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Graph Structure and Correlation Coefficient for Face Detection

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Abstract

Human face detection has been the subject of extensive research for several decades. Face detection has become increasingly important with the advent of video surveillance, security access control, and content-based information retrieval applications. Due to the non-rigid nature of faces and their high degree of variability, face detection remains challenging. Many studies have examined various face detection methods under different conditions, including illumination, facial expressions, head rotations, occlusions, and ageing. A novel approach to face detection is described in this paper using Local Graph Structure and Correlation Coefficient (LGS-CC). Through LGS-CC, texture information is enhanced by considering both texture and local shape, rather than relying solely on grayscale information. The proposed method has been shown to achieve encouraging results in extensive experiments.

***Keywords**:* local graph structure, image processing, pattern recognition, local binary pattern, correlation coefficient.

1. Introduction

The application of face detection has expanded and gained more interest in recent years. Advances in technology and computers have led to face detection applications becoming faster and more efficient. Therefore, face detection is becoming an integral part of our life. Recently, body gestures or facial expressions have been tested and applied to human-computer interaction to replace conventional interfaces such as the keyboard and the mouse. Most of these applications require face detection as an initial step. The general idea of face detection is to detect and localize all the occurrences of an unknown number of faces in still grey images. The system of detection tries to capture the most discriminated features that differentiate between non-faces and faces objects. There are some factors that affect the performance of detection, such as variations of illumination and pose, which are the main challenges of face detection as it needs to account for all possible appearance variations, In addition to, additives, such as glasses, moustaches and beards. Regardless of all these difficulties, remarkable advancements have been made in the last decade and many systems have been discovered that stimulate real-time performance.

The current advances in these algorithms have also made considerable contributions in detecting other objects, such as cars and humans' movement. Knowing about the information impeded in the face is considered as face detection problem; there are different ways to exploit this information. It can be categorized into two main broad groups, the first is features-based and the second is view-based or image-based. Features-based which try to extract features of the image and match it against the information of the face features (Hasoon et al., 2011). View-based or image-based which works in a straight line with the image and the aim is to extract most important and condensed descriptions of faces while ignoring redundant data. Significant redundancies exist in natural images; therefore, statistical dependencies exist amongst pixel values in space and time. With the aim of utilizing the resources efficiently, the face detection system should reduce redundancy by removing statistical dependencies. As a rule, face

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detection attempts to classify the input image into two classes, a face or non-face class. This classification also applies for general object classification and detection as in Hjelmås, and Low (2001), another more specialized categorization of face detection methods could be found in Yang (2004). In general, the classification of single image detection methods falls into four categories.

1. Knowledge-based methods. Knowledge-based methods encode human awareness of what makes up a typical face. Usually, the Knowledge based consider the relationships between facial features. These methods are designed primarily for face localization as reported by Verma, et al. (2010).

2. Feature invariant approaches. These approaches intend to locate structural features of faces that exist even when the viewpoint, pose, or lighting conditions differ, and then utilize these to find faces. Feature invariant approaches are considered for face localization.

3. Template matching methods. Template matching is used in this method. Therefore, quite numbers of regular patterns of a face are stored to illustrate the face as a whole or the facial features separately. For matching the correlations between stored patterns and an input image and are computed for detection. These techniques have been used for both face detection and localization.

4. Appearance-based methods. The difference between Appearance-based and template matching method, Appearance-based methods are learned from training images which should capture the facial appearance by extracting representative variability of features. These learned representations are then used for detection. These methods are designed mainly for detection of face.

Tables 1 illustrate the methods and representative works for face detection in a single image within these four categories according to Yang, et al. (2002).

TABLE1: face detection approaches

Method	Approach
Knowledge-based method	Multiresolution rule-based method as Yang and Huang (1994).
Feature invariant approach	
-Facial Features	Grouping of edges according to Kirby and Sirovich (1990), Yow and Cipolla (1997).
-Texture	Space Gray-Level Dependence matrix(SGLD) of face pattern as in Dai and Nakano(1996).
-Skin Color	Mixture of Gaussian as reported by Yang and Waibel(1996) and McKenna, et al.(1998).
-Multiple Features	Integrated of skin color, size and shape as in Kjeldsen and Kender(1996).
Template matching approach	
-Predefined face templates	Shape template as in Craw, et al. (1992).
-Deformable Templates	Active Shape Model (ASM) Lanitis, et al. (1995).
Appearance-based method	
-Eigenface	Eigenvector decomposition and clustering as in Turk, M., & Pentland, A. (1991).
-Distribution-based	Gaussian distribution and multilayer perception in the study by Sung and Poggio, (1998).
-Neural Network	Ensemble of neural networks and arbitration schemes as in Rowley et al. (1998).
-Support Vector Machine (SVM)	SVM with polynomial kernel as reported by Osuna, et al. (1997).
-Naïve Bayes Classifier	Joint statistics of local appearance and position as in Schneiderman and Kanade (1998).
-Hidden Markov Model (HMM)	Higher order with HMM as in Rajagopalanet al. (1998).
-Information-Theoretical Approach	Kullback relative information as in Lew (1998) and Colmenarez and Huang(1997).

As has been mentioned in the previous section, the modelling of facial features for face detection has been troubled explicitly by the unpredictability of environmental conditions and face appearance such as pose, illumination, and etc.

There is still a need to handle the face detection problem in challenging situations such as detection of several faces with mess backgrounds. This problem has motivated a new research area in which face detection is treated as a pattern recognition problem. By formulating these requirements as one of learning to identify a face sample from examples, the specific application of face knowledge is avoided. This eradicates the possibility of modelling error due to partial or incorrect face knowledge. The fundamental approach in identifying face patterns is via a training process which classifies examples into face and non-face prototype classes. Comparison between these classes and a 2Dintensity array extracted from an input image allows the decision of face existence to be made.

One of the Appearance-based methods is image-based approaches, the simplest approach is relied on template matching as reported by Lowe, et al. (2000) and Sirovich and Kirby, M. (1987), but these methods do not perform well. Most of the image-based approaches apply a window scanning method for detecting faces. The intention of the window scanning algorithm is basically just an in-depth search for the input image to find any possible face location in the input image, but there are variations in the implementation of this algorithm for almost all the image-based systems. Typically, the size of the scanning window, the step size, the sub sampling rate, and the number of iterations differ depending on the method proposed and the need for a computationally efficient system. In the following sections the image-based approaches have been divided into three classes, linear subspace methods, neural networks, and statistical approaches. In each division a brief description is highlighted and followed by our proposed method.

1.1. Linear Subspace Methods

Human faces images lie in the subspace of the overall image space. To represent the subspace of images, several approaches can be used. Neural approaches such as artificial neural networks (ANN) and statistical analysis techniques which can be applied. statistical analysis techniques such as linear discriminant analysis (LDA), principal component analysis (PCA), and factor analysis (FA). In the late 1980s, Sirovich and Kirby (1987) developed a technique using PCA to competently represent human faces. In his approach by given a set of different face images, he tried to find the principal components of the distribution of faces, represented in terms of eigenvectors (covariance matrix of the distribution). Each face image in the face set can then be estimated by a linear combination of the largest eigenvectors, which commonly referred to as eigenfaces. Turk and Pentland (1991) later adopted this procedure for face recognition. Their technique founded on nature of the weights of eigenfaces exploits the distinct nature of the weights of eigenfaces in individual face representation. in view of the fact that the face rebuilding by its principal components is an estimate, a residual error is approximated in the algorithm as a preliminary measure of “faceness.” This residual error which they termed “distance-from-face-space” provides a high-quality clue of face existence through the observation of global minima in the distance map.

1.2. Statistical Approaches

Apart from neural networks and linear subspace methods, there are also a number of statistical techniques that are used for face detection. Such as face detection based on support vector machine, information theory, and Bayes’ decision rule. Based on an earlier work of maximum likelihood face detection as in Colmenarez and Huang (1997), Colmenarez and Huang (1997) proposed a new system based on Kullback relative information (Kullback divergence). Face images from the training data set of each class are analyzed as observations of a random process and are characterized by two probability functions. Two popular methods among these techniques are Local Binary Pattern (LBP), Gabor wavelets, Local Graph Structure as in Abusham (2021) and LPRR (2024).

In the next section, Local Binary Pattern (LBP) and our novel face detection method based on Local Graph Structure (LGS) and neural network are introduced. In Section 2, Local Graph Structure model based on neural network adopted in this paper is introduced. Finally, in Section 3, conclusions are drawn.

2. Local Graph Structure

2.1. Local Graph Structure

The idea of Local Graph Structure (LGS) comes from a dominating set for a graph G = (V, E) is a subset D of V such that every vertex not in is joined to at least one member of D by some edge. The domination number γ (G) is the number of vertices in a smallest dominating set for G.

LGS works with the six neighbors of a pixel, by choosing the target pixel C as a threshold, then we start by moving anti clockwise at the left region of the target pixel C, If a neighbor pixel has a higher gray value than the target pixel (or the same gray value) then assign a binary value equal to 1on the edge connecting the two vertices, else we assign a value equal to 0. After finish on the left region of graph we stop at the target pixel C and then we move in a horizontal way (clockwise) to the right region of the graph and we apply the same process till we get back to the target pixel C.

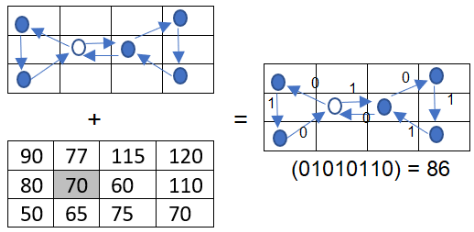

Figure 1: Local Graph Structure.

To produce the LGS for pixel (x_d, y_d) a binomial weight 2^p is assigned to each sign $s(g_d - g_n)$. These binomial weights are summed:

$$LGS(x_d, y_d) = \sum_{K=0}^{7} s(g_d - g_n)2^p \qquad (1)$$

$$s(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0 \end{cases}$$

where

Where $p = 7.$ $p = 7, 6, \ldots 0.$

Algorithm

1. *Start moving from the target pixel in anti clockwise direction to the first neighbor.*
2. *If the move from large vertex to small vertex we assign a value = 1 to that edge.*
   Else we assign a value to that edge.
3. *Loop until get back to the target pixel.*
4. *Then move to the right side of the graph and compare the target pixel with its neighbor in the right side.*
5. *Assign the target pixel to the next pixel on the right hand side of the target pixel.*
6. *Move a clock wise and apply the same as in step 2.*
7. *At the end, get back to the original target pixel which assigned 2 values.*
8. *End*

2.2. Correlation Coefficient

Correlation is used to computes the correlation coefficient of histogram between two images, to classify where the image is face or non-face based. For e.g. A and B are two different histograms of images, A and B are vectors of the same size. The correlation coefficient is computed as follows:

$$result = \frac{\sum_m \sum_n (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\left[\sum_m \sum_n (A_{mn} - A^2)\right]\left[\sum_m \sum_n (B_{mn} - \bar{B}^2)\right]} \qquad (2)$$

The proposed method Graph Structure and Correlation Coefficient (LGS-CC) has been proved to be efficient. The method works as follow; a decimal representation of the image is obtained by taking the binary sequence as a binary number between 0 and 255. To calculate decimal representation of pixels, Local Graph Structure is applied to all face and non-face to extract the histogram. LGS considers the relative relationship between the target pixel C and its neighbors, and also consider the relationship between the pixels that form the local graph of the target pixel C , while discarding the information of amplitude, and this makes the resulting LGS values very insensitive to illumination intensities. The 8-bit binary series with binomial weights consequently result in 256 different patterns in total for the pixel representation. A new generated image from original image Figure 3 using LGS from original image Figure 2, a histogram of the LGSs for original image is calculated. Histogram of the image representing the distribution of 256 patterns across face image see Fig3. The advantage of LGS; Firstly, it is a local measure, so LGS in a certain region will not be affected by the illumination conditions in other regions. Secondly it is a relative measure, and is invariant to any monotonic transformation such as shifting, scaling, or logarithm of the pixel-values. Therefore, it can be invariant to a certain range of illumination changes.

Figure 2. Original Image

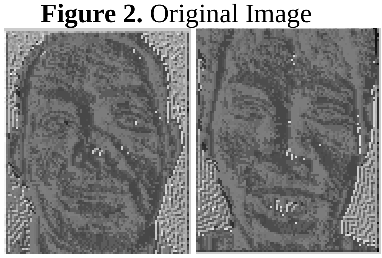

Figure 3. Generated Image

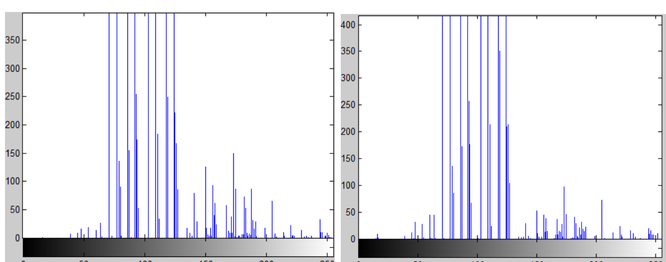

Figure 4. Histogram of the Image

To assess the performance of the proposed method on face detection CBCL Face Database (Zhu et al., 2024) was used. The dataset we used as training was 2479 images; the number faces is 2429 and non face 50 images divided into two sets, the index of non face from 1-50 and faces from 51- 2479 respectively. The number of testing image was 472 faces. LGS was applied to find the histograms for the entire training and testing set, the histograms of processed images were classified by ``the proposed method.

3. Experiments and Results

The proposed method Graph Structure and Correlation Coefficient (LGS-CC) has been proved to be efficient. The method works as follow; a decimal representation of the image is obtained by taking the binary sequence as a binary number between 0 and 255. To calculate decimal representation of pixels, Local Graph Structure is applied to all face and non face to extract the histogram. LGS consider the relative relationship between the target pixel C and its neighbours, and also consider the relationship between the pixels that form the local graph of the target pixel C , while discarding the information of amplitude, and this makes the resulting LGS values very insensitive to illumination intensities. The 8-bit binary series with binomial weights consequently result in 256 different patterns in total for the pixel representation. A new generated image from original image Fig.2 using LGS from original image Fig.1, a histogram of the LGSs for original image is calculated. Histogram of the image representing the distribution of 256 patterns across face image as shown in Figure 3. The advantage of LGS; Firstly, it is a local measure, so LGS in a certain region will not be affected by the illumination conditions in other regions. Secondly it is a relative measure, and is invariant to any monotonic transformation such as shifting, scaling, or logarithm of the pixel-values. Therefore, it can be invariant to a certain range of illumination changes.

TABLE 1: Detection Rate

Index	Detection Rate
680	0.979356040740267
318	0.973111027473330
1801	0.977286159734992
1616	0.972030482634402
203	0.960473523385280
805	0.978742545290955
397	0.972803764484088
1681	0.980225195934410
1808	0.977765528656564
460	0.961245438024570
460	0.967845764006899
1023	0.974600677727892
257	0.970533436221506
805	0.979965202581908
680	0.966965261951934
368	0.975350571141945
202	0.968711650131563
912	0.970808587496484
1616	0.971585825405432
598	0.983414360910564
1309	0.969709125785825

The detection rate results for the Local Graph Structure (LGS) and LGC-CC in overall are compared with Table 2 and Fig 5. In LGS. local relationships and connectivity disappear in a global snapshot This helps find local variations, or behaviors that would never register at the full-graph level since it will make them disappear (Abusham & Bashir, 2011; Abusham & Wong, 2009; Al-Shibli & Abusham, 2017).

In contrast, LGS-CC introduces the idea of correlation coefficients to the graph analysis. This method aims to find relationships that are statistically significant between the attributes of a set of nodes and their connections. This could improve detection of patterns that could be missed by just structural analysis, thus a better understanding could emerge from the data.

TABLE 2: Overall detection Rate

Method	LGS	LGS-CC
Detection Rate - Overall	93.75%	92.37%

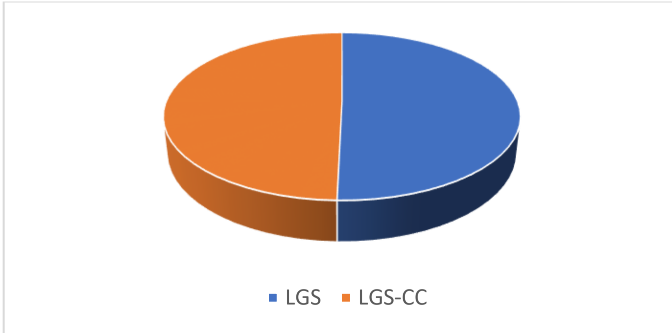

Figure 5. Detection Rate - Overall

We believe that the main explanation for the better performance of the proposed method over other techniques, it takes in consideration the relationship between the pixels that form the local graph of the target pixel C and consideration tolerance to monotonic gray-scale changes in the images. An additional advantage of the proposed method is the computational efficiency, beside simplicity the method is quite fast so that it can be easily applied in many fields, such as image processing, pattern recognition, medical image as pre-processing step.

4. Conclusion

This paper presents a novel and efficient algorithm for face detection based on local graph structure (LGS) and Correlation Coefficient. The features of local graph structure are derived from a general definition of texture in a local graph neighborhood. The advantages of our method over other methods are invariant to illumination changes, computational efficiency, and fast so that it can be easily applied in real-time system. The method assigns weight for target pixels by considering not only the relationship of one pixel to its neighbors but also the relationship between the pixels that form the local graph of the target pixel; this feature is unique to the proposed method and leads to improve the image appearance and subsequently the recognition performance.

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