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INVESTIGATING NEW ASPECTS FOR FACE RECOGNITION

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ABSTRACT

In recent decades, research in Face Recognition (FR) has grown very rapidly due to the broad demand on face recognition systems. Researchers in this area attempt to tackle the difficulties that can affect the accuracy of FR. Extracting relevant information from face images was the first research topic in this area; many approaches have been proposed for this purpose such as Principle Component Analysis (PCA), Linear Discriminant Analysis (LDA), Discrete Cosine Transform (DCT), and Sparse Representation Coding (SRC). In addition to that, researchers attempt to deal with some other factors that can negatively affect the recognition accuracy including: facial expressions, illumination (lighting conditions), pose variations, occlusion and distance. Too many research papers have been introduced to solve these problems resulting in very high recognition rate. However, each single research focuses only on one factor discarding other factors. Unfortunately, face recognition systems don’t have the ability of recognising most of the above factors, especially, illumination.

In this paper: First , we will show the shortcomings of the current research in dealing with the above mentioned factors. Secondly, we will clearly define different information that can be obtained from face images, namely discriminate information and similarity/shared information. Then, we will illustrate how this information can be used effectively to increase Face Recognition rate. Thirdly, based on the previous work on face recognition research, we will show that the embedded information such as Local Binary Pattern (LBP) can be improved efficiently for FR. Such improvement can be achieved by effective extraction of embedded information and good estimation of the value of features obtained from this information. Finally, we propose adding a new distinct component to the structure of current face recognition systems, i.e. Facial State Recognition (FSR), including pose, illumination, occlusion, and distance, therefore, convenient FR method can be used based on FSR.

Keywords: Face Recognition, Features extraction, Pattern Recognition, Facial State Recognition.

الملخص

في العقود الأخيرة تنامى البحث في مجال التعرف على الوجه بسرعة كبيرة نظرا للطلب الشديد على نظم التعرف على الوجه. وقد حاولت الأبحاث في هذا المجال أن تتناول الصعوبات التي يمكن أن تؤثر على دقة التعرف على الوجوه، وقد كان أول موضوع يبحث في هذا المجال هو استخلاص المعلومات ذات العلاقة من صور الوجه، وتم اقتراح العديد من الطرق لهذا الغرض مثل تحليل المركب الأساسي **PCA**، تحليل المميز الخطي **LDA**، تحوير جيب التمام المنفصل **DCT**، و التمثيل المتباعد **SRC**. إضافة إلى ذلك فقد حاول الباحثين التعامل مع بعض العوامل التي بمكن أن تؤثر سلباً على دقة التعرف، بما في ذلك تعابير الوجه، الإضاءة، التغير في الوضع، حجب جزء من الوجه، والمسافة. وقد قدمت العديد من ورقات البحث لحل هذه المشاكل،

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نتج عنها دقة تمييز عالية جداً. الا أن كل بحث تركز على عامل واحد فقط متجاهلا العوامل الأخرى. كذلك فإن نظم التعرف على الوجه لاتملك القدرة على تمييز أغلب العوامل المذكورة أعلاه، خصوصاً الإضاءة.

في هذه الورقة فإننا أولاً سنعرف بوضوح المعلومات المختلفة التي يمكن الحصول عليها من صورة الوجه، وتحديد المعلومات المميزة ومعلومات التشابه، والتشويش. ثم سنوضح كيف يمكن استخدام هذه المعلومات بفاعلية لزيادة كفاءة تمييز الوجه. ثالثاً: سنبين أوجه القصور في البحث المعاصر في التعامل مع العوامل المذكورة أعلاه. رابعاً: سنقترح إضافة عنصر جديد إلى بنية نظم التعرف على الوجه الحالية، وهو تمييز الحالة **FSR**، بما في ذلك الوضع، والإضاءة، والإخفاء، والمسافة. و أخيرا وبناءً على البحوث السابقة حول تمييز الوجه، سنبين أن استخلاص المعلومات الدفينة من صور الوجه يمكن أن تطور نسبة التعرف بشكل مؤثر.

الكلمات المفتاحية : التعرف على الوجه، استخلاص السمات، التعرف على حالة الوجه، التعرف على الأنماط.

1. INTRODUCTION

The demand on Face Recognition applications attracts researchers in the area of pattern recognition (Jain and Li 2011). A large number of research papers have been introduced to improve the accuracy, efficiency, and reliability of FR systems. FR is the most challenging field in the area of pattern recognition due to the fact that all human faces are similar; they all have the same organs located in the same locations. Moreover, there are some other factors that can negatively affect the accuracy of FR such as lighting conditions, occlusions, pose variations, facial expressions, and distance. Due to the above mentioned factors, the research in FR follows different directions in order to tackle different FR challenges.

The first direction is extracting discriminant features. The Principle Component Analysis PCA (Turk and Pentland 1991), (Kshirsagar, Baviskar et al.) is considered as the base of most of this research direction. It employs Eigen values and Eigen vectors to extract discriminant face features. These features are then used to recognise input face images by matching them with features of other known face images (reference). Other examples of dimensionality reduction are; Linear Discriminant Analysis (LDA) (Belhumeur, Hespanha et al. 1996), Discrete Cosine Transform (DCT) (Er, Chen et al. 2005), Fast Fourier Transform (FFT) (Spies and Ricketts 2000), Walsh Hadamard Transform (WHT) (Hassan, Osman et al. 2007) and Discrete Wavelet Transform (DWT) (Kakarwal and Deshmukh 2010). Some approaches merge feature extraction and image matching in one phase. A clear example of these approaches is Sparse Representation Coding (SRC) (Wright, Yang et al. 2008). Some of the above mentioned methods can only be used with clear images such as PCA and LDA while other methods like DCT, DWT and FFT are effective with noisy images.

The second direction of FR research focuses on the problem of lighting conditions (illumination). In real applications, images are usually affected by environmental lighting conditions caused by darkness, reflection, and shadow. These conditions can change the texture of input face image, resulting in very low FR accuracy (Braje, Kersten et al. 1998), (Zou, Kittler et al. 2007). To solve this problem, a large number of papers have been introduced. Some researches in this direction propose removing the illumination to restore the normal image (Zou, Kittler et al. 2007), (Chen, Er et al. 2006) , while others propose new image representations that can minimise illumination and maximise image texture then use this representation for FR. A clear example of this approach is Local Binary Pattern (LBP) (Vishwakarma, Pandey et al. 2007), (Sharif, Ali et al. 2015), (Podilchuk and Zhang 1996). Other image representations like (Alrjebi, Liu et al. 2018), (Zhang, Fang et al. 2009), are also used to enhance FR with illuminations, resulting in high recognition accuracy.

Occlusion is the third research direction in the field of Face Recognitions. Occlusion happens when part of the input face image disappears by accessories or any other objects. Sunglasses, scarfs, and masks are some examples of face occlusion. Occluded face images contains less information than unoccluded images.

So, occlusion can result in low FR accuracy (Azeem, Sharif et al. 2014). Mainly, two approaches are used to solve this problem. First approach attempts to detect and remove the occlusion before recognizing the face image (Min, Hadid et al. 2014), whereas the second approach utilizes a specific image representation that can reduce the effect of occlusion without removing it (Alrjebi, Pathirage et al. 2017).

The fourth direction in FR is facial expressions. A face image can be regular (with no expressions), smiley, angry, sad, surprised or laughing. These expressions – especially extreme expressions- change the face texture and dimensions resulting in low recognition accuracy in FR systems (Naoko, Mitsuo et al. 1992). Selecting an appropriate image representation can reduce the effect of facial expressions (Alrjebi, Liu et al. 2015), (Pathirage, Li et al. 2015). Moreover, normalizing the input image to recover the regular image is also used in many researches (Alrjebi, Liu et al. 2015). In this case, the input image is firstly normalized to a regular image, then, the regular image is recognized by appropriate FR method (Chen, Er et al. 2006).

The fifth FR research direction is pose variations, which is considered as one of the most challenging problems in FR (Azeem, Sharif et al. 2014). Reference face images are usually frontal; however, the input face images can have any pose variations. Based on pose angle, part of the face disappears, and as a result, part of the discriminant information is missed. These variations can therefore negatively affect FR accuracy (Zhang and Gao 2009). Researchers attempt to solve this problem by one of two main approaches: First approach requires reference images with different pose angles, then, appropriate FR methods can be used to recognize the input face image (Ding and Tao 2016). Unfortunately, this approach is impractical due to the difficulty of having reference images with wide range of pose angles. The other approach is based on correcting the input image into frontal image, either after estimating pose angle, or without pose estimation as in (Kan, Shan et al. 2014). After correcting the face image into frontal pose, the corrected face image is recognised by an appropriate FR method.

Distance is the sixth FR direction. In this literature, Distance refers to the distance between the capturing camera and the captured face image. Increasing the distance between the camera and the captured face image leads to decreasing its size. Research in FR shows that, the best accuracy is achieved with image size of 32×32 to 120×120 (Jain and Li 2011). Therefore, smaller image sizes lead to a decrease in FR accuracy. Unfortunately, resizing images mathematically doesn't have any effect on FR accuracy, because it doesn't add any information to the image. Many researches have been introduced to tackle this problem, including (Liu, Shum et al. 2007), (Xu, Liu et al. 2013), (Xu, Liu et al. 2012). This direction of FR is known as face hallucination i.e. enlarging distant of a small face image and enriching it with valuable discriminant information.

The common factor between all research directions in FR is that most of them suppose that the problem is known then propose a solution. This solution is proposed only for one problem (i.e facial expressions). In real applications, the images are usually captured in uncontrolled environment, where the conditions of lighting, occlusion and facial expressions are unpredictable and can vary from one image to another. In addition, embedded information is still underutilized as we will clarify hereafter in this paper.

The rest of this paper is organised as follows: The next section, attempts to summarise the drawbacks of current research in FR. Section 3 will show the importance of effective extraction/use of embedded information and how it can support (without conflict) different FR research methods. While section 4, will show the importance of selecting the appropriate method for FR based on the image state, then it will propose adding a new component to FR called Face State Recognition (FSR) and show the importance of this step in any FR system. Finally, we conclude the paper with recommendations for future work.

2. DRAWBACKS OF CURRENTRESEARCH.

As mentioned above, the current research in FR focuses only on one direction, neglecting the interconnection between different directions. This means, if the research attempts to solve one FR problem it doesn't take into account its efficiency against other FR problems. Even worse, researchers also neglect Face State Recognition (FSR), which is an important process for selecting the proper FR method, as we will illustrate later in this paper. Moreover, in the current research, there is no clear definition of different types of information in any given face image. This type of definition is necessary to extract the discriminant information for FR. Finally, there is no enough interest in embedded information – which is the information that can be extracted by different image representations-. We believe that the effective use of such information can improve the efficiency and reliability of FR systems.

3. THE ROLE OF EMBEDDED INFORMATION IN FACE RECOGNITION.

In this paper the term embedded information will be used to refer to the information obtained after converting an image to another representation, or transforming it using a mathematical transform. In other words, embedded information is the information that cannot be extracted from the image itself, but from other representations/transformations of the image. Embedded information have been used in FR in order to improve the quality of discriminant information, showing powerful performance as compared with original RGB and grey scale representations. Some examples are Discrete Wavelet Transform (DWT) (Murugan, Arumugam et al. 2010, Wang, Jiang et al. 2010), Discrete Cosine Transform (DCT) (Podilchuk and Zhang 1996) (Sharif, Ali et al. 2015), Local binary pattern (LBP)(Ahonen, Hadid et al. 2004) and Multi Scale Logarithm Difference Edge maps MSLDE (Lai, Dai et al. 2015).Researches also attempt to improve the quality of embedded information by combining more than one image representation for better results, and the results were promising. Examples for that are MCF (Li, An et al. 2011), 2DMCF (Alrjebi, Liu et al. 2015), LBP with DCT (Haritha, Srinivasa Rao et al. 2012). Based on these researches, we discovered that embedded information can be improved and utilized in a much better way. We will outline hereafter some suggestions to improve the quality of embedded information for face recognition:

3.1 Removing shared information.

Based on the fact that all human faces are similar, there is shared information contained in all face images. This shared information can effectively degrade the FR rate. Therefore, researchers should attempt to remove/ minimize the shared information among all face images , or redundant data, before establishing any FR process.

Operations research methods can be employed for this purpose by maximizing discriminant information and minimizing shared information. Moreover, feature extraction methods such as PCA (Turk and Pentland 1991) and LDA (Belhumeur, Hespanha et al. 1996) can be used first for dimensionality reduction, then low dimension feature victors can be utilized to remove shared information. It is clear that information in any face image can be described by discriminant and shared information as follows:

$$Image\ Info = Discriminant\ Info + Shared\ Info \qquad (1).$$

Therefore:

$$Discriminant\ Info = Image\ Info - Shared\ Info \qquad (2)$$

Where $info \neq row\ data.$

So, simple (direct) subtraction cannot be applied in Eq2.

3.2 Removing redundant data.

In the literature of Face Recognition, it is known that redundant data cane negatively affect FR accuracy. Therefore, redundant data should be removed before starting FR. Researches in the field of FR didn't pay enough attention to the redundant data within the same face image. Based on the fact that the right and left sides of the face are quite similar, there is repetitive information (redundancy) located in both sides of face. Correlation analysis can be utilized to prove the existence of redundancy. Therefore, removing the redundant data will result in powerful discriminant information for FR.

One suggestion for removing this type of redundancy is subtracting the right side matrix from the left side matrix of the face, or vice versa. This simple but effective method is used in the very well-known Normalized RGB colour model (Yang, Liu et al. 2010) (Yang, Liu et al. 2010) that outperforms the original RGB colour space in FR processes. Moreover, more complex scenarios can be utilized to eliminate redundancy.

3.3 Optimizing image representations.

Some image representations enrich face images by valuable discriminant information, resulting in very high recognition accuracy (Yang, Liu et al. 2010) . Fortunately, most of these representations have no conflict with different existing FR techniques including deep learning techniques. A clear example of these representations is *Multi size Multiple Colour Fusion* (MMCF) (Alrjebi, Liu et al. 2016). This method has been used for face image representation and shows very high recognition accuracy especially when used with *Stacked Progressive Auto Encoder (SPAE) (Kan, Shan et al. 2014)*, the improvement of FR accuracy over the original SPAE was 10% to 40%.

Unfortunately, the MMCF and some other image representations such as 2DMCF (Alrjebi, Liu et al. 2015), haven't been optimized, that is, the colour channels contained in these representations have been selected using a poor search method which is the greedy search (Cormen, Leiserson et al. 2009). Therefore, these image representations can be further improved for best FR accuracy.

Optimization techniques and more powerful search methods can be utilized for better image representations.

4. THE ROLE OF FACE STATE RECOGNITION (FSR).

As we mentioned above, each FR method is usually designed for a specific FR problem. This means a method designed for a specific problem is not necessarily effective against other problems. For example, methods designed to tackle the problem of facial expression variations is not necessarily effective against illuminations or occlusions. Therefore, a method to recognise a given face image should be selected based on the situation of that image, for best FR performance we need to recognise the *image state* before recognising face image. Hereafter, we will outline this process for each FR problem separately, and then, we propose adding FSR component to FR system.

4.1 For facial expression problem: There is a variety of methods to recognise the expressions. Facial expressions can be: smiling, sad, surprised, happy, exhausted and screaming. It is worth mentioning her that we need to classify face images into only two classes; *regular and Expression.* So, all we need is adding one of the Facial Expression Recognition methods to the FR system as will be explained later in this paper.

4.2 **For occlusions:** Some of the existing FR methods against occlusions have the ability to recognise occlusion, while other methods don't have this ability. Therefore, we suggest utilising Occlusion detection process anyway. So, methods designed for occluded face images will be applied only if occlusion exists.

4.3 **For pose variations:** Most of current FR methods designed for pose variations are pose-*estimation based* (Ding and Tao 2016). Even though there are some methods that don't require pose estimation, we suggest establishing pose estimation process for any FR method.

4.4 For distant images: Distant face image means small sized image. In Face Recognition literature, the best image size ranges between 32×32 and 120×120 (Jain and Li 2011). Therefore, images smaller than this range will result in low FR accuracy. In this case a technique named Face Hallucination is used to enlarge the small images to the proper size (Wang, Tao et al. 2014).

4.5 **For lighting variations (illumination)*:*** To the best of our knowledge, there is no illumination detection for face images in the literature. Researchers focus only on building algorithms to improve FR accuracy under illumination conditions, even though, improper illumination can significantly degrade the FR accuracy. Current work to tackle this problem is based mainly on grey scale image representation (Braje, Kersten et al. 1998) (Chen, Er et al. 2006) (Alrjebi, Liu et al. 2018), without having previous knowledge about illumination. Therefore:

- Only illumination invariant FR methods are applicable.
- Colour information cannot be used because it is inefficient in the presence of illumination variations.

Based on the above analysis, illumination detection should be applied before passing any input image to FR process. Next, we will outline some tips for this purpose.

- We must have a standard, measuring unit, or reference module to measure illumination density.
- Illumination condition can be classified into three classes which are: brightness, regular and darkness.
- For FR purposes, we need to classify a given face image as: regular or illuminated, where illuminated includes dark image and bright image. The reason behind that is: an image can have different illumination conditions at the same time, i,e some parts of the image can be bright, while other parts are dark and/or regular.
- An image must be classified as illuminated image in the following cases:
  - The image is completely dark.
  - The image is completely bright.
  - The image has any combination of the above mentioned three classes.
- An image can be classified as regular only if it has a regular illumination without any bright or dark areas.
- For illumination classification, we need a set of gallery/reference face images belonging either to illuminated and regular classes based on the above mentioned standards.
- One of the classification methods such as PCA or LDA can be utilised to classify the input image to one of the illumination classes.
- Because we have only two classes, Support Vector Machine (SVM) (Noble 2006)is preferred for classification.
- Mathematical transformations like DCT can be utilised to increase the effect of illumination in order to achieve the best illumination classification. That is, some transformations have the ability to partially separate noise (including illumination) from image features.
- After classifying the input image *as illuminated or regular*, a proper FR method can be performed.

4.6 Adding FSR component to FR system.

Face State Recognition FSR contains four components which are facial expression detection, occlusion detection, pose estimation, and illumination recognition. Adding FSR to the FR system increases the efficiency and reliability of the system especially in uncontrolled environment. Fig.1 illustrates the current FR system and the proposed system.

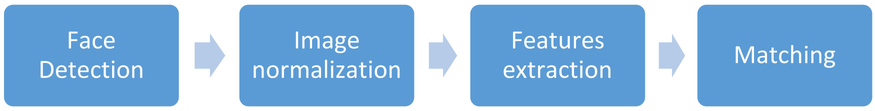

Figure 1.A. Current Face Recognition System

Figure 1.B. Adding FSR To Face Recognition System

5. CONCLUSIONS

In this paper, new aspects for Face Recognition were investigated. The goal is to standardize research in Face Recognition in order to gain a reliable FR system. Removing similarity/shared information from a face image will increase the value of discriminant information. Moreover, discarding redundant data within the image can also improve the quality of discriminant information. The selection of an appropriate image representation is vital for robust FR. By recognizing face state, a proper technique can be utilized for FR processes and as a result, best performance is guaranteed. It is clear that we need to recognize all possible face states. In the previous research, illumination variations are undetectable. Therefore, this will be our future research topic. Moreover, removing redundant data, removing shared information and improving image representation are also interesting topics for future work.

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