Rapid Face Detection and Annotation with Loosely Face Geometry

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Abstract*—Recent advancements in research paved way for face can be detection in cluttered background in real time. However, much attention need to be given still in partially occluded face detection with varying degree of face occlusion. This paper presents a strategic approach for rapid detection and annotation of partially occluded face. Partially Occluded Face Detection (POFD) problem is addressed by using a combination of feature-based and part-based face detection methods with the help of face part dictionary. In this approach, the devised algorithm aims to automatically detect face components individually and it starts from mostly un-occluded face component called Nose. Nose is very hard to cover up without drawing suspicion. Keeping nose component as a reference, algorithm search the surrounding area for other main facial features, if any. Once face parts qualify facial geometry, they are normalized (scale and rotational) and tag with annotation about each facial features so that partial face recognition algorithm can be adapted accordingly with the test image.

Keywords—face component; occluded face; face parts; face detection; partial occlusion.

I. Introduction

In the past decades, face recognition has been a subject of intensive research due to increasing security demands and its potential in commercial and law enforcements. Several applications of face recognition (FR) includes Human-Computer-Interaction, Content-based coding of image video, Biometric Analysis etc. FR has the potential of being a non-intrusive form of biometric identification that can operate without the cooperation of human. Though technological advancements in digital image capturing and transmitting equipment manage to shrink most noise factors, partial face occlusion still pose an open challenge to automated face recognition system. Commercial face recognition systems are not well equipped to solve partially occluded face recognition problem since they need to be aligned faces by facial landmarks that may be occluded. Facial occlusion can occur for several deliberate or undeliberate reasons such as sun glasses, scarf, medical mask, helmet, veils, beard and mustache, facial makeup, hat etc. Face detection is the initial phase of an automated face recognition system, since a face has to be located before it is recognized [1]. Basic techniques used for partially occluded face detection can be classified as part-based methods, feature-based methods and fractal based methods. In part-based methods, the face image is divided into several overlapping and/or non-overlapping parts which are then used for recognition [2]. Feature-based methods consider all facial features like eye, nose and mouth region individually [3]. Fractal-based methods computes self-similarities among the image.

We present a rapid partially occluded face detection (POFD) with loosely face geometry technique based on feature-based method blended with part-based method. First skin region is detected and then local facial features are searched in skin region in an attempt to find the most probable face part candidates. Skin region is computed based on [4].

Generally it is found that in human face nose is not occluded. Noses literally stick out from human face, do not change much with facial expression. Nose is very hard to cover up without drawing suspicion. So they are actually quite easy to capture with non-cooperative subjects. Clue is to find the nose on the face that normally closes to the center of the face. Once the tip of the nose is detected, the other two facial features left eye and the right eye are detected. Mouth is also detected in given facial geometric context. Based on these the center points of the eyes i.e. midpoint is determined and Scale normalization and alignment is also done using straight line between center of left and right eye. All face components are searched in skin region and tested for loose face geometry.

Global face region usually have different local facial structures/ features and it can be exploited for detecting region-specific occlusion with the help of facial geometry. A possible way to detect partially occluded face in a given image is to find local facial features for different regions individually.

This research paper is presented in the following sections as follows. Section II describes on the proposed approach to identify possible partially occluded face. Section III explains process and strategy of rapid POFD and annotation with loosely face geometry, whereas section IV explores experimental results and discussion. Conclusion and future work scope are drawn in Section V.

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II. PROPOSED METHOD

Fusion of feature-based method and part based-method is used for POFD. The main POFD problem is divided in two sub-problems:

i. How to locate possible face component regions
ii. How to conclude partially occluded face for annotation

For (i), skin area is detected in the probe-image, and then face-components are searched in skin area and array of presented face-components candidates are created. For (ii), assumption is made that nose is present in the probe-image and few other facial components might be missing. The major face parts in face detection are Nose, Left Eye, Right Eye, Mouth, Left Ear, Right Ear and Chin. Face components list can be extended to Left Nostril, Right Nostril, Left Corner Mouth, Right Corner Mouth, Upper Lip, Lower Lip, Left Chick and Right Chick. The major and most common face parts and their characteristics for coarse face detection are considered. These are Nose, Eyes (Left eye and Right Eye) and mouth. The approaches for sub-problems are as follows:

A. Skin region detection

Skin detection reduces area to search face feature detection and computationally reasonable to implement and this characteristic encourages to use skin detection in face detection. To detect faces using skin, all human skin color are spanned in pre specified range, so that any pixel within that range shall be classified as skin pixel. But finding this range itself is a challenging task as skin range varies through race and ethnicity. Several skin color methods are approached as RGB [5], HSV [6], Lab [7], YCbCr [8] etc. Separation between chrominance and luminance components can be achieved with HSV and Lab etc. which makes easier to search specified color and avoids illumination variance effect. Bin Abdul Rahman [9] has combined skin range RGB, HSV, YCbCr and ultimately improves skin detection. Skin detection technique [9] inspires to adapt it for skin and non-skin classification. Morphological operations are used to remove small non-face objects inside skin area and finally achieved bounding area for most probable face region or face component region.

B. Algorithm for face annotation

Algorithm: For possible face detection and annotation
Input: Probe image I, Skin bounding coordinates, Threshold
Output: array of possible face-components candidates

Step 1: search possible nose features in probe image within skin bounding area
Step 2: create Arrays for all possible major face components
Step 3: test for loose face geometry
Step 4: create a threshold bound Array for the array resulting from step 3.
Step 5: annotate partially occluded detected face(s)

Step 1: *search possible nose features in probe image within skin bounding area*

Here nose features are searched within skin region defined by skin detection procedure. Nose has three different local characteristics in frontal faces [10]. Nose has similarity on both sides horizontally. Nose follows dark-white-dark pattern, nose tip plays white (illuminated) role while nostril dark shades. Nostril region are usually less illuminated than half of the average of nose tip region. There is a clear variation in upper part of the nose and lower part of the nose. Nose tip is very brighter than other part of the face. The lowest tip of brighter region is considered as Nose tip [11].

Step 2: *create Arrays for all possible major face components*

Each face component has some unique features such as mouth (neutral face) has long horizontal bar with dark pixels than its surrounding skin color; Lips darker red to purple in normal lighting; Lips are very contrast with skin color in any human race; Eyes are darker than other part of the face and center of the eye region is darker than its surrounding [11]; and left eye features are vertical mirror of right eye features. All major face-components are searched in probe image and arranged in separate arrays dedicated for each face components.

Step 3: *test for loose face geometry*

Each face-component in human face has specific relative position with other face-components like nose lying always below eyes and above mouth. This can be easily understood by direction model Fig.1 (c). Let Nose be at center, and Left eye will be always located in North-West of nose. Similarly right eye will be located in North-East of the nose.

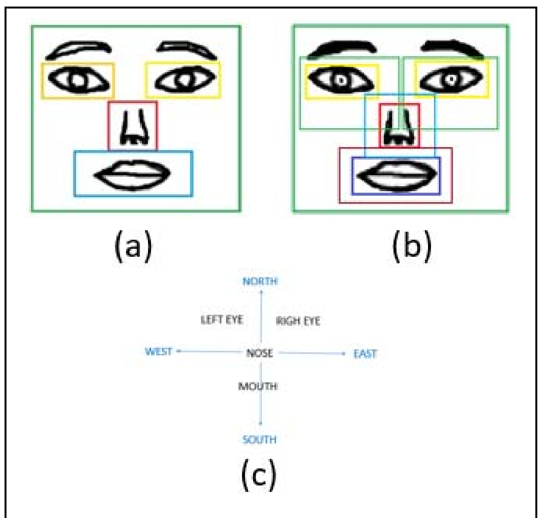


Fig. 1

Mouth always will be found in South of nose. Fig.1 (a) Eyes are bound by yellow rectangle, nose by red rectangle and mouth with blue rectangle. Fig.1 (b) shows overlapped face parts regions that compensate small rotational variation in face image. Small rotational and distance variation between face components are derived by loose face geometry. Each face-component present in step-2 arrays is tested for loose face geometry and all who passed loose face geometry are stored in threshold bound array of possible face components.

Step 4: *create a threshold bound Array of possible face*

Threshold T is introduced for tuning face detector. It tunes the number of face-component required to be eligible partially occluded face as face-present. If four major face component [Left eye, Right eye, Nose, Mouth] are considered, then threshold T will be in the range [1-4]. Minimum threshold T is 1, which indicates detection is concluded on single face-component and it produce weak face detection. And if T is 4, it indicates that detection is concluded on all face-component, which produces strong face detection. Threshold T is applied on arrays resulting from step-3.

Step 5: annotate partially occluded detected face(s)

There are 2^n types of occlusion possible with n face-components. For each particular face component: either face-component is present (indicated by numerical 1) or not-present (indicated by numerical 0) in possible face. For run time occluded face part detection, all possible combination of present and not-present major face components are created, and stored in key-value pair in dictionary shown in Table I. Here key is a string of 0s and 1s. Suppose for four major face components Nose, Right eye, Left eye and Mouth [N, R, L, M], the key can be represented by [1 1 1 1] and [0 0 0 0] for all face-part present and no face-part present respectively. Each 0s or 1s place value corresponds to unique face-part, and [1 0 0 0] represents only Nose present in above setup.

All qualified face components grouped as partially occluded face based on above steps and draw face boundary. Using face part dictionary each detected face with appropriate tag is annotated. This tag can vary from full face present to no face present. Each partially occluded annotated face now can be used for face recognition and other face processing task.

III. Experimental results and discussion

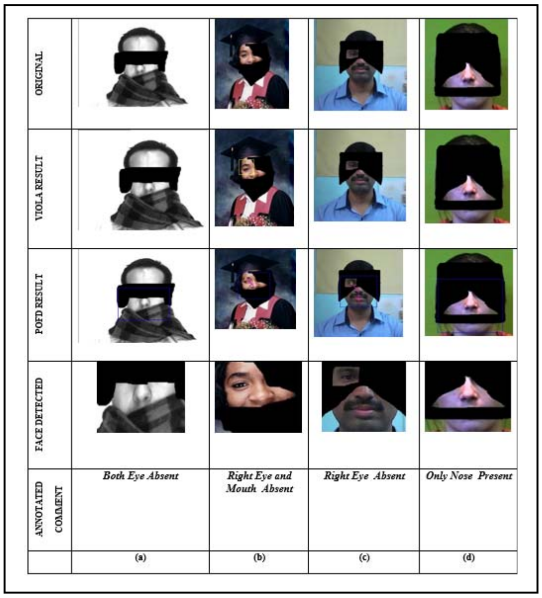
The POFD model is implemented using Matlab on Core i5, 2.4 GHz CPU with 8GB of RAM. The experiment is restricted with four major face components (i.e. Nose, Right Eye, Left Eye and Mouth) and the performance of POFD is evaluated using a series of experiments on standard Face Datasets and publicly available face images. There is a simple tradeoff between number of face-component considered with time and computational complexity. The devised algorithm is tested on color and gray scale images (skin detection step excluded). from AR database [12], which consists more than 3200 color images of 126 subjects with different facial expressions, illumination conditions including realistic occlusions (sunglasses and scarf), ORL database [13] that consists of ten different images each of 40 distinct subjects, where images are taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses) and from ESSEX database [14] that consists of 395 individuals with 20 images per person with some occlusions like Glasses and beards.

Table II, shows the performance of the proposed rapid POFD and annotation with Viola Jones based Method. Table 1, column (a) and (d) represent sample image from AR database and ESSEX database respectively and column (b) and (c) are from public domain. Table 1, Row 1 shows original sample images from popular database and public images with manually hidden face features. Second row shows failure of normal holistic approach while row 3 shows success of partial face detection with proposed rapid POFD approach. Fourth row shows detected faces with rapid POFD approach while the Last row shows annotation result for corresponding occlusion. As it is evident from table's results that normal approach to detect partially face detection fails with limited facial features while the proposed rapid POFD still able to detect partially occluded face successfully. The rapid POFD is compared with the popular Viola Jones holistic method and our rapid POFD approach outperforms in the means of it can detect partial face with very few face-components. This clearly shows that the rapid POFD could detect partially occluded faces and can be used for crucial criminal investigation etc.

TABLE I. ANNOTATION DICTIONARY

N R L M	ANNOTATION
0 0 0 0	Face Not Present
0 0 0 1	Only Mouth Present
0 0 1 0	Only Left Eye Present
0 0 1 1	Nose and Right Eye Missing
0 1 0 0	Only Right Eye Present
0 1 0 1	Nose and Left Eye Missing
0 1 1 0	Nose and Mouth Missing
0 1 1 1	Nose Missing
1 0 0 0	Only Nose Present
1 0 0 1	Both Eyes Missing
1 0 1 0	Right Eye and Mouth Missing
1 0 1 1	Right Eye Missing
1 1 0 0	Left Eye and Mouth Missing
1 1 0 1	Left Eye Missing
1 1 1 0	Mouth Missing
1 1 1 1	Full face Present

TABLE II. RAPID POFD RESULTS



IV. CONCLUSION

It is evident that partially occluded face can be detected and annotated with fewer facial components in real time scenarios by the means of loosely face geometry based face part detection techniques. This approach provides an extended arm for rapid and more complex occluded face detection in real time. The proposed technique intuitively exploits the feature based techniques for detection, when they are prone to major occlusions. In the near future, the POFD technique would be extended over a wide range of partially occluded face recognition problems in real time.

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