Automatic and Robust Detection of Facial Features in Posed and Tilted Face Images

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ABSTRACT

Face detection has advanced dramatically over the past three decades. Algorithms can now quite reliably detect faces in clutter in or near real time. However, much still needs to be done to provide a detailed description of external and internal feature. It should be robust and easy to implement in the real time approach. This paper presents an approach to achieve this goal. Previous learning algorithms have limited success on this task because shape and texture of facial features varies widely under changing expression, pose and illumination. This problem is addressed with the use of corners correlation in facial features. In this approach, an algorithm is used to automatically find the facial features and its corners. The key idea used to achieve accurate detections is to not only learn the textural information of the facial feature to be detected but that of its corners and their correlations also. This process permits a precise detection of key facial features. This approach is then combined with skin color detection to provide an accurate and detailed detection of the shape of the major facial features (ears, eyes, nose and mouth).

Keywords – **face detection, facial feature extraction, ROI, face dataset, skin color detection.**

1. INTRODUCTION

Face detection is essential front end for a face recognition system. Face detection locates and segments face regions from cluttered images, either obtained from video or still image. It has numerous applications in areas like surveillance and security control systems, content based image retrieval, video conferencing and intelligent human computer interfaces. Most of the current face recognition systems presume that faces are readily available for processing. However, we do not typically get images with just faces. We need a system that will segment faces in cluttered images. With a portable system, we can sometimes ask the user to pose for the face identification task. In addition to creating a more cooperative target, we can interact with the system in order to improve and monitor its detection. With a portable system, detection seems easier. The task of face detection is seemingly trivial for the human brain, yet it still remains a challenging and difficult problem to enable a computer/mobile phone/PDA to do face detection. This is because the human face changes with respect to internal factors like facial expression, beard, moustache glasses etc. and it is also affected by external factors like scale, lightning conditions, and contrast between face, background and orientation of face.

Face detection remains an open problem. Many researchers have proposed different methods addressing the problem of face detection. In a recent survey face detection technique is classified into feature based and image based. The feature based techniques use edge information, skin color, motion and symmetry measures, feature analysis, snakes, deformable templates and point distribution. Image based techniques include neural networks, linear subspace method like Eigen faces, fisher faces etc.

Face detection is an important topic in many applications. To analyze the information included in face images, a robust and efficient face detection algorithm is required. Variation of illumination and pose in addition to existence occlusion and orientation decrease the algorithm performance. These factors change global facial appearance while face components are less affected by these factors. Using component-based method, we can overcome the referred problems. In component based face detection algorithm [2], skin color regions are segmented in transformed color spaces as the candidate faces using color features. Then the most important facial features, eyes and mouth, are localized as necessary components in face candidate regions. In order to localize the facial features two new maps are proposed. To confirm each candidate face as a face, a flexible geometric model is used. This model by construction of a triangle between detected facial components verifies the existence of the face. A robust face detection method is even able to localize occluded facial features. In this method, by combination of reliable component detectors and considering the logical geometric relation between facial components, in addition to high detection rate, the algorithm has a low alarm rate. Furthermore it can detect not only single face but also multiple faces in an image.

Locating facial feature points in images of faces is an important stage for numerous facial image interpretation tasks. A method [6] for fully automatic detection of facial feature points in images of expressionless faces using Gabor feature based boosted classifiers is presented. The method adopts fast and robust face detection algorithm, which represents an adapted version of the original Viola-Jones face detector. The detected face region is then divided into 20 relevant ROIs, each of which is examined further to predict the location of the facial feature points. The facial feature point detection method uses individual feature patch templates to detect points in the relevant region of interest. These feature models are GentleBoost templates built from both gray level intensities and Gabor wavelet features.

Face detection algorithm can now quite reliably detect faces in clutter in or near real time. However, much still needs to be done to provide an accurate and detailed description of external and internal features.

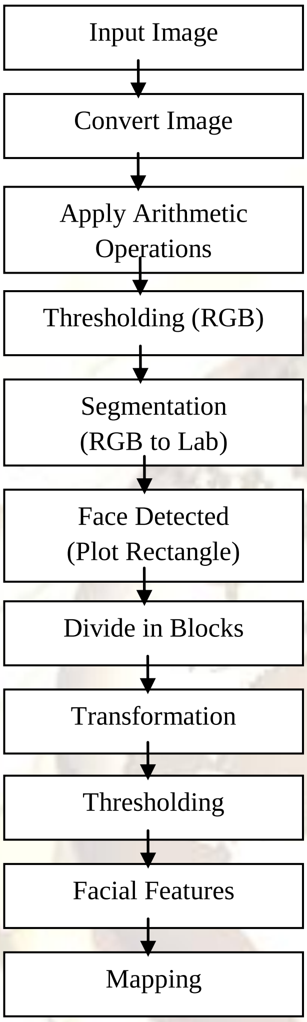


Fig. 1: Proposed facial feature detection method

The problem of face detection in still images is more challenging and difficult when compared to the problem of face detection in video since emotion information can lead to probable regions where face could be located.

To achieve this goal we propose here a robust, highly accurate method for detecting 6 facial features in digital color images. An automatic detection method is based on image skin regions, therefore a skin-based segmentation of RGB images is provided first. Then, we decide for each skin region if it represents a human face or not, using a set of face images, an edge detection process, and a threshold-based method. Facial features match values is obtained using the proposed method.

The remainder of this paper is organized as follows. In Section 2 we describe the steps of our proposed facial feature detection approach. Section 3 describes the facial feature extraction methods which describes about our proposed algorithm for facial feature detection of frontal face images and posed and tilted face images using "skin color detection" and "Harris and Shi & Tomasi's" algorithm in "Geometrical shapes of facial features". The tested results of some of the face database (MIT- CBCL face dataset) [16] images are shown in Section 4. Finally conclusion is described in section 5.

2. Automatic Facial Feature Detection Approach

In this paper, the most effective approach to facial feature detection is found to be a coarse-to-fine approach. This effectively splits the problem into two stages: 1) Locate the face using a face detector. 2) Find facial features within the region indicated by the face detector.

In stage 1, skin color detection method is implemented and tested. The region supplied by best performing face detector is then taken as the starting point for testing algorithms in stage 2.

To solve stage 2 and find features given a face region, a simple approach Harris and Shi & Tomasi feature extraction method is used.

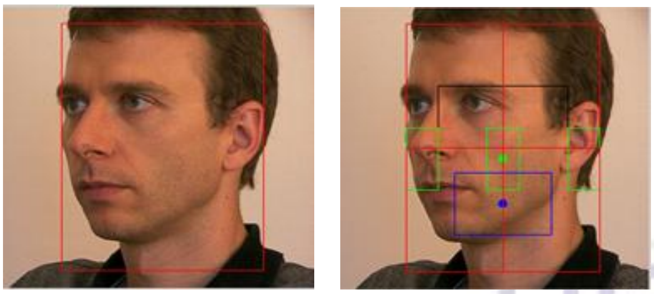
2.1 Facial Feature Detection Algorithm

The procedure of our proposed algorithm for face detection and face extraction is shown in (fig. 1). The algorithm includes two major modules: 1) localizing human face by using skin color segmentation, 2) verifying the regions as human faces by using geometric relations between detected facial features. At first, take an input image and apply arithmetic operations, an image get thresholded and the RGB color space is segmented in the Lab color space. The face is detected using a skin color detection method. Now, apply Harris and Shi-Tomasi corner detection method on detected face region to divide it in 6 relevant ROIs with the help of geometrical shapes of facial features to extract the different features of a face. Transformation and binarization of an image is performed to get the facial features (eyes, mouth, nose and ears).

2.2 Detecting Regions of Interest

The next step in the automatic facial feature detection is to determine Region of Interest (ROI) for each facial feature, that is, to define more or less a large region (fig. 2(a)) which contains the facial features that we want to detect. To achieve this we apply a fully automated method which determines the ROIs within the face region.

The nose, ears, eyes and mouth detection is achieved as follows. First, we divide the face region horizontally and vertically into two parts: the upper face region containing the eyes and the lower face region containing mouth. Since the face detector used is highly accurate and the detected face region is always extracted in the same way regarding the relative size and position of the face box, it is sufficient, for the first step, to roughly divide the face region horizontally and vertically in two halves (fig. 2(b)). Again it is sub-divided into six relevant ROIs to extract each facial feature.



(a) (b)

Fig. 2: (a) ROI image of the face. (b) Dividing the face into blocks.

2.3 Skin Color Detection Method

Skin detection [14] is a very popular and useful technique for detecting and tracking human-body parts. It receives much attention mainly because of its wide range of applications such as, face detection and tracking, naked people detection, hand detection and tracking, people retrieval in databases and internet, etc. The main goal of skin color detection or classification is to build a decision rule that will discriminate between skin and non-skin pixels. Identifying skin colored pixels involves finding the range of values for which most skin pixels would fall in a given color space. In general, a good skin color model must have a high detection rate and a low false positive rate. That is, it must detect most skin pixels while minimizing the amount of non-skin pixels classified as skin. Commonly used skin detection algorithms can detect skin regions accurately.

2.3.1 Color Models for Skin Color Detection

The study on skin color classification has gained increasing attention in recent years due to the active research in content-based image representation. For instance, the ability to locate image object as a face can be exploited for image coding, editing, indexing or other user interactivity purposes. Moreover, face localization also provides a good stepping stone in facial expression studies. It would be fair to say that the most popular algorithm to face localization is the use of color information, whereby estimating areas with skin color is often the first vital step of such strategy. Hence, skin color classification has become an important task. Much of the research in skin color based face localization and detection is based on RGB, YCbCr and HSI color spaces. In this section the RGB color space is being described which is used further.

2.3.2 RGB Color space

RGB is a color space originated from CRT (or similar) display applications, when it was convenient to describe color as a combination of three coloured rays (red, green and blue). It is one of the most widely used color spaces for processing and storing of digital image data. However, high correlation between channels, significant perceptual non-uniformity, mixing of chrominance and luminance data make RGB not a very favourable choice for color analysis and color- based recognition algorithms. (Fig. 3) shows the general color model for RGB color space.

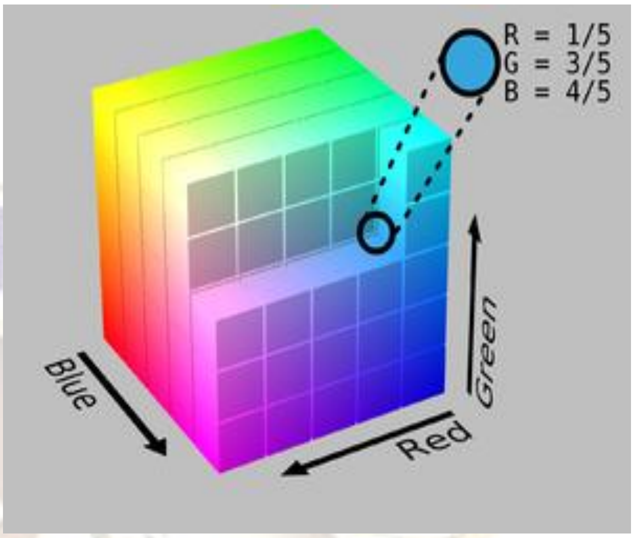


Fig. 3: General Color Model- RGB

3. FACIAL FEATURE EXTRACTION ALGORITHM

Facial feature points are generally referred to as facial salient points such as the corners of the eyes, corners of the

$$R = \det M - k(trace\, M)^2$$

$$\det M = \lambda_1 \lambda_2$$

$$trace\, M = \lambda_1 + \lambda_2$$

eyebrows, corners and outer mid points of the lips, corners of the nostrils, tip of the nose, and tip of the chin. Transforming the input data into the set of features is called feature extraction. If the features extracted are carefully chosen it is expected that the features set will extract the relevant information from the input data in order to perform the desired task using this reduced representation instead of the full size input.

3.1 Harris Corner Detector

The Harris corner detector is a mathematical operator that finds features in an image. It is simple to compute, and is fast enough to work on computers. Also, it is popular because it is rotation, scale and illumination variation independent.

The “score” calculated for each pixel in the Harris Corner Detector is based on the two eigen values of a matrix. The expression to calculate it is not arbitrary, but based on observations of how the expression varies with different eigen values. Here's a graphical explanation of how it is done.

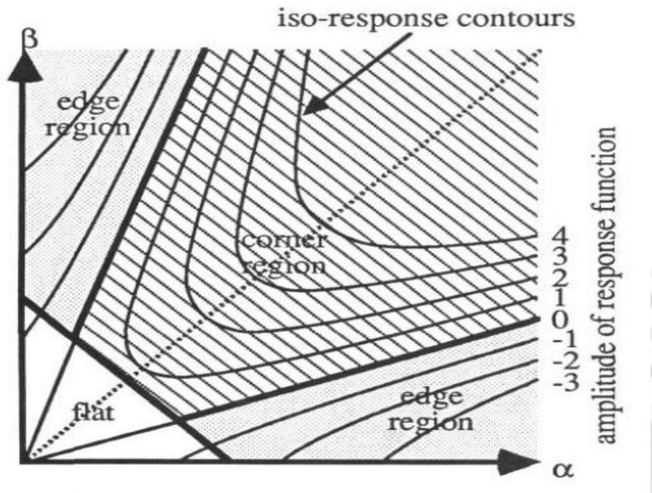


Fig. 4: Graph for Harris corner detector

The (fig. 4) describes the graph for Harris corner detector (a combined corner and edge detector, Harris and Stephens, 1988). Here, alpha and beta are the two eigen values.

- Both eigen values are small, then the pixel is "flat" (the white region)
- One eigen value is large, and the other is small, then the pixel is an edge (the gray region)
- Both eigen values are large, then the pixel is a corner (the crossed region)

The (fig.4) also show contours for the score function. On selecting a proper value, we get positive values in the corner region and negative values everywhere else. And thus, the expression for calculating score for each pixel was created.

Improvements: Later on, in 1994, Shi and Tomasi [9] came up with a better corner detection scheme. Their works involved only minor changes in the Harris corner detector, but were able to produce better results in corner detection.

3.2 Shi-Tomasi Corner Detector

The Shi-Tomasi corner detector is based entirely on the Harris corner detector. However, one slight variation in a "selection criteria" made this detector much better than the original. It works quite well where even the Harris corner detector fails. So here is the minor change that Shi and Tomasi did to the original Harris corner detector.

The change: The Harris corner detector has a corner selection criterion. A score is calculated for each pixel, and if the score is above a certain value, the pixel is marked as a corner. The score is calculated using two eigen values. That is, we gave the two eigen values to a function. The function manipulates them, and gave back a score. Shi and Tomasi suggested that the function should be done away with. Only the eigen values should be used to check if the pixel was a corner or not. For **Shi-Tomasi**, score (R) is calculated like this:

$$R = min(\lambda_1, \lambda_2)$$

Shi and Tomasi demonstrated experimentally that this score criterion was much better. If R is greater than a certain predefined value, it can be marked as a corner. Thus, the effect region for a point to be a corner is something like this:

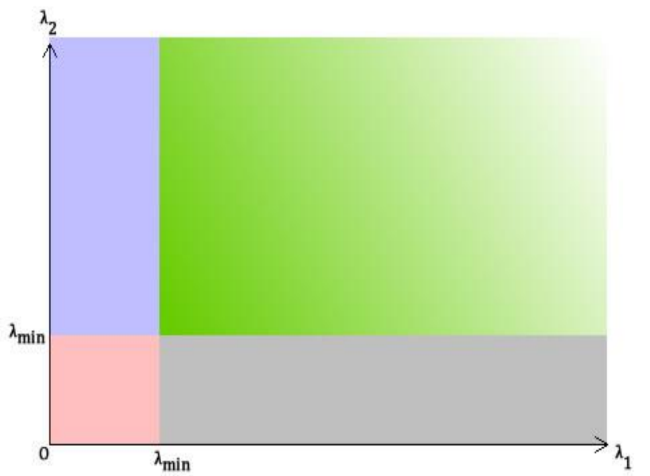


Fig. 5: Graph for Shi-Tomasi Corner Detector

In the above (fig. 5) the green region indicates both λ_1 and λ_2 are greater than a certain value. Thus, this region is for pixels "accepted" as corners. In the blue and gray regions, either λ_1 or λ_2 is less than the required minimum. In the red region, both λ_1 and λ_2 are less than the required minimum.

Compare the above with a similar graph for Harris corner detector. We will see the blue and gray areas are equivalent to the "edge" areas. The red region is for "flat" areas. The green is for corners.

4. RESULTS

4.1 Training Dataset

The choice of a good database is crucial for the learning step. To detect salient facial features that are robust under changing conditions, different posed and front images have been used. The facial feature detection method was trained and tested on the MIT-CBCL face dataset (fig.6) to perform the experiment, which consists of 40 color images, both male and female. Further registration of a sample image was performed. The proposed method has been trained and tested using skin color detection and Shi-Tomasi feature extraction method. We applied this method for extracting six different facial features (left eye, right eye, nose, mouth, left ear and right ear) and find features match values.

Fig. 6 MIT-CBCL face dataset

4.2 Facial Features Match Values

The proposed method has been tested on 40 different images of MIT-CBCL face dataset to give the experimental result and compared with a registered sample image to get the facial features match values.

At first, we take an input image and apply our proposed algorithm, we get the six different extracted facial features (i.e. left eye, right eye, nose, left ear, right ear and mouth) and by registering the sample image we can recognize whether image is frontal, posed and tilted face images. Secondly, registered image is compared with the same and several different images to get the facial features match value. If the features match value of an image is 1, then the image taken is the registered image and if the features match value is less than 1, then the image taken is different from the registered image.

4.3 Time Complexity

Harris and Shi-Tomasi detection method gives the better result than the Gabor feature extraction method in terms of time complexity. Performance analysis of our proposed algorithm is more accurate than the existing one.

Table 1: Elapsed time (sec.) of the two approaches

Elapsed Time (seconds)		
Approaches / No. Of Images	Gabor Feature Extraction	Harris and Shi-Tomasi
Image 01	21.186249	1.881896
Image 02	17.763925	1.935010
Image 03	20.924200	1.957752
Image 04	17.352001	2.057444
Image 05	27.570966	1.926554
Image 06	38.160432	1.967997
Image 07	17.114266	2.021782
Image 08	29.855816	1.964284
Image 09	15.567891	2.137495
Image 10	24.895421	1.832469
Image 11	17.888324	1.763287
Image 12	18.239654	1.045879
Image 13	19.673962	1.956732
Image 14	23.873209	1.647869
Image 15	27.045683	1.873894
Image 16	25.845785	1.678488
Image 17	29.564738	1.768399
Image 18	15.567389	1.783468
Image 19	28.736476	1.568996
Image 20	13.879758	1.965673
Image 21	21.737647	1.578940
Image 22	17.678438	1.749807
Image 23	18.488374	1.329890
Image 24	26.487989	1.864689
Image 25	18.786482	1.889846
Image 26	17.324979	1.688999
Image 27	13.734874	2.012789
Image 28	19.639899	1.674949
Image 29	16.897938	1.674899
Image 30	26.458939	1.974890

Image 31	28.807489	1.557678
Image 32	26.589859	1.894090
Image 33	27.789492	1.893478
Image 34	19.786254	1.786487
Image 35	21.789489	2.345956
Image 36	18.898479	2.687788
Image 37	26.896329	1.897859
Image 38	23.789548	1.897034
Image 39	30.863489	1.365990
Image 40	17.867586	2.547658

The above (table 1) shows the total time taken by the two different algorithms while extracting the different facial features in color images. The two approaches are "Gabor feature extraction" and "Harris and Shi- Tomasi corner feature detector". It is clear from the above table that proposed approach achieves better detection result for posed and tilted face images, than the Gabor feature extraction to detect the faces. Gabor feature extraction method takes more time while detecting and extracting features of a face. In Gabor feature extraction method we first locate the feature points and then apply Gabor filters at each point in order to extract facial features. Neural network analysis has been used because it can localize, in space-frequency, characteristics of images and it can represent faces in different spatial resolutions and orientations. The test is performed on same images as used in proposed method to get the total time taken by the algorithm.

4.4 Comparison Table

Comparison of the existing and proposed approaches for detecting and extracting facial features on 40 different face images has been done and shown in table 2.

Table 2: Comparison result among the two approaches

	Feature Extraction					
	Left Eye	**Right Eye**	**Mouth**	**Nose**	**Left Ear**	**Right Ear**
Existing Approach	Yes	Yes	Yes	Yes	No	No
Proposed Approach	Yes	Yes	Yes	Yes	Yes	Yes

In (table 2) comparison result among two approaches is given. In the existing approach eyes, mouth and nose are extracted but in proposed approach additional left ear and right ear is also extracted with the help of ears match values.

5. CONCLUSION

This paper is all about the face detection (frontal, posed and tilted face images) by skin color detection and facial feature extraction by the Harris corner and Shi- Tomasi corner detection in "Geometrical shapes of facial features" which will be used in future recognition of the faces. Proposed approach is much accurate in terms of time complexity. The special feature of this work is the posed detection by the ear features matching values to find the ear features and determine the posed faces.

In this paper, face detection has been done by skin color and Harris and Shi- Tomasi corner features detection in still images and it can be extended in videos (moving images). It will be very useful for the fast face detection and recognition for the defence and intelligence department and the secure access of the confidential systems too.

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