors, and also it is invariant to the rotation, translation and orientation. Second, priority is given to the colour features, as these features are invariant to the rotation and translation. Third, priority is given to the texture features. By defining these criteria along with the fuzzy rules, we assume that better results can be achieved using our proposed approach. The Mamdani fuzzy inference method is used to perform fuzzy rules in our proposed approach [72].

X, Y and Z are three visual features of images that have been retrieved using Moment Invariants, Histogram of images (Red, Green, Blue and Intensity) and Gabor Wavelet. Based on the Euclidean distance algorithm the images are searched that have high similarity between query and database image. After obtaining the relevant images to the query image, we need to find common images between X, Y and Z set of images. The common set of images are considered the most relevant images. Commonality is measured using the below criteria.

X = Shape features are used to calculate the distance between query and database image

Y = Colour features are used to calculate the distance between query and database image

Z = Texture features are used to calculate the distance between query and database image

S = Image similarity

By adopting the following steps, a set of fuzzy rules are introduced to process the results achieved by applying the three distinct algorithms as discussed above.

- Step 1: A number of inputs are defined. Three inputs are used such as shape distance, colour distance and texture distance between query image and database images.
- Step 2: The membership functions for three types of input have been defined. There are three different types of fuzzy set that identified each input as low, medium and high.
- Step 3: Three types of output fuzzy sets have been declared such as high similar, medium similar and low similar.
- Step 4: A fuzzy rule can be defined as a conditional statement such as if then. Fuzzy rules applied using logical operator. The fuzzy rules are as written above.
- Step 5: To process the Mamdani fuzzy inference method, the crisp inputs are taken and fuzzified to determine the degree to which these inputs belong to each of the appropriate fuzzy set.
- Step 6: This set applies the AND fuzzy operator to get one number that represents the result of antecedent of rules. The output is a single truth value.
- Step 7: The process of unification of the output of all the rules that have been used until last step. The output of this step is one fuzzy set for each output variable. The process is called an aggregation.
- Step 8: Lastly the aggregate output fuzzy set is transformed to a single crisp number. This is carried by the process of defuzzification.

3.2.6. Results and evaluation of content-based image retrieval approach

3.2.6.1. Dataset. In order to assess the performance of the proposed approach, the same dataset that was used by previous researchers [32,34,36,37] 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 proposed approach thoroughly on different data sets so that the effectiveness and usefulness of the proposed approach can be demonstrated. The different categories of the images were labelled according to the type of images each data set contained.

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 proposed approach in different environments. Importantly, the goal was to investigate whether the performance of the proposed approach can be affected by the large number of images or search space. Our results show that the proposed

Fig. 8. Query image (at top) and results obtained.

Fig. 9. Query image (at top) and results obtained.

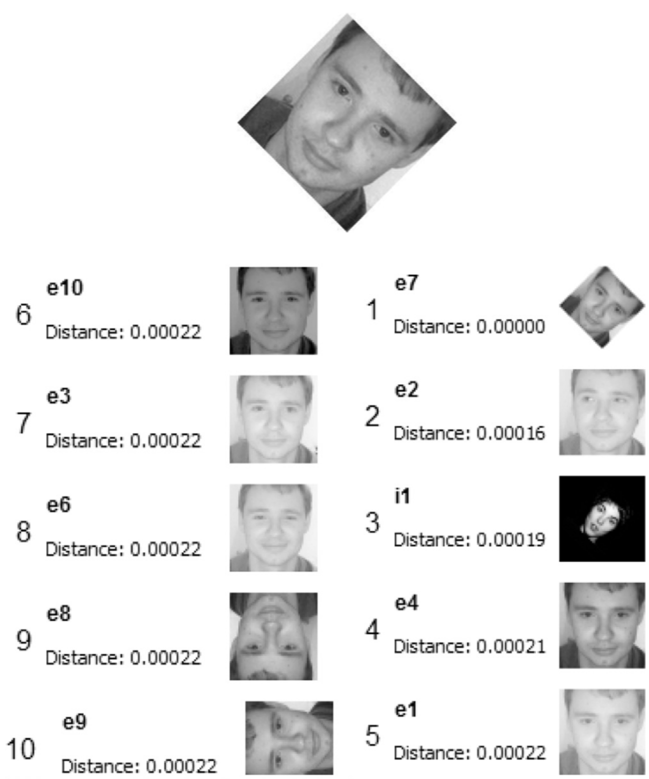

Fig. 10. Query image (at top) and results obtained.

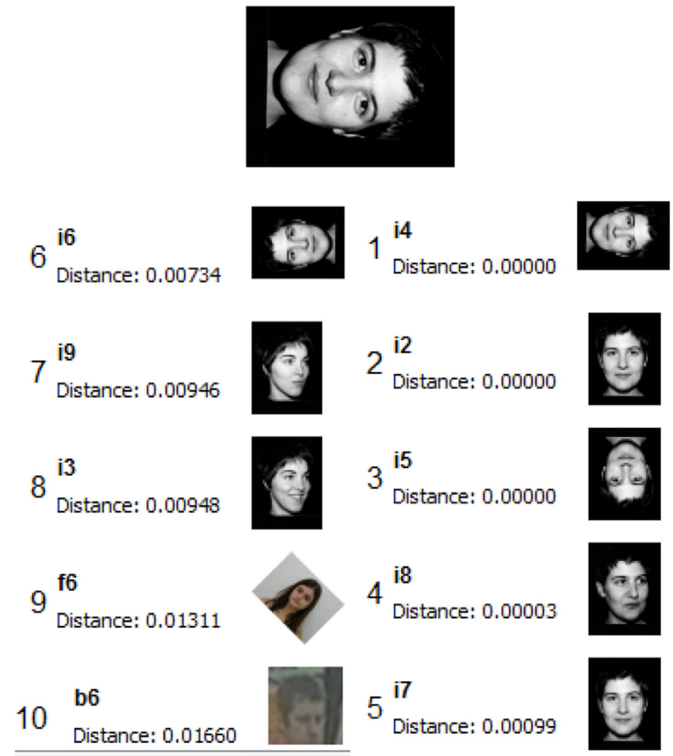

Fig. 11. Query image (at top) and results obtained.

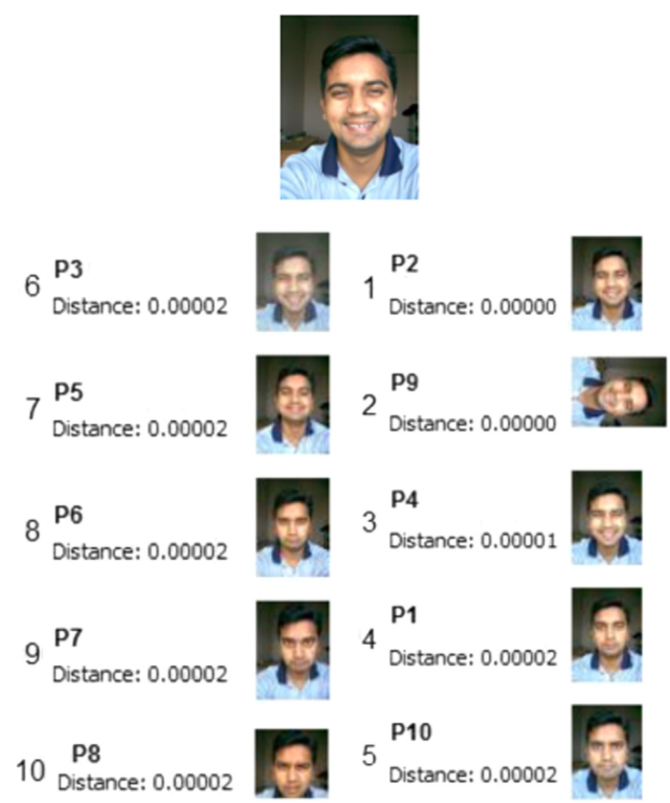

Fig. 12. Query image (at top) and results obtained.

approach is able to search for similar images and retrieve them effectively from a huge data-set of images (see Figs. 8–16).

3.2.6.2. Results and evaluation. In order to evaluate the effectiveness of the proposed approach, 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 [69–71,73]. The Precision and Recall are defined below:

$$\text{Precision} = I_N/R \tag{36}$$

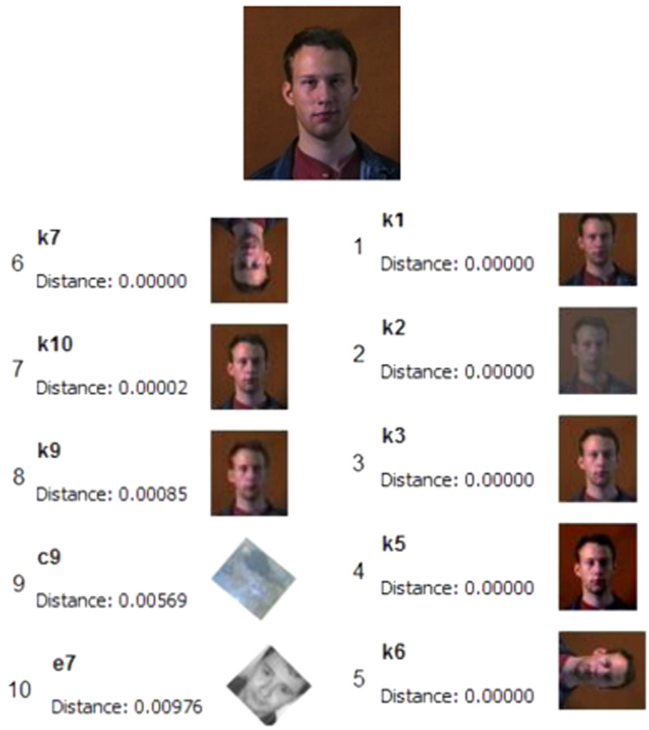

Fig. 13. Query image (at top) and results obtained.

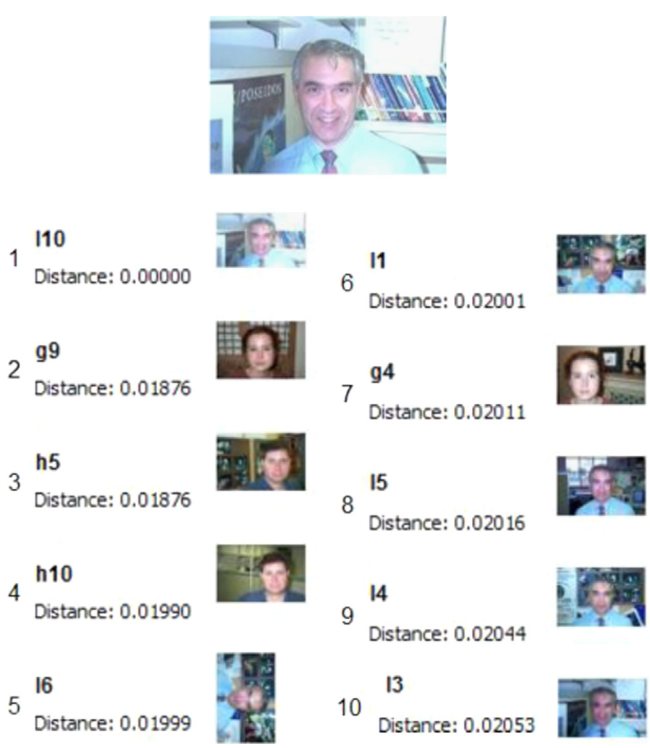

Fig. 14. Query image (at top) and results obtained.

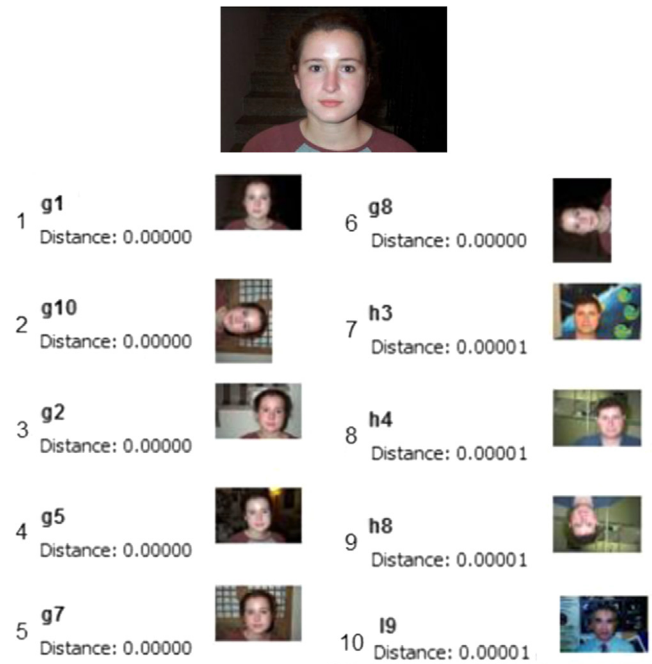

Fig. 15. Query image (at top) and results obtained.

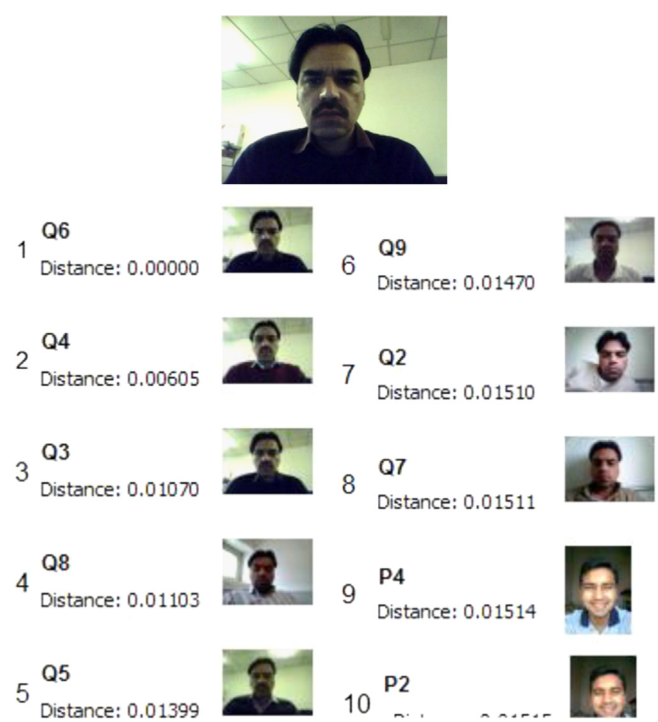

Fig. 16. Query image (at top) and results obtained.

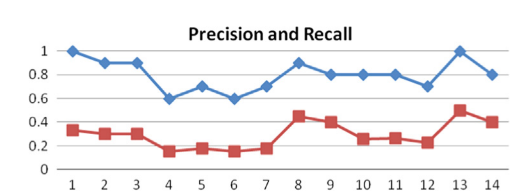

Fig. 17. Precision and Recall on the obtained results using proposed approach.

$$\text{Recall} = I_N/T \tag{37}$$

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 [74]. We used $R=10$ and $T=20$–40 to assess the performance of the proposed approach. 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.

The image showing a person on the elevator was used as an image query as shown in Fig. 8. Based on the given image query the most relevant images were retrieved, out of 1140 images in the database. All the retrieved images were of the same person. The proposed approach 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 Fig. 17. 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 proposed approach accurately retrieved the same person images from 30 similar images in the database based on image query.

Another category of images in which a person entered a shop was used as an image query. In this experiment only face of the person was used in the image query (see Fig. 9). Based on the image query, nine out of ten most relevant images were retrieved by the proposed approach. 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 proposed approach intelligently retrieved all those images regardless of their orientation and visibility. This is an important feature of the proposed approach. The proposed approach is able to search for relevant results without taking into account visibility and orientation of the image. The Precision and the Recall of the retrieved images is also shown in Fig. 17. The Precision value was 0.9 which shows that 90% accuracy was achieved. The Recall values show that the most accurate images were retrieved out of 30 similar images by searching 1140 images in the database.

The performance of the proposed content based image retrieval approach 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 Fig. 10). 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 proposed approach accurately retrieved the images that belong to the same person. One irrelevant image was also retrieved along with the nine relevant images. The irrelevant image had the same 45° orientation to the image query. The Precision and Recall of these results are shown in Fig. 17, 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.

In another query, an image of an Iranian girl was used as an image query as shown in Fig. 11. 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 displays the top 10 most relevant images from the database. As can be seen in Fig. 11, 8 images were of the same person but the last two retrieved images did not belong to the same person. The Precision and the Recall rate of achieved results are displayed in Fig. 17. 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.

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 proposed approach 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 proposed approach was able to retrieve all the images of the same person accurately. The results are shown in Fig. 12. The Precision and the Recall are shown in Fig. 17. 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.

In order to evaluate the proposed approach thoroughly different light condition images were also used as shown in Fig. 13. 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 proposed approach 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 Fig. 17. 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.

Another category of images which were affected by colour cast were also used to test the performance of the proposed approach. An image having blue colour cast and background objects was used as an image query as shown in Fig. 14. As can be seen in Fig. 14 the proposed content based image retrieval approach 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 similar to the image query. The Precision and Recall are shown in Fig. 17. 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.

An image in black background with stair objects is used as an image query (Fig. 15). 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. The Precision and Recall are shown in Fig. 17. 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.

Another image query was used to evaluate the performance of the proposed content based image retrieval approach as shown in Fig. 16. 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 Fig. 17. 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.

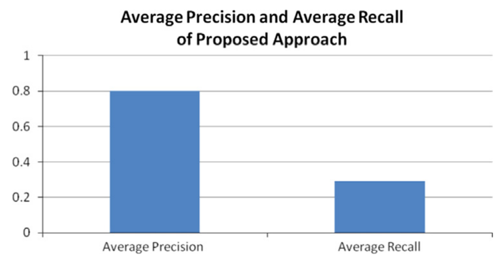

Fig. 18. Average Precision and average Recall of proposed approach.

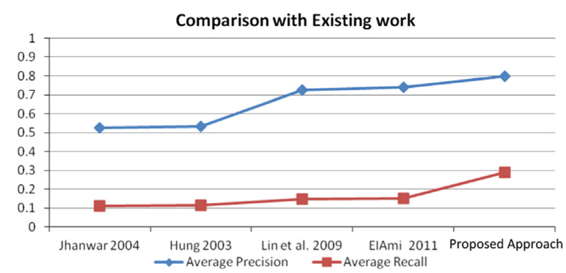

Fig. 19. Results comparison using existing methods and proposed approach.

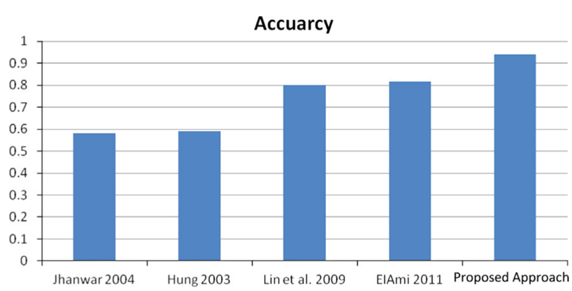

Fig. 20. Accuracy comparison using existing methods and proposed approach.

Precision and Recall values are calculated based on 14 different types of queries as shown in Fig. 17 and some of these are discussed above in brief. 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 show the number of queries which are used in the experiment for evaluation purpose. Average Precision and Recall values are also calculated and shown in Fig. 18. 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.

3.2.6.3. Comparative Evaluation. In the previous section we discussed the evaluation results using standard metrics such as Precision and Recall. In this section we compare the results with four well-known approaches in order to demonstrate the effectiveness of the new content-based image retrieval system.

Compared to the well-known approaches [32,34,36,37] based on the average Precision and average Recall, the proposed approach achieved the best results as can be seen in Fig. 19. The accuracy of the proposed approach was calculated based on the following equation [75].

$$Accuracy = (Precision + Recall)/2 \quad (38)$$

In order to calculate the accuracy, we firstly calculated the average Precision value based on all image queries results as shown in Fig. 18. Similarly, the average Recall value was calculated based on the achieved results. Following that, a sum of Precision value and Recall value was divided by 2 in order to get accuracy. The accuracy of the proposed approach was compared with that of the four well-known approaches as shown in Fig. 20.

4.Conclusion

This paper proposed an efficient scheme image quality enhancement for video surveillance applications. More precisely, face detection has been improved by enhancing the quality of images, and a content-based image retrieval approach is capable of retrieving images based on colour feature, texture, and shape features. An integrated approach is proposed for image enhancement. The integrated approach addresses the problem related to the quality of surveillance images. 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 integrated image enhancement approach, two methods are integrated namely the contrast enhancement method and the colour balancing method. Importantly, in the colour balancing method, a new process for colour cast adjustment is introduced which relies on statistical calculation. In order to evaluate the performance of the 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 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 second proposed approach is content-based image retrieval. A content-based image retrieval approach 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. An approach is based on three well-known algorithms: colour, texture and shape. 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 an image and using a similarity metrics based on the Euclidean measure. The evaluation of a content based image retrieval approach is carried out using the standard Precision and Recall measures, and the results are compared with well-known methods. The presented results show that the proposed approach produces better results as compared to the existing methods. Further work will be applying the proposed approach to the real world surveillance data by considering the processing speed that may be an issue when dealing with real world data.

References

[1] B. Ahrens, Genetic algorithm optimization of superresolution parameters. GECCO '05 Genetic and Evolutionary Computation Conference. held 25 – 29 June, 2005 at Washington, DC, USA, 2005.

[2] G. An, J. Wu, Q. Ruan, An illumination normalization model for face recognition under varied lighting conditions, Pattern Recognit. Lett. 31 (2010) 1056–1067.

[3] Y. Hatakeyama, K. Kawamoto, H. Nobuhara, S.I. Yoshida, K. Hirota, Color restoration algorithm for dynamic images under multiple luminance conditions using correction vector, Pattern Recognit. Lett. 26 (9) (2005) 1304–1315.
[4] A.K. Jain, A. Ross, S. Prabhakar, An introduction to biometric recognition, IEEE Trans. Circuits Syst. Video Technol. 14 (1) (2004) 420.
[5] Y. Kim, A.B.J. Teoh, K.A. Toh, A performance driven methodology for cancelable face templates generatio, Pattern Recognit. 43 (2010) 2544–2559.
[6] R. Mudigoudar, S. Bagal, Z. Yue, P. Lakshmi, P. Topiwala, Video super-resolution: from QVGA to HD in real-time Applications of Digital Image Processing XXXII, Proc. SPIE 7443 (2015) 74430W-74430W-12.
[7] J. Wang, C. Zhang, H.Y. Shum, Face image resolution versus face recognition performance based on two global methods, In: Proceeding of Asian Conference on Computer Vision, Jeju Island, Korea, 2004.
[8] C. Kim and N.E. O'Connor, Using the discrete hadamard transform to detect moving objects in surveillance video, In: Proceedings of the International Conference on Computer Vision Theory and Applications. held 5–8 February 2009 at Porto, Portugal, 2009.
[9] L. Zhang, H. Shen, P. Li, 'A super-resolution reconstruction algorithm for surveillance images', Signal Process. 90 (3) (2010) 848–859.
[10] T. Becsi, T. Peter, A Mixture of distributions background model for traffic video surveillance, Period. Polytech. Ser. Transp. Eng. 34 (1–2) (2006) 109–117.
[11] V. Santhaseelan V.K. Asari, Phase congruency based technique for the removal of rain from video. image analysis and recognition, Lecture Notes in Computer Science, vol. 6753, pp. 30–39, 2011.
[12] B.S. Chauhan, E. David, P.K. Datta, Sensors for desert surveillance, Def. Sci. J. 55 (4) (2005) 493–503.
[13] M. Smids, Background Subtraction for Urban Traffic Monitoring Using Webcams , 1 (2) (2015).
[14] A. Çavuşoğlu, S. Görgünoğlu, A fast fingerprint image enhancement algorithm using a parabolic mask, Comput. Electr. Eng. 34 (3) (2008) 250–256.
[15] S. Chen, E. Berglund, A. Bigdeli, C. Sanderson and B. C. Lovell 'Experimental analysis of face recognition on still and cctv images. In: Proceedings of the IEEE International Conference on Advanced Video and Signal Based Surveillance, 2008, pp. 317–324.
[16] W.I. Grosky, Image Retrieval-Existing Techniques, Content-Based (CBIR) Systems', . Department of Computer and Information Science, University of Michigan-Dearborn, Dearborn, MI, USA, 2011.
[17] W.C. Kao, M.C. Hsu, Y.Y. Yang, Local contrast enhancement and adaptive feature extraction for illumination-invariant face recognition, Pattern Recognit. Lett. 43 (5) (2010) 1736–1747.
[18] M.P. Tehrani, A. Ishikawa, S. Sakazawa, A. Koikea, Iterative colour correction of multicamera system using corresponding feature points', J. Vis. Commun. Image Represent., 21 (5-6) (2010) 377–391.
[19] S.F. Hasan, J. Stauder, A. Trémeau, Robust color correction for stereo, In: Proceedings of the 8th European Conference On Visual Media Production, held 16–17 November 2011 at London, UK, 2011.
[20] S. Bianco, G. Ciocca, C. Cusano, R. Schettini, Automatic color constancy algorithm selection and combination,, Pattern Recognit. 43 (2010) 695–705.
[21] M. Royal, R. Chang and X. Qi, Learning from Relevance Feedback Sessions Using a K-nearest-neighbor-based semantic repository, In: Proceedings of the IEEE International Conference on Multimedia and Expo (ICME'07), held 2007 at Beijing, China, 2007, pp. 1994–1997.
[22] K. Shkurko, X. Qi, A radial basis function and semantic learning space based composite learning approach to image retrieval, In: Proceedings of IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP'07), Honolulu, Hawaii, vol. 1, 2007, pp. 945–948.
[23] M. Wacht, J. Shan and X. Qi, A short-term and long-term learning approach for content-based image retrieval, In: Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP'06), Toulouse, France, 2006, pp. 389-392.
[24] A.M. González-Quevedo, E.G., Reyes, Content Based Image Retrieval Using Topological Descriptor. RNPS no. 2142, ISSN 2072-6287, 2011.
[25] J. Wang, J. Li, G. Wiederhold, SIMPLIcity: semantics-sensitive integrated matching for picture libraries, IEEE Trans. Pattern Anal. Mach. Intell. 23 (9) (2001) 947–963.
[26] A.S. Sahoolizadehi, Semantic Image Retrieval Using Relevance Feedback and Transaction Logs, Louisiana State University, 2007, Phd thesis.
[27] C. Carson, M. Thomas, S. Belongie, J. Hellerstein, J. Malik, Blobworld: a system for region-based image indexing retrieval, In: 3rd International Conference on Visual Information Systems, Springer. 1999, pp.509–516.
[28] R. Datta, D. Joshi, J. Li, J.Z. Wang, Image retrieval: ideas, influences, and trends of the new age, ACM Transactions on Computing Surveys 40 (2) (2008) 1–60.
[29] J. Li, J.Z. Wang, Real-time computerized annotation of pictures, IEEE Trans. Pattern Anal. Mach. Intell. 30 (6) (2008) 985–1002.
[30] M. Rizon, et al., Object detection using geometric invariant moment, Am. J. Appl. Sci. 2 (6) (2006) 1876–1878.
[31] Y. Zhu, L.C.D. Silva, C.C. Ko, Using moment invariant and hmm in facial expression recognition, Pattern Recognit. Lett. 23 (2002) 83–91.
[32] P.W. Huang, S.K. Dai, Image retrieval by texture similarity, Pattern Recognit. 36 (3) (2003) 665–679.
[33] K.A. Wang, H.H. Lin, P.C. Chan, C.H. Lin, S.H. Chang, Y.F. Chen, An Image retrieval system based on wavelet decomposition and gradient variation, WSEAS Trans. Comput.. 7 (6) (2008) 724–734.
[34] N. Jhanwar, S. Chaudhurib, G. Seetharamanc, B. Zavidovique, Content Based Image Retrieval Using Motif Co-Occurrence Matrix, Image and Vision Computing 22 (14) (2004) 1211–1220.
[35] A. Spink, R. Losee, Feedback in information retrieval, Annu. Rev. Inf. Sci. Technol. 31 (1996) 33–78.
[36] C.H. Lin, R.T. Chen, Y.K. Chan, Image Vis. Comput. 27 (2009) 658–665.
[37] M.E. ElAlami, A novel image retrieval model base on the most relevant features, Knowl. Based Syst. 24 (1) (2011) 23–32.
[38] R. Fisher, S. Perkins, A. Walker, E. Wolfart, Contrast Stretching, available from ⟨http://homepages.inf.ed.ac.uk/rbf/HIPR2/stretch.htm⟩, 2003 (25 september 2010).
[39] Schweng, Detlef (2006) Hexagonal Color Pixel Structure with White Pixels. United States Patent 20060146064.
[40] C.C. Weng, H. Chen, C.H. Fuh, A novel automatic white balance method for digital still cameras, ISCAS 2005, In: Proceedings of the IEEE International Symposium on Circuits and Systems, International Conference Center Kobe in Japan, Vol. 4, 2005, pp. 3801–3804.
[41] V. Chikane, C.S. Fuh, Automatic white balance for digital still camera, J. Inf. Sci. Eng. 22 (2006) 497–509.
[42] V. Chikane, C.S. Fuh, White balance method. United States Patent 20060164521, 27, 2006.
[43] M. H. Yap, H. Ugail, R. Zwiggelaar, B. Rajoub, V. Doherty, S. Appleyard, G. Hurdy, A Short Review of Methods for Face Detection and Multifractal Analysis, In: Proceedings of the International Conference on CyberWorlds, held 07–11 September 2009 at Bradford, West Yorkshire, UK.
[44] H. Sahoolizadeh, D. Sarikhanimoghadam, H. Dehghani, Face detection using Gabor wavelets and neural networks, World Academy of Science, Engineering and Technology 2 (2008) 9–20.
[45] K. Ericsson, A. Lehmann, 'Expert and exceptional performance: evidence of maximal adaptation to task constraint, Annu. Rev. Psychol. 47 (1) (1996) 273–305.
[46] Obada, A., Iqbal, R., Faiyaz, D., and Amin, S., Adaptive information retrieval system based on fuzzy profiling, In Proceeding s of the 2015 International conference on Fuzzy Systems (FUZZ-IEEE 2015), Istanbul, Turkey.
[47] S. Krug, Don't make me think! : a common sense approach to Web usability, Berkeley, California, USA: New Riders Publishing, 2006.
[48] I. Lopatovska, I. Arapakis, Theories, methods and current research on emotions in library and information science, information retrieval and human–computer interaction, Inf. Process. Manag. 47 (4) (2011) 575–592.
[49] A. Oulasvirta J. Hukkinen B. Schwartz When More Is Less The Paradox Of Choice In Search Engine Use, 2009, pp. 516–516.
[50] G. AlGarni, M. Hamiane, A novel technique for automatic shoeprint image retrieval, Forensic Sci. Int. 181 (2008) 10–14.
[51] L. Cinque, G. Ciocca, S. Levialdi, A. Pellicano, R. Schettini, Colour-based image retrieval using spatial-chromatic histogram, Image Vis. Comput. 19 (2001) 979–986.
[52] H.B. Kekre, S.D. Thepade, Color Traits Transfer to Grayscale Images, In: IEEE International Conference on Emerging Trends in Engineering and Technology, ICETET, 2008.
[53] R. Krishnamoorthi, S.S. devi, A multiresolution approach for rotation invariant texture image retrieval with orthogonal polynomials model, J. Vis. Commun. Image Represent. 23 (1) (2012) 18–30.
[54] C.M. Pun, C.F. Wong, Fast and robust color feature extraction for content-based image retrieva, Int. J. Adv. Comput. Technol. 3 (6) (2011) 75–83.
[55] P. Premaratne, Q. Nguyen, Consumer Electronics Control System Based on Hand Gesture Moment Invariants, IET Comput. Vis. 1 (2007) 35–41.
[56] P. Premaratne, F. Safaei, Ship Classification By Superstructure Moment Invariants, In: Proceedings of the ICIC'09 5th International Conference On Emerging Intelligent Computing Technology and Applications, Springer-Verlag, Berlin, Heidelberg, 2009.
[57] F. Zhang, S.Q. Liu, D.B. Wang, W. Guan, Aircraft recognition in infrared image using wavelet moment invariant, Image Vis. Comput., 27, (2009) 313–318.
[58] J. Wu, Z. Wei, Y. Chang, Color and texture feature for content based image retrieva, Int. J. Digit. Content Technol. Appl. 4 (3) (2010) 75–83.
[59] B.S. Manjunathi, W.Y. Ma, Texture features for browsing and retrieval of image data, IEEE Trans. Pattern Anal. Mach. Intell. 18 (8) (1996) 837–842.
[60] M.N. Do, M. Vetterli, Wavelet-Based texture retrieval using generalized guassian density and Kullback–Leibler distance, IEEE Trans. on Image Process. 11 (2) (2002) 146–158.
[61] J. Han, K.K. Ma, Rotation-invariant and scale-invariant Gabor features for texture image retrieva, Image Vis. Comput. 25 (2007) 1474–1481.
[62] M. Idrissa, M. Acheroy, Rotation-invariant and scale-invariant gabor features for texture image retrieva, Pattern Recognit. Lett., 23, (2002) 1095–1102.
[63] K. Choudhary, M. Pundlik, D. Choukse, An integrated approach for image retrieval based on content, Int. J. Comput. Sci. Issues 7 (3) (2010).
[64] W. Khan, S. Kumar, N. Gupta, N. Khan, A proposed method for image retrieval using histogram values and texture descriptor analysis, Int. J. Soft Comput. Eng. 1 (1) (2011) 33–36.
[65] T. Chaira, A.K. Ray, Fuzzy measures for color image retrieval, Fuzzy Set Syst. 150 (2005) 545–560.
[66] S. Jeong, C.S. Won, R.M. Gray, Image retrieval using color histograms generated by gauss mixture vector quantization, Comput. Vis. Image Underst., 94, (2004) 44–66.

[67] A.M.W. Smeulders, M. Worring, S. Santini, A. Gupta, R. Jain, Content-based image retrieval at the end of the early years, IEEE Trans. Pattern Anal. Mach. Intell. 22 (12) (2000) 1349–1380.
[68] F. Long, H. Zhang, D.D. Feng, Fundamentals of Content-based Image Retrieval'. Multimedia Information Retrieval And Management: Technological Fundamentals And Applications, Springer, 2003.
[69] John Y. Chianga, Shuenn-Ren Cheng, Multiple-instance content-based image retrieval employing isometric embedded similarity measure, Pattern Recognition, Elsevier. 42 (2009) 158–166.
[70] Ying-Ho Liu, Anthony J.T. Lee, Fu Chang, Object recognition using discriminative parts', Comput. Vis. Image Underst. 116 (2012) 854–867.
[71] N. Puviarasan, A.Vasanthi dr.R.Bhavani, Image retrieval using combination of texture and shape features, Int. J. Adv. Res. Comput. Commun. Eng. 3 (3) (2014).
[72] D.R. Keshwani, D.D. Jones, G.E. Meyer, R.M. Brand, Rule-based mamdani-type fuzzy modeling of skin permeability, Appl. Soft Comput. 8 (1) (2008) 285–294.
[73] V. Viitaniemi, J. Laaksonen, Evaluating the performance in automatic image annotation: example case by adaptive fusion of global image features, Signal Process.: Image Commun. 22 (6) (2007) 557–568.
[74] G.H. Liu, L. Zhang, Y.K. Hou, Z.Y. Li, J.Y. Yang, Image retrieval based on multi-texton histogram, Pattern Recognit. 43 (7) (2010) 2380–2389.
[75] N. Sharma, P. Rawat, J. Singh, Efficient CBIR using color histogram processing, Signal Image Process.: Int. J. 2 (1) (2011).
[76] A. Grzywaczewski, R. Iqbal, A. James, J. Halloran, An approach for capturing human information behaviour. In Emerging Pervasive and Ubiquitous Aspects of Information Systems: Cross-Disciplinary Advancements, IGI Global, (2011) 322-347. http://dx.doi.org/10.4018/978-1-60960-487-5.ch018.
[77] A. Grzywaczewski, R. Iqbal, Task-specific information retrieval systems for software engineers. Journal of Computer and System Sciences 78 (4) (2012) 1204–1218.

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