

Recovering Planar Surfaces by Stereovision Based on Projective Geometry*

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Abstract

Our purpose is to build the planar surfaces (3D faces) of the objects of a polyhedral scene using a binocular stereovision system. Before the reconstruction step and after the step of matching, we search among the set of triplets of matched 2D faces (assigned to be the projection of 3D faces) for the triplets which really correspond to planar 3D surfaces. To accurately reconstruct the surface, we then check in 2D space for the classes of triplets of faces which correspond to 3D coplanar structures. This paper presents how these 3D properties are checked in the 2D space, using tools of projective geometry, allowing us to constrain the 3D reconstruction to maintain these 3D properties.

1 Introduction

Our principal point of interest is to build the planar surfaces of the objects, called 3D faces, using stereovision system with non aligned cameras. In this paper, we assume that 2D faces have already been extracted from the images and that they have been matched [1] and we focus on :

- the step of 2D verification of 3D properties, which checks in 2D space for the 3D planarity and coplanarity of the 3D faces related to triplets of matched 2D faces;
- the step of 3D construction which is done under the assumptions of planarity and coplanarity.

2 Reference plane and trace

Π is said to be a reference plane if it does not pass through any optical center of our stereovision rig. Then given a reference plane Π with a projective coordinate system B , we introduce the following application:

$$T_{i,j}^{\Pi}: (Im_i, B_i) \rightarrow (Im_j, B_j)$$
$$p_i = (k_1, k_2, k_3)_B \mapsto p_{i,j} = (k_1, k_2, k_3)_{B_j}$$

where each B_j is composed of the projection of the four 3D points building up B (see Fig. 1) on the image plane Im_j , $i = 1..3$.

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Figure 1: Applications: $T_{1,2}$ and $T_{1,3}$.

Definition 1. The trace T_S^{Π} of a segment S on a reference plane Π is the projection onto the image plane¹ Im_i of the intersection of the straight line L , supporting S , with Π .

Given the matched projections (s_i, s_2, s_3) of the segment S on the three image planes, let (l_1, l_2, l_3) be the supporting straight lines such as $s_i \in l_i, i = 1..3$, we give the following result.

$$T_S^{\Pi} = l_1 \cap T_{2,3}^{\Pi}(l_2) \cap T_{3,1}^{\Pi}(l_3).$$

As well, we define the trace $T_{S_M}^{\Pi}$ of S_M of a set $S_M = \{S_1, \dots, S_n\}$ on a reference plane Π as the union of the traces of the segments composing S_M :

$$T_{S_M}^{\Pi} = \bigcup_{S_i \in S_M} T_S^{\Pi}$$

3 Checking the planarity and coplanarity

To prove the planarity of a face and to check for the classes of coplanar faces we establish a constraint about the coplanarity of a set S of 3D segments only using their corresponding set of matched triplets and three reference planes Π_i , $i = 1..3$.

¹The trace can be defined relatively to any image plane. But all this definitions of traces are equivalent.

Constrain 1 S is made of coplanar 3D segments if:

1. either there exists $i \in \{1, 2, 3\}$ such that $T_{\mathcal{F}_i}^{\Pi_1} = \bigcup_{j=1}^3 T_j : S$ is coplanar to Π_1 ,
2. or there exists three straight lines $\ell_i \in Tm_i, i \in \{1, 2, 3\}$, such as $T_{\mathcal{F}_i}^{\Pi_1} \subset \ell_i$.

Then, we recall that a 2D face is a chain of 2D segments and that each triplet of 2D matched faces $\mathcal{F}\mathcal{F}$ is associated its set $\mathcal{S}_{\mathcal{F}\mathcal{F}}$ of 4 triplets of matched 3D segments. Then, a triplet of 2D matched faces $\mathcal{F}\mathcal{F}$ is said to be the projection of a 3D planar face, if and only if applying Constrain 1 we prove the 3D coplanarity of the set of 3D segments corresponding to $\mathcal{S}_{\mathcal{F}\mathcal{F}}$.

We then have a method which allows us to select among all the triplets of matched 2D faces the set of triplets which are the projection of planar surfaces. Let us note that the use of Constrain 1 determines the classes of faces coplanar to one of the reference planes. In order to determine the remaining classes of coplanar faces we establish an algorithm based on the following theorem: Let $\mathcal{F}\mathcal{F}_1$ and $\mathcal{F}\mathcal{F}_2$ be two triplets of 2D faces and let $T_{\mathcal{F}_1}^{\Pi_1}, T_{\mathcal{F}_2}^{\Pi_1}, T_{\mathcal{F}_1}^{\Pi_2}$ and $T_{\mathcal{F}_2}^{\Pi_2}$ be their respective traces on the reference planes Π_1 and Π_2 where ($j = 2, 3$), then we state the following theorem:

Theorem $\mathcal{F}\mathcal{F}_1$ and $\mathcal{F}\mathcal{F}_2$ of $\mathcal{F}\mathcal{F}_{\Pi_1}, j = 2, 3$ is a projection of a couple of 3D coplanar faces if and only if:

$$T_{\mathcal{F}_1}^{\Pi_1} = T_{\mathcal{F}_2}^{\Pi_1} \text{ and } T_{\mathcal{F}_1}^{\Pi_2} = T_{\mathcal{F}_2}^{\Pi_2}.$$

Remark 1 At this note that in practice, we have to take into account the effect of noise when computing the traces of a triplet. Besides, the process of coplanarity checking has to fit all the couples of traces of each coplanar faces class to a shared traces values (for more details see [1]).

4 The 3D reconstruction process

We first compute for each triplet $\mathcal{F}\mathcal{F}_i$ the supporting 3D plane $P(\mathcal{F}\mathcal{F}_i)$. Two cases are possible to check

for $P(\mathcal{F}\mathcal{F}_i)$: either the 3D face related to $\mathcal{F}\mathcal{F}_i$ is proved to be coplanar to one of the reference plane $\Pi_i, i = 1, 3$, then $P(\mathcal{F}\mathcal{F}_i) = \Pi_i$ or the 3D face related to $\mathcal{F}\mathcal{F}_i$ is not coplanar to any reference plane. In this case, we have associated to $\mathcal{F}\mathcal{F}_i$ two traces on two given reference planes Π_2 and Π_3 . Each couple of traces represents its fact the projections of two straight lines belonging to the plane $P(\mathcal{F}\mathcal{F}_i)$. Note that thanks to our research about the sets of coplanarity, we have associated the same traces for the noncoplanar faces. Knowing the 3D position of the used reference planes, we can then build up the 3D straight line associated to each trace by backprojection. Having now two 3D straight lines, we deduce the parameter of the unique 3D plane $P(\mathcal{F}\mathcal{F}_i)$ passing through these two lines.

Then having determined the parameter of the supporting plane, we backproject the corresponding 2D arguments of the 2D face on the plane $P(\mathcal{F}\mathcal{F}_i)$ and de limit the 3D face.

5 Conclusion

We show in this paper how simple principles of projective geometry can be used to get the planarity information about triplets of 2D faces. We have also introduced a simple method for checking for the classes of 3D coplanar faces before their 3D reconstruction.

All those 3D properties information lead to a 3D reconstruction process which includes constraints of planarity and coplanarity. Such a reconstruction necessarily leads to a better localization of the 3D edges of the observed objects as shown in Figure 2.

References

- [1] H. Chabbi and M.-O. Berger. Recovering Planar Surfaces by Stereovision Based on Projective Geometry, technical report IS-R-054, CRIN, 1999.

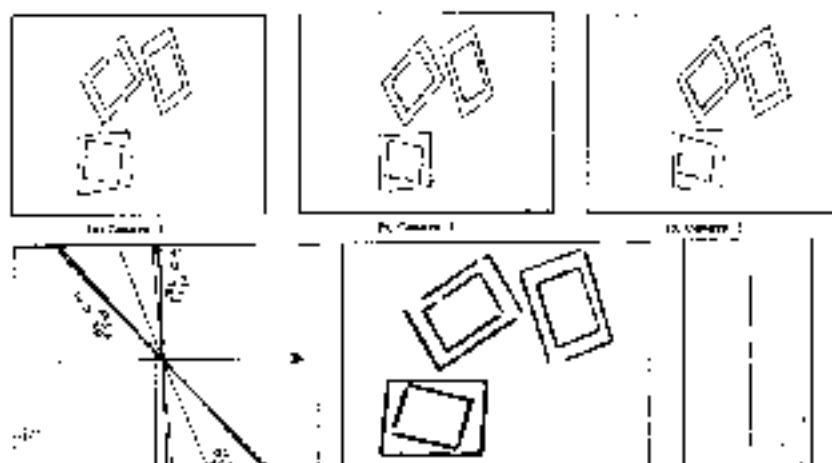


Figure 2. Above we present the triplet of images of the 2D matched faces. Below we show the trace of this faces on two different reference planes and the result 3D face reconstruction: a front view and a top view of the reconstruction.