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FACE AUTHENTIFICATION OR RECOGNITION BY PROFILE EXTRACTION FROM RANGE IMAGES

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ABSTRACT :

This work is related with authentification or recognition of human faces from their range images. The approach consists in comparing a part of the profile or of the surface of two faces. For this aim, the profile plane of each face considered as a quasi-symmetry plane is extracted with an iterative process which involves the similarity of the Gaussian curvature values of the face surface. Then an optimal matching of the two profiles is done which allows the calculus of similarity indices of profiles or of surfaces. Tests for robustness and the authentification or recognition results show the efficiency of the whole procedure.

KEY WORDS :

3D Vision, Range Images, Human Faces, Face Profile, Authentification, Recognition, Principal and Gaussian Curvatures, Symmetry Plane.

1 INTRODUCTION.

Face identification is a natural ability for human beings. It is such a need in social life that evolution has selected individuals able to recognize faces even long after the first look. In fact recent experiments in Neurobiology have proved there exists a specific cortex area in the human brain to perform this task [THP-88].

Automatic recognition by computer of human faces is a recent claim resulting of the growing urbanization of the human environment and of securities enforcement. Recognition can be distinguished from authentification since in the first case, the problem is to find a person in a (possibly) large population and in the second the question is rather to judge if a given person is the one he pretends to be. However, the real nature of the two problems is not so different because in each case comparisons must take place between a face to identify and a registered model.

The investigation can be done from two kinds of data : brightness or range images. Theoretically, these two classes bear the same information as radiance is functionally related to surface geometry. However, if finding radiance from geometry assuming (for example) a Lambertian model is rather simple, the converse is an ill-posed Hardy problem which has not been solved in the general case yet. It is then pertinent to say that range images are today the most convenient information to expect good results in automatic face recognition.

This paper presents works which follow studies reported in [CAR-87] and [LAP-88]. The precedent approach was partially invalidated when dealing with new range images obtained from a range finder developed in the French "Institut Géographique National" [THO-88]. Its field of view is such that it is not always possible to obtain a closed concave domain surrounding the eyes and the nose. The computation of this domain was the base of the determination of the profile plane (considered as a quasi-symmetry plane of the face). Figure 1 presents transition lines between concave and convex parts of a face range image. It is clear that there is no hope to get a closed concave domain in the center part of the image.

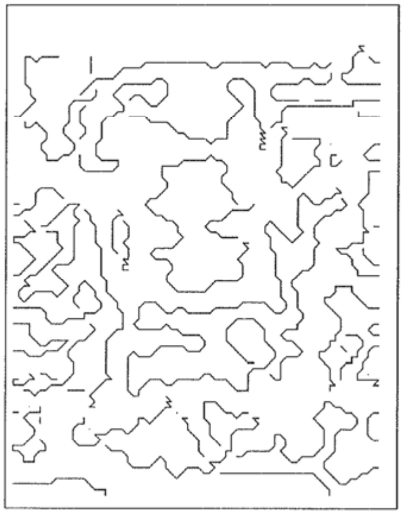

Figure 1: Transition lines between convex et concave domains of John1 face.

Thus an other approach for the determination of the profile plane was necessary. It appeared to be more reliable than the precedent one as shown in the next section.

2 EXTRACTING THE FACE SYMMETRY PLANE.

2.1 General principle.

It comes from the following simple idea: the profile plane of a face which is a quasi-symmetry one segments the face surface in two parts that are approximately equal after application of an isometry. In particular, its 3-D image is divided in two parts sharing the same principal curvatures values. Conversely, if these two sets can be constituted, the symmetry plane computation is almost trivial.

Let us suppose we are given an initial symmetry plane, even roughly determined, considered as the profile plane (we shall discuss of its determination in the next section). It is then possible to intersect the surface by a set of parallel plane sections, normal to this initial plane and to the XOY plane (plane normal to the camera optical axis OZ).

The problem is now to analyze each of the cuts to extract pairs of points (cach in one of the two half spaces determined by the initial symmetry plane) for which the distribution of the Gaussian curvature values in a neighbourhood of this points is nearly the same. From the set of these pairs a new symmetry plane is obtained.

Iterating this analysis from this last plane until satisfaction of a stopping criteria (involving stability of the successive values of the plane parameters) leads to the final plane.

2.2 Computing the symmetry plane.

2.2.1 First determination

A good choice of the initial plane can reduce notably the number of iterations needed for the convergence of the determination process.

It is supposed that when the image image is acquired, the head is in a normal "position" in front of thc range finder, i.e. the head is nearly vertical, the profile plane is nearly parallel to the optical axis, and their distance is not too high. Two choices for the initial plane have been tested:

i) The plane normal to XOY and XOZ which goes through a point considered as the nose tip,

ii) the plane normal to XOY going through the same point and a point called nasion.

Nose tip and nasion are determined in the following way:

- The elliptical or umbilical convex point with maximal Z-coordinate can be taken as a good approximation of the nose tip.
As the image edges are noisy the search is restricted to a central area of the image face.

- Above the nose tip the barycenter of a convex hyperbolic area is looked for. This barycenter must satisfy the two following conditions:

1) to be at a minimal fixed distance from the nose tip.

2) after projections on the XOY plane, the straight line joining these two points must be parallel to the average of the minimal curvature direction on the convex domain above the nose tip and under this point.

In the second case the convergence of the process is much faster. However as the determination of the nasion is more or less face dependent and can fail, the initial plane is chosen according to the following strategy:

- find the nose tip, which is ever possible,
- look for a nasion, if success then take choose ii) else choose i) (as defined before) and increase the maximal number of iterations allowed in the next step.

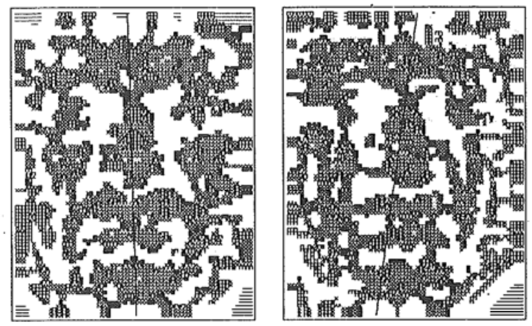

Figure 2: Convex domain and initial symmetry plane trace
for Bill1 (*left*) and John2 (*right*) faces.

The trace on the plan XOY of the initial plane so chosen is shown in Figure 2 which gives also the labelling of the convex points of the face images Bill1 and John2 according to the geometrical nature of the the face surface deduced from the principal curvatures.

2.2.2 Iteration details.

For each cut C_i, a symmetrical point $M_{i'j'}$ of each point M_{ij} situated at the left of the symmetry plane is looked for. For this, at the right of the symmetry plane, the points of C_i and of the neighbouring cuts $(C_{i-1}\ldots C_{i-N_a}, C_{i+1}\ldots C_{i+N_a})$ are investigated, N_a being the maximal number of neighbouring cuts to analyze.

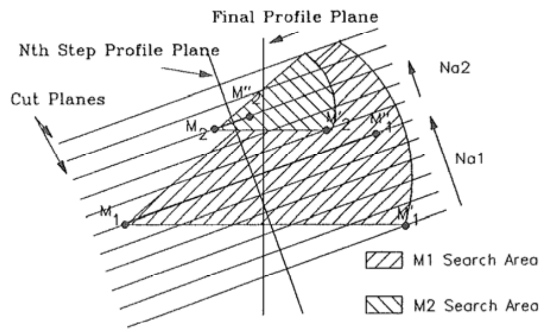

Figure 3: Adaptation of N_a in profile plane evaluation.

N_a must be adapted to the position of the current point with respect to the profile plane. Figure 3 shows the traces in the XOY plane of neighbouring cut planes, of the profile plane at the Nth iteration and of the final profile plane obtained after convergence of the process. To detect the symmetrical point M'_1 (resp M'_2) of point M_1 (resp M_2), we have to examine five adjacent cuts for M_1 and only two for M_2, because M_1 is further from the profile plane than M_2. The size of the research area for points far from the profile plane has to be greater than for points situated in the neighbourhood of the symmetry plane to keep the same rotation possibilities.

For each pair $(M_{ij}, M_{i'j'})$, a matching coefficient $\Phi_{ij}(i', j')$ is calculated from the Gaussian curvatures of points taken in a $(3\times(2\cdot T_M+1))$ neighbourhood around M_{ij} and in a neighbourhood of same size but symmetrical around $M_{i'j'}$, T_M being a neighbourhood parameter (of value 3 in all our experiments).

We note V_{ij} (resp. $V_{i'j'}$) the vector whose dimension is $(3\times(2\cdot T_M+1))$, and whose coordinates are the Gaussian curvature values in the $(3\times(2\cdot T_M+1))$ neighborhood around M_{ij} (resp. $M_{i'j'}$). The similarity coefficient which measure the quality of the matching of M_{ij} and $M_{i'j'}$ is then given by :

$$\Psi_V(V_{ij}, V_{i'j'}) = 1 - \frac{|V_{ij} - V_{i'j'}|^2}{2(K+1)|V_{ij}||V_{i'j'}|} = \Phi_{ij}(i', j')$$

where K is an adjustment coefficient [CAR-89].

- Matching validation

The matching between M_{ij} and $M_{i'j'}$ is considered valid if:

$$\Phi_{ij}(i', j') > Threshold$$

Moreover, if during the search for the symmetrical of a given point M_{ij} we get:

$$\begin{cases} \Phi_{ij}(i', j') > Threshold \\ \Phi_{ij}(i'', j'') > Threshold \end{cases}$$

which means that $M_{i'j'}$ and $M_{i''j''}$ can be matched with the same point M_{ij}, we keep the pair associated with the maximal matching coefficient.

- Determination of the symmetry plane

Let N_c be the number of cuts leading to at least a pair of matched points. We shall denote by n_{c_i} the number of pairs given by the cut C_i. We compute the barycenter G_i of the pairs $(M_{ij}, M_{i'j'})$ with the matching coefficients used as weights, on the cut C_i, using the following relation:

$$\overrightarrow{OG_i} = \frac{\sum_{j=1}^{n_{c_i}} \Phi_{ij}(i', j') \cdot \frac{\overrightarrow{OM_{ij}} + \overrightarrow{OM_{i'j'}}}{2}}{\sum_{j=1}^{n_{c_i}} \Phi_{ij}(i', j')}$$

The unit normal $\overrightarrow{N_{Psu}}$ to the symmetry plane Ps is given by:

$$\begin{cases} \overrightarrow{N_{Ps}} = \dfrac{\sum_{i=1}^{N_c}\left(\sum_{j=1}^{n_{c_i}} \Phi_{ij}(i', j') \cdot \dfrac{\overrightarrow{M_{ij}M_{i'j'}}}{|\overrightarrow{M_{ij}M_{i'j'}}|}\right)}{\sum_{i=1}^{N_c} \sum_{j=1}^{n_{c_i}} \Phi_{ij}(i', j')} \\ \overrightarrow{N_{Psu}} = \dfrac{\overrightarrow{N_{Ps}}}{|\overrightarrow{N_{Ps}}|} \end{cases}$$

To find the remaining plane parameter, the barycenter B, of the previously computed barycenters G_i weighted by the number of pairs n_{c_i} of each cut, is calculated:

$$\overrightarrow{OB} = \frac{\sum_{i=1}^{N_c} n_{c_i} \cdot \overrightarrow{OG_i}}{\sum_{i=1}^{N_c} n_{c_i}}$$

The symmetry plane is now completely determined by its normal $\overrightarrow{N_{Psu}}$ and one of its points, B.

2.3 Results.

The results for two pairs of images are presented here. Each pair corresponds to two different views of the same face.

Figures 4 a, b, c et d present the 3D images (restored and filtered) of these faces. On each one the calculated profile plane trace is drawn. The profiles extracted from John1, Bill1 and Bill2 faces are shown in Figure 5.

The evolution of profile curves of face John2 along the steps of the process are shown on Figure 6.

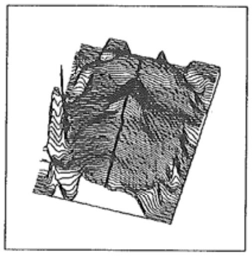

Figure 4 a: Bill1 face.

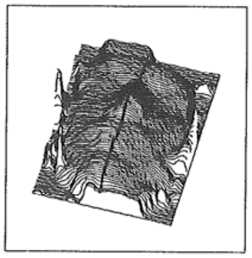

Figure 4 b: Bill2 face.

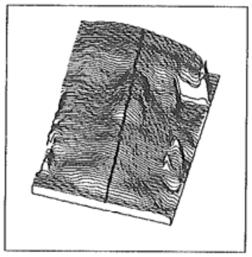

Figure 4 c: John1 face.

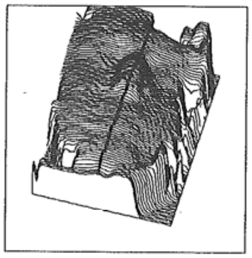

Figure 4 d: John2 face.

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