Face Recognition and Face Liveness

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***Abstract*— Spoofing attack is a threat for biometric authentication systems. Liveness detection aims at recognition of human physiological activities as the liveness indicator to prevent spoofing attack. Facial photograph of valid user is the most common way to spoof face recognition systems as photo attack is the cheapest and easiest spoofing approach. Anti-spoof problem is a challenging task before face recognition could be applied. Video spoofing is another big threat to face recognition systems as it is very similar to live face. It has many physiological clues that photo does not have. Human is able to distinguish a live face and a photograph without any effort, since human can very easily recognize many physiological clues of liveness. The tasks of computing these clues are complicated for computer, even impossible for some clues under the unconstrained environment. This paper is an effort to explore future aspects for face liveness detection. Various existing face recognition methods and liveness indicators for face liveness detection are covered in this paper.**

***Index Terms*— Spoofing; physiological clues; PCA; LDA; face recognition systems; liveness indicator; holistic/non-holistic approach; depth information**

INTRODUCTION

One of the most remarkable ability of human vision system is to recognize face. However in computer vision developing a computer algorithm to do the same thing is one of the toughest tasks. Research over the last several years in this field enables similar recognitions automatically [1]. Recognizing faces is something that people usually do effortlessly and without much conscious thought, yet it remained a difficult problem in the area of computer vision. Human face recognition is an important task in computer vision with numerous potential applications including biometric system for video surveillance, identification, human computer interaction, face tracking, law enforcement, face image database management and security applications [2]. We can recognize a number of faces learned throughout our lifespan and identify faces at a glance even after years of separation despite of large variations in visual stimulus due to changing conditions, aging and distractions such as beard, glasses or change in hairstyle.

Computer based face detection and recognition could be applied to a wide variety of tasks including image and film processing, criminal identification, security system, identity verification, tagging purposes and human computer interaction. Major advances and initiatives in the past two decades have propelled face recognition technology into spotlight. Face recognition technology involves analysing various facial characteristics, storing them in database and using them to identify. Despite this growing attention, the current state of the art face recognition systems perform well when facial images are captured under uniform and controlled conditions. Face recognition is a very challenging problem and up to date as there is no technique that provides a robust solution under all situations and different applications that face recognition may encounter [3].

FACE RECOGNITION METHODS

In the past two decades automatic face recognition has been extensively studied due to its important role in a number of application domains including visual surveillance, access control, and government issued identity documents (e.g., driver license and passport) to name a few [4]. The influence of some features make face recognition a hard and complicated task i.e. moustaches, glasses, beard, environment factors (lighting conditions and background) and the fact there are variations in human face as colour, age and size. Since, the problem exists for many years and because of its importance lot of work has been done for solving it. The most popular and successful approaches use template matching, neural networks, geometric methods, Viola-Jones method, etc. The categorization of different schemes and strategies for the face recognition is not easy and different criteria are usually used in literature [5]. Various face recognition methods can be grouped into four categories: a) knowledge based methods, b) feature invariant methods, c) template matching methods and d) appearance-based approaches [6].

A. *Knowledge-based methods:*

These methods use pre-defined rules to determine a face based on human knowledge. These methods encode human knowledge that constitutes a typical face, usually by finding the relationships between facial features. A face is represented using a set of human-coded rules. These rules are then used to guide the face search process. The advantages of the knowledge-based techniques are the easy rules to describe the face features and their relationships. Their disadvantages are the difficulty to translate the human knowledge in rules precisely and the difficulty to extend these methods to detect faces in different poses.

B. *Feature invariant methods*:

Feature invariant methods aim to find face structure features that are robust to pose and lighting variations i.e. to detect invariant face features. The structural features of a face that exist even when the pose, viewpoint or lighting conditions vary. The main advantage of the feature oriented face detection approaches consists in the fact that these features are invariant to rotation changes. Their main drawback is the difficulty to located facial features in a complex background. These approaches are used for detecting features [39], [40] like eyes, nose, ears, mouth lips etc.

C. *Template matching methods:*

These methods use pre-stored face templates to judge if an image is a face. Usually, these approaches use correlation operations to locate faces in images. The templates are handcoded, not learned. Also, these templates have to be created for different poses. These methods [41], [42] are used for face localization and detection by computing the correlation of an input image to a standard face pattern.

D. *Appearance-based methods:*

These methods learn face models from a set of representative training face images to perform detection with eigenface [43], [44], [45], neural network [46], [47], and information theoretical approach [48], [49]. Appearance-based techniques train a classifier using various examples of faces. The classifiers which can be used in the training process include: Neural Networks (Multilayer Perceptrons) , Hidden Markov Models , Bayes classifiers , Support Vector Machines (SVM) , Sparse Network of Winnows (SNoW) , Principal Component Analysis (PCA) and Boosting algorithms (Ada-Boost).

Another popular classification scheme is the holistic/non-holistic philosophy of the methods [7], [8]. In holistic methods the face is recognized in the image using overall information, that is, the face as a whole. Holistic methods are commonly known as appearance-based approaches. On the other hand, non-holistic approaches are based on identifying particular features of the face such as the eyes, the nose, etc. and their relations to make the final decision. Some recent methods also known as hybrid methods try to combine the advantages of both holistic/non-holistic approaches at the same time. It would be impossible to make an exhaustive enumeration of all publications related with 2D face recognition as there are hundreds of 2D face recognition algorithms with huge variety of approaches. Brunelli et al. and Nefian have used correlation-based approaches [9], [10]. In these approaches, the image is represented as a bi-dimensional array of intensity values and is compared with a single template that represents the whole face. It was the beginning of the appearance based methods for face recognition in 1990's when Turk and Pendland implemented the Eigenfaces approach [11], [12] and it is surely the most popular face recognition method.

Different statistical approaches have appeared that improve the results of Eigenfaces under certain constraints. One method implements Linear Discriminant Analysis (LDA) to perform dimensionality reduction while preserving as much of the class discriminatory information as possible [13]. LDA method group images of same class and separates images of different class. Other methods are Kernel PCA [14] and Independent Component Analysis [15] that exploit higher order statistics, or an two dimensional extension of the PCA [16]. Principle Component Analysis (PCA) is a dimensionality reduction technique that is used for image recognition and compression. The basic concept of PCA is to describe the variation of a set of multivariate data in terms of linearly independent (uncorrelated) variables, which are a particular linear combination of the original variables.

One another approach implements neural networks for solving the problem of face recognition [17], [18], [19], [20], [22]. Neural networks approach promise good performance but these have to be further improved and investigated mainly because of the difficulty of the training the system. One method that intends to solve the conceptual problems of conventional artificial neural networks is Elastic Bunch Graph Matching [23], [24]. Face recognition using Elastic Bunch Graph Matching (EBGM) [23] is based on the neural information processing concept, the Dynamic Link Architecture (DLA). EBGM relies on the concept that real face images have non- linear characteristics such as variations in illumination, pose and expression are not addressed by the linear analysis methods.

Although all methods report encouraging and excellent results, the real fact is that approaches based on statistical appearance-based methods like Principal Component Analysis (PCA) and Elastic Bunch Graph Matching [23], [24] present good face recognition rates [25].

FACE LIVENESS DETECTION METHODS

Ross describes biometrics as an emerging technology that enables uniquely recognizing humans based upon one or more intrinsic physiological or behavioral characteristics, such as faces, fingerprints, irises and voices [26]. However, spoofing attack is still a fatal threat for biometric authentication systems [27]. Liveness detection is very active topic in field of fingerprint recognition and iris recognition as it aims at recognition of human physiological activities as the liveness indicator to prevent spoofing attack [27], [28], [29], [30].

Numerous approaches have been presented in face recognition, the effort on anti-spoofing is still very limited [7]. Facial photograph of valid user is the most common way to spoof face recognition systems. Photo attack is the cheapest and easiest spoofing approach as one's facial image is usually very easily available for the public. As example facial image can be downloaded from the web or captured unknowingly by a camera [31]. The imposter can shift, rotate or bend the facial photo in front of camera like a live person to fool the authentication system. In face liveness detection field it is still a challenging task to detect whether an input facial image is of a live person or from a photograph. Therefore anti-spoof problem must be well solved before face recognition could be widely applied in our daily life.

Video spoofing is another big threat to face recognition systems as it is very similar to live face and can be shot in front of legal user’s face with the help of needle camera. It contains many physiological clues that photo does not have like head movement, facial expression and eye blinking etc. Hence photo and video are most common spoofing ways to attack face recognition system. Human is capable to distinguish a live face and a photograph without any effort as human can very easily recognize many physiological clues of liveness, such as facial expression variation, mouth movement, eye blinking and head rotation. However, for computer the tasks of computing these clues are complicated, even impossible for some clues under the unconstrained environment.

An essential difference between a live face and a photograph from the static view point is that a photograph could be considered as a two dimensional planar structure while a live face is a fully three dimensional object. Choudhary et al used this natural trait by employing the structure from motion yielding the depth information of face to detect live person or still photo [32]. There are some limitations of depth information, first is that it is very hard to estimate depth information when head is still. Second is that the estimate is very sensitive to noise and lighting condition, hence becoming unreliable. Kollreider et al applied the optical flow to the input video to obtain the information of face motion for liveness detection [35], but it is vulnerable to calculate depth information in photo motion or when photo is bending. Some researchers use the multi-modal approaches of face and voice against spoofing [33], [34], by exploiting the lip movement during speaking. This kind of method requires voice recorder and user collaboration. Frischholz et al also tried an interactive approach, requiring user to act an obvious response of head movement [33].

Face liveness detection approaches can be categorized on basis of liveness indicator used [36]. Texture analysis is based on the assumption that printed faces contain detectable texture patterns. Texture features are extracted from face images under the assumption that fake faces are printed, and the printing process or the material printed on produces certain texture patterns that do not exist in real faces [36]. Motion analysis methods are associated with the optical flow calculations between different frames in a video sequence while life sign detection tries to analyze features like eye blinking and lips movement. Still images taken from live faces and 2D paper masks were found to bear differences in terms of shape and details [37]. Focus based methods could significantly increase the level of difficulty of spoof attacks, which is also a way to improve the security of Face Recognition systems [38].

CONCLUSION AND FUTURE WORK

I. This paper covers various face recognizing methods which are categorized under knowledge based methods, feature based methods, template matching methods for face localization and appearance based methods. Photo and video are most common spoofing ways to attack face recognition system. Face liveness can be detected by using texture analysis methods and motion analysis methods. For future research options are still open to develop a framework for improved life sign detection and liveness detection issue for face through texture analysis.

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