

DETECTION AND ANALYSIS OF SYMMETRICAL PARTS ON FACE FOR HEAD POSE ESTIMATION

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ABSTRACT

In this paper, we demonstrate in the first that the amount (lengths and widths) of symmetrical parts on face are good and robust geometric features for head pose estimation. Secondly, we selected from all proposed algorithms of symmetry detection in the literature, the more suitable algorithm and the values of the proposed features are computed using some head poses which correspond to Yaw and Pitch motions. The obtained results demonstrate the validity of the proposed approach.

1. INTRODUCTION

Head pose estimation is one of challenging tasks for computer vision researchers. The crucial problem encountered in all proposed approaches is to find the most discriminate set of facial features which permits to satisfy a set of criteria [1]: Accuracy, Monocular, Autonomous, Multi-person, Identity and Lighting invariant, Resolution independent, Full range of head motion and Real time. Many approaches has been proposed to solve this problem and may be classified into Appearance template methods, Detector array, Non linear regression methods, Manifolds embedding methods, Flexible models, Tacking methods, Hybrid methods [1] and Geometrical methods ([2], [3], [4], [5]) which require the visibility of facial features and their high precision in their extraction. Psychophysical experiments conducted by H. Wilson et al [6] support that the head orientation discrimination is based upon two cues: the deviation of the head shape from bilateral symmetry, and deviation of the nose orientation from the vertical. In addition to these cues, geometrical configuration of local features located on face was one of followed approaches. However, even the head pose may be estimated from their known properties, the location of these features is a hard task when the head is relatively far from the camera and becomes more difficult when a person wears glasses and obscures the high part of face.

Few works has been devoted to use of symmetry detection for head pose estimation. Symmetry based illumination model proposed in [7] is based on a three features (eyes and nose tip). For every combination of two eyes and a nose, head

pose is computed using a weak geometry projection and internally calibrated camera. In [8], an algorithm is proposed for only the detection of facial symmetry axis when the subject is looking directly into the camera. Gray level difference histogram analysis is used assuming a clean gray background under controlled illumination. Local symmetry, color and geometry information of human face are used to obtain potential feature points like eyes [9]. The face pose (roll and yaw angles) are estimated from a single uncalibrated view in [10] where the symmetric structure of human face is exploited taking the mirror image of a test face image as a virtual second view and based on the extraction of facial feature points of the test and its mirror image and their matching.

Instead of a good location of facial features which is a hard task and constitutes the major inconvenient of the proposed methods, we propose the use of the amount of symmetrical points on face. When the face is in front of camera, the symmetry between its two parts appear clearly and the line which passes between the two eyes and nose tip defines the symmetry axis. However, when the head performs a motion, for example, a yaw motion towards the left, this symmetry disappears and three or less pairs of face regions present reflectional symmetrical with different symmetry axes (region of eyes, region of nose and region of the mouth). In the first part of this work, we study theoretically the properties of different symmetries on face when the head is performing motion. Precisely, the variation of widths and lengths of symmetrical parts which constitute new features for head pose estimation.

The second part of this work is devoted for the detection of regions with reflectional symmetry. From the proposed methods, we selected the algorithm of Stentiford [11] because is the more suitable and may be applied without constraints on considered shapes. We show in the third part of this work the result obtained demonstrating that these new features may be used in the training and recognition process of head pose.

In this paper, we will start by a theoretical study of face symmetry according to head motion in section 2 and 3. In section 4, we present the experimental results. Finally, in section 5, we conclude the paper by some remarks.

2. THEORETICAL STUDY OF THE SYMMETRY ON FACE ACCORDING TO HEAD MOTION

2.1. Length variation of symmetrical parts according to Yaw motion

In this section we study the area variation of symmetrical parts on face when head performs a yaw motion. We assume in the first that face is parallel to the camera and let a, m, b be three points on face chosen so as m is the middle point of the segment (ab) . Let a_i, b_i, m_i be the projection of a, b, m on the image plane. If (ab) is parallel to the image plane, the point m_i is middle of $(a_i b_i)$ and the segments $(a_i m_i)$ and $(m_i b_i)$ are symmetrical with respect to (m_i) (see figure 1.a).

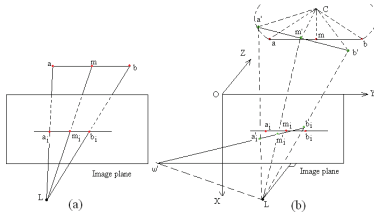


Fig. 1. (a) Projection of symmetry center m of a segment (ab) parallel to the image plane, (b) Projection of symmetry center of a segment line after a yaw motion

We assume now that the head performs a yaw motion which may be assimilated as a rotation of face points (a, b, m) around a center (C) (see figure 1.b). As a consequence of this motion, features points (a, b, m) moves towards (a', b', m') and are projected into (a_i', b_i', m_i') . Let ω' be the vanishing point associated to the direction of $(a' b')$ in the image plane.

Applying the invariance of the cross-ratio [12], we obtain:

$$(a', b', m', \infty) = (a_i', b_i', m_i', \omega') \quad (1)$$

$$\frac{m' a'}{m' b'} = \frac{m_i' a_i'}{m_i' b_i'} \div \frac{\omega' a_i'}{\omega' b_i'} \quad (2)$$

As two members of the equation 2 are equal to one, the point m_i' is not the middle of $a_i' b_i'$ and its position depends on the position of $a_i' b_i'$ relatively to ω' .

In figure 1.b, as a_i' is near from ω' , m_i' will be also near from a_i' than from b_i' . We conclude then, $m_i' a_i'$ is not symmetrical to $m_i' b_i'$.

If we consider that m and m' are the symmetry centers of respectively ab and $a' b'$, then the pixels of segment line $a_i' b_i'$ may satisfy a partial symmetry but in this case the symmetry center not will be the middle of $a_i' b_i'$, but it will be m_i' and the symmetry will concerns the segments $m_i' a_i'$ and $m_i' d_i'$ where d_i' is located between m_i' and b_i' so as $m_i' a_i' = m_i' d_i'$ (see figure 2).

Figure 3 illustrates two segment lines fixed on face for two different poses. The graphic giving the grey levels of all pixels

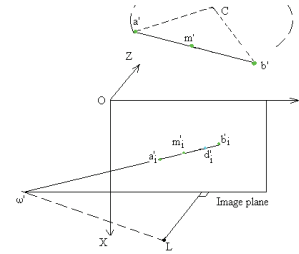


Fig. 2. Symmetrical segment lines after a yaw motion

indicate clearly there is a symmetry relatively to the point at middle distance from the eyes. The difference between the lengths of the two segments ((3.a) and 3.b) is due to the yaw motion.

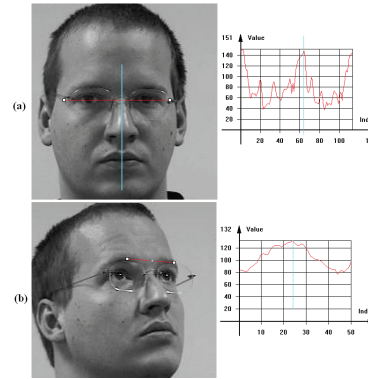


Fig. 3. Grey level variation of the red segment line for initial pose (a), after a yaw motion (b)

When head performs more important yaw motion, the distance of the segments which contains bilateral symmetry decreases for two reasons:

- The first one is that a' does not appear on the image plane,
- The seconde one is that m_i' becomes more close of a_i' because the vanishing point ω' becomes closer of a_i' .

The lengths of symmetrical segments decrease and become zero when the angle of rotation is 90° (see figure 4).

We conclude then that the amount of symmetrical pixels on face decreases then when the angle of Yaw motion increases.

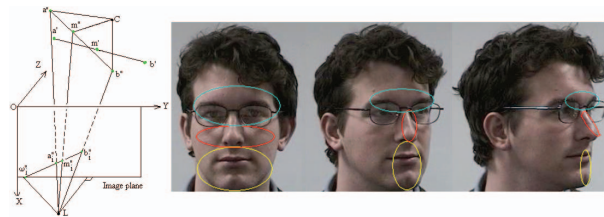


Fig. 4. Variation of the length of symmetrical parts for yaw motions

2.2. Width variation of symmetrical parts according to Pitch motion

Let A_1, B_1 be two extremities points of the symmetry axis (Δ_1) of a part of the face such as the region of eyes or the region of the mouth. We assume that (Δ_1) is parallel to the image plan and projected into a_1b_1

When the head performs a Pitch motion, the axis (Δ_1) performs the same motion and becomes (Δ_2) which is not parallel to the image plan. The length of its projection a_2b_2 is less than the length of a_1b_1 and decreases when the pitch motion angle increases (see figure 5).

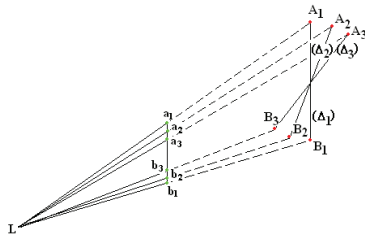


Fig. 5. Variation of the width of symmetrical parts for Pitch motions

3. COMPUTATION OF THE YAW AN PITCH MOTIONS

We assume that a database of model poses are available representing all main angles of Yaw an Pitch motions. The first step is the location on the face of each one image the pairs of symmetrical parts. In general case, there are at maximum three pairs: at the top of face (eyes), at the middle (nose) and at low (mouth).

The second step is to measure the lengths and widths of these parts and to associate for each category of Yaw motion and Pitch motion the intervals of normalized values.

To determine the amount of the Yaw motion and Pitch motion, a classifier is trained using the relative length and width of symmetrical parts according the amount of motion. We use for this the high and low parts of the face which correspond to the surfaces of the face which contain respectively the eyes and the mouth.

This task constitutes our current work so as the estimation of Roll motion.

4. SYMMETRY DETECTION AND EXPERIMENTAL RESULT

In the literature many approaches was proposed to resolve the problem of reflectional symmetry detection in the image [13], [14], [15, 16], [17], [18], [19]. Each one find symmetrical parts using some constraints or initial assumptions or are based on feature points that are difficult to extract when the

face is not near from the camera. However, the method proposed by of Stentiford [11] is more suitable in our case. It permits the extraction of symmetries from 2D facial images without manual intervention or the prior specification of features that characterize those symmetries.

We implemented this algorithm with some improvement in order to reduce the time processing. Figure 6 shows the all symmetrical points located on face parallel to the camera and the symmetry axis. The number of pixels pairs is 4590.

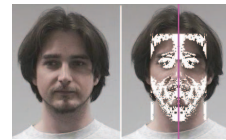


Fig. 6. Symmetrical pixels located for face parallel to the camera

Figure 7 shows for four poses (Yaw motions of $+15^\circ$, $+15^\circ$, $+30^\circ$ and -30° the symmetry axes computed and the pairs of symmetrical pixels whose number is equal respectively to 2681, 1645, 1245 and 1120. We can see that the lengths of symmetrical parts decreases when the head performs a Yaw motion towards the left or right.



Fig. 7. Symmetrical pixels located for Yaw motion

Figure 8 shows two poses (Pitch Motions of 30° and 60°) and the symmetry axes computed, the number of pairs of symmetrical pixels is 2270 for the first motion and 1810 for the second one. Equivalent results are obtained for two Pitch motions of -60° and $+60^\circ$ where the number of pairs of symmetrical pixels is respectively 3286 and 3341 (see figure 9). We can see that the width of symmetrical parts decreases when the Pitch motion increases.

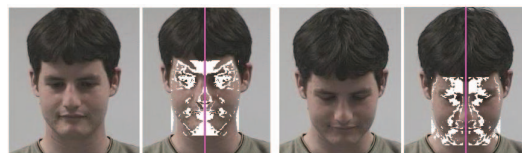


Fig. 8. Symmetrical pixels located for Pitch motions

5. CONCLUSION

In this paper we proposed a set of new features extracted from the symmetry of face. We explained also how use these fea-



Fig. 9. Symmetrical pixels located for Pitch motions

tures for head pose estimation; precisely, how to compute the yaw and pitch motions. The proposed features may be extracted even if the head is relatively far from the camera and not necessitate the location of interest points on face. The first obtained results are promising and encourage us to use the new measures for head pose estimation by means of classifier.

6. REFERENCES

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