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Literature review of image compression effects on face recognition

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Abstract

In this research work, a literature review is conducted to assess the progress made in the field of image compression effects on the face recognition. The DCT algorithms are considered for the review and their application is limited only to JPEG compression. In this review, progress made in the DCT algorithms of a single image, and a series images from a video, namely 2D DCT and 3D DCT respectively, along with several other algorithms in the application of face recognition are discussed in detail.

Keywords: Face recognition, 2D DCT, 3D DCT, image compression and face recognition.

INTRODUCTION

Face recognition has been considered as an important subject of research work over the last fifteen years. This subject has gained as much importance as the areas of image analysis, pattern recognition and more precisely biometrics [1-4], because it has become one of the identification methods to be used in e-passports and identification of candidates appearing in various national and international academic examinations. The resolution or the size of the image plays an important role in the face recognition. Higher the resolution the better it is. However, the image compression effects on the face recognition system are not given as importance it deserves in the recent years.

Images are compressed for different reasons like storing the images in a small memory like mobile devices or low capacity devices, for transmitting the large data over network, or storing large number of images in databases for experimentation or research purpose. This is essential due to the reason that compressed images occupy less memory space or it can be transmitted faster due its small size. Due to this reason, the effects of image compression on face recognition started gaining importance and have become one of the important areas of research work in other biometric approaches as well like iris recognition and fingerprint recognition. Most recent contribution were made in iris recognition [5, 6] and fingerprint recognition [7,8]. In addition to paying importance to standard compression methods in recognition, researchers have focused in developing special purpose compression algorithms, e.g. a recent low bit-rate compression of face images [9].

One of the major drawbacks in the face recognition using compressed images is, the image has to in the decompressed mode. However, the task of decompressing a compressed image for the purpose of face recognition is computationally expensive and the face recognition systems would benefit if full decompression could somehow be eliminated. In other words, the face recognition is carried out while the images are in compressed mode and it would additionally increase computation speed and overall performance of a face recognition system.

The most popular compression techniques are JPEG [10,11] and their related transformations are Discrete Cosine Transform and Discrete Wavelet Transform. It is treated that common image compression standards such as JPEG and JPEG2000 have the highest number of applications for actual usage in real life, since the image will always have to decompressed and presented to a human at some point.

In this review, progress made in the DCT and other algorithms of a single image, and a series images from a video, namely 2D DCT and 3D DCT respectively, in the application of face recognition are discussed in detail.

2D DCT

The Two dimensional discrete cosine transform (2D DCT) has become one of the most popular transforms for many image compression applications due to its near optimal performances compared to the statistically optimal Karhunen-Loeve transform [12]. The 2D DCT is computationally intensive and as such there is a great demand for high speed, high throughput and short latency computing architectures. Due to the high computation requirements, the 2D DCT processor design has been concentrated on small nonoverlapping blocks (typical 8x8 or 16x16). Many 2D DCT algorithms have been proposed to achieve reduction of computational complexity and thus increase the operational speed and throughput.

The two-dimensional DCT can be treated as a composition of two 1D DCT along each dimension. The formal definition is

$$X(l, m) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} x(i, j).\, C_{li} C_{mj} \qquad (1)$$

Where $x(i, j)$ is a value of the image element or the pixel which is located at the coordinates i, j. X(l, m) is the 2D DCT coefficient at the position (l, m) and can be computed using the Eq. 1. Index take values l, m = 0,1,.....,N-1. The multiplication of 2D DCT base functions $C_{li}.\, C_{mj}$ can be defined as

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$$C_{li}C_{mj} = cos\left[\frac{\pi}{N}\left(i+\frac{1}{2}\right)l\right].cos\left[\frac{\pi}{N}\left(j+\frac{1}{2}\right)m\right] \quad (2)$$

Considering a block of 8x8 in the image and treating the top left corner as the location of (0,0), a square of frequency components is the product of the 2D DCT. It contains one DC coefficient X(0,0) at the zero coordinates. The most important elements of the signal are concerned near this DC coefficient.

One of the popular techniques in the face recognition is vector quantization algorithms. Several methods are proposed already to extract feature vector from the image. They are PCA [13], Wavelet analysis, LDA [14], EBGM [13] are some of the examples in this regard. Principle Component Analysis (PCA) technique reduces the dimension of data by one order by means of data compression basics and produces the most effective lower dimensional structure of facial patterns [15]. Due to reduction in dimension, it removes some information which is not useful and precisely decomposes the face structure into orthogonal components. These orthogonal components are known as eigen faces. Each face image after the application of PCA is represented as a feature vector which is stored in the form of a 1D array. The distance between the respective feature vectors of images is compared to find the match [16]. In LDA, samples of unknown classes are segregated based on training samples of known classes. While the linear characteristics of the faces are treated in LDA, the nonlinear characteristics of face are considered in EBGM. Two dimensional DCT [25] has been used as a feature extraction step in various studies on face recognition. Other popular transforms Walsh-Hadamard transform [27, 28, 29], Wavelet transform also have been proposed [17, 23, 24, 26, 27] in the past. As a different approach, for recognizing objects from large image databases, methods based on histograms were proposed in the recent years. Color histograms were launched initially by Swain and Ballard and developed by others[18,19,20,21,22].

3D DCT

3D DCT is generally used both for JPEG and MPEG in image and video compression methods. However, these methods are not lossless. With growing demand for higher compression ratio (CR) the quality of the output image or video sequence reduces as a result of removing redundant data. Both methods use Three-Dimensional Discrete Cosine Transform (3D DCT) to produce a kind of spatial frequency spectrum. The coefficients of the DCT matrix of low frequency components can be stored with lower accuracy accordingly to different sensitivity of human vision to color or brightness changes in large areas than to the high frequency brightness variations.

The MPEG video sequence can be treated as series of 2D images and all such images can be compressed using 3D DCT. Also, it is possible to compressed different images of same size using 3D DCT. This idea differs by using "video cube" which is a cube of N × N × N video elements.

The three-dimensional DCT can be treated as a composition of three 1D DCT along each dimension. The formal definition is

$$X(l, m, n)=\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\sum_{k=0}^{N-1} x(i,j,k).C_{li}.C_{mj}.C_{nk} \quad (3)$$

Where x(i, j, k) is a value of the video cube element or series of images. For example, 8 images can be considered if a block size of 8x8 is taken for transformation. In this configuration, k is the position of the image. For the pixel which is positioned at the coordinates (i, j, k), X(l, m, n) is a 3D DCT coefficient at the position l, m, n and index take values l, m, n = 0,1,…..,N-1.

The multiplication of the 3D DCT base function $C_{li}.C_{mj}.C_{nk}$ can be defined as

$$C_{li}C_{mj}C_{nk}= cos\left[\frac{\pi}{N}\left(i+\frac{1}{2}\right)l\right].cos\left[\frac{\pi}{N}\left(j+\frac{1}{2}\right)m\right].cos\left[\frac{\pi}{N}\left(k+\frac{1}{2}\right)n\right]$$

As a result, a cube of frequency components is produced. It contains one DC coefficient X(0,0,0) at the zero coordinates. The most important elements of the signal are concerned near this DC coefficient.

Quantization

The human eye allows removing a lot of redundant information in the zone of higher frequency coefficients. This can be achieved by dividing each frequency component by an appropriate constant and by rounding it to the nearest integer. As a consequence, many of the higher frequency coefficients become zero. The quantized can be computed with

$$X_4(l,m,n) = \frac{X(l,m,n)}{Q(l,m,n)} \quad (3)$$

Where *X(l,m,n)* are the frequency coefficients before quantizing $X_4(l,m,n)$ are the frequency coefficients after quantizing and *Q(l,m,n)* are the quantizing coefficients. This operation produces lossy information and as a result these components cannot be restored in the decompression process due to loss of information occurred when the coefficients are rounded. The advantage of carrying out such an operation is it results in lesser amount of data to store. It is necessary to decide which constant will be used for quantizing each frequency component therefore the quantization cube must be defined. Its segments determine the compression ratio and the quality of output video sequence.

Entropy Coding

Entropy coding is one of the popular methods of lossless data compression. One of the most common techniques in the entropy coding is the Huffman coding which is also used in JPEG and MPEG. Data is the quantized cube, in the case of a video or set of images, must be rearranged into a "zig-zag" order. If it is a single image, then it is known as a quantized block. The more zeros will be in the straight line the less data will be necessary to store. Consequently it also influences the final compression ratio.

A 3D face recognition method was proposed by some researchers in ref [30]. This method consists of 3 parts, namely, face feature detection, face alignment and face matching which in turn include surface matching, principal component analysis (PCA) [31] and linear discriminant analysis (LDA) [32]. In the recognition method detailed in [30], the initial step is to identify the face feature points. Such identified feature points are located automatically. These feature points are used in rotating and translation so that the unknown probe faces and those in the database are frontal facing. To match up the probe and database face more efficiently, they are aligned to a fixed position and a surface matching method is used. One of the important aspects in the face recognition is to identify the areas in the face which are less susceptible to facial expression. Usually, the area between forehead and nose are ideal for this purpose. To achieve this, the face row with the nose tip is identified and then the horizontal face slice is segmented out slice by slice between the nose row and 100-120 rows above it. The distance between images stored in the database, also known as database candidates candidates and unknown probe slice is calculated by the vertical distance. Since each contour slice does not have a line equation, a replacement is to connect each neighboring point with a straight line.

Therefore, the vertical distance line, created in the process explained above, will intersect with two lines from the database and the probe; and the distance between the two intersection points will be the distance required. As the faces of the database and the probe are not aligned using Iterative Closest Point (ICP) [33], using only the surface matching method will not result accurate face recognition. To achieve a good face recognition, Principal Component Analysis (PCA) [31] along with Linear Discriminant Analysis (LDA) [32] is performed in addition on the 20 closest matches from the surface matching result. For the PCA with LDA method, instead of using 2D gray images, the method proposed in [34] uses 3D range information instead to create the LDA eigen space. This 3D face recognition method is performed on both compressed and uncompressed 3D range images to determine how much degradation the recognition rate will have due to using compressed images.

CONCLUSIONS

In this review, the progress made in the area of face recognition using various compression algorithms especially 2D DCT and 3D DCT. While 2D DCT is limited to compression of only the images, the 3D DCT can be applied both to the compression of both videos and a set of images. Based on the study conducted, though there is great deal of progress made in the area of 2D DCT related face recognition in decompressed mode and compressed modes, it is not so in the case of 3D DCT related face recognition. 3D DCT can be used to compress multiple images depending upon the block size chosen, with higher compression ratios compared to the 2D DCT. Hence there is a great opportunity to deploy the 3D DCT in face recognition.

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