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A New Method to Resolve the Matching Problem Without Using a Calibration of Camera

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Abstract: In this study, we present a novel approach to match a line segment in the sequence of images obtained by camera in motion. The proposed method is based only on the formalism of the slope of the segment in the sequence of images. We use the definition of the projection of points and the relation which exists between the slopes of the segment in various images. The approach developed not needs the calibration of camera. To resolve the matching problem, two segments in three images are necessary. Experiment showed feasibility as well as robustness of the algorithm.

Key words: Matching, tracking, estimation of the structure and the motion, projective geometry, computer vision

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INTRODUCTION

Convergence motion of cameras, similar to the movements of eyes, constitutes a subject of search in artificial vision. The introduction in the algorithms of stereoscopic vision allows getting closer to the human perception which is essentially dynamic (Faugeras, 1988).

Indeed the estimation of the movement is important for various applications such as: 3D reconstruction, objects tracking and the visual subjection.

Various methods were developed for the estimation of the movement and the structure (Bazin and Vezien, 2000; Martine and Pajdla, 2003). We distinguish two classes of methods; the first is based on the calculation of the optical flow and the spatio-temporal relations (Dekeyser *et al*., 2000); the second's on the feature matching (Bartolli and Sturm, 2003; Huang and Netravali, 1994).

In this last case, used approaches are based generally on Euclidian's models and require a calibration of cameras (Faugeras and Mourrain, 1996; Meer *et al*., 1991; Spetsakis and Aloimonos, 1990) uses the matching to resolve the problem of the movement and the structure; but there are practically no methods which use movement to resolve the problem of the feature tracking.

Our goal is to resolve the feature matching problem in a sequence of images obtained by camera in rotation motion, without any knowledge about geometrical models of camera.

Our method is based only on the formalism of the slope of the segment, using projective coordinates of extremities of the segment in the image plane.

In this study, we present at first the theoretical aspects and the algorithmic of matching method, based on the calculation of the slopes of a line segment in the projective space. We also present the experimental results obtained by tested algorithm on different images.

POSITION OF THE PROBLEM

Hypotheses

- We have a binocular system of vision not anthropomorphic in convergence motion;
- We suppose that every image was segmented and the contour approximated by line segments.
- Let us note IM , IM , IM,.., IM,…,IM the sequence of images taken with the camera where IM is image obtained with the camera after I rotations.
- IM = {S, S, S,..., S,... S} where S is the segment k in the image I obtained by the camera after the I rotations.
- Every segment is defined with its two point's extremities.

Geometrical model of convergence motion: The camera is placed on a support plan and when it makes a movement of rotation, the centre of projection likened to a point is considered as moving on the same plan.

Because of the uncertainties of the mechanics, we take place in the unfavourable case where the centre of rotation of the camera is not unique (the theoretical optical axes intersect in various points) (Fig. 1). This has no repercussion on the proposed algorithm because it is

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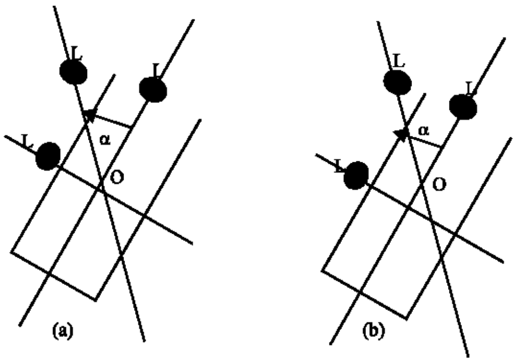

Fig. 1: Example of camera in rotation motion. (a) With fixed rotation centre (b) variable centre of rotation

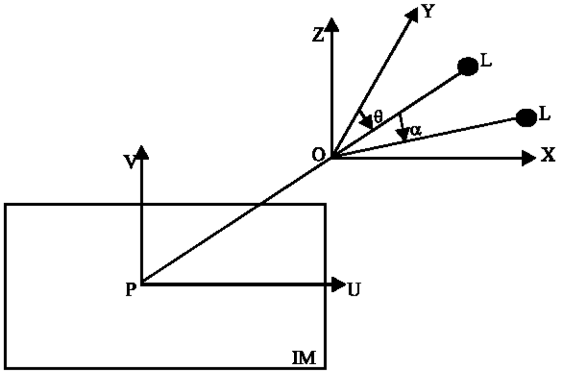

Fig. 2: Geometrical model of camera's motion

independent from the centre of rotation. The geometrical model of the movement of rotation of the camera is illustrated by it Fig. 2.

Where

- IM is projective plan
- P is the intersection of the optical axis with the image plan
- PUV is the theoretical frame in IM
- L is the centre of projection
- PL = f (focal length)
- . is the initial angle between the optical axes PL and OY
- . is the angle of rotation of the camera
- O is the theoretical centre of the rotation of the camera, obtained as intersection of the optical axes corresponding to the two states of the camera
- PO = d
- (OXYZ) is a external orthonormal frame of the camera; it can be fixed such as OX //PU, OY coincides with the optical axis and OZ // PV
- ex, ez define the dimensions of the pixel

In our theoretical study none of these parameters are supposed known.

For any point M (x, y, z) of the 3D space, it projective coordinates u, v. on IM are (Duda and Hart, 1973):

$$u_M = ex.f.\frac{-\text{Cos}(\theta).x + \sin(\theta).y}{\sin(\theta).x + \cos(\theta).y + d - f}$$

$$v_M = ez.f.\frac{-z}{\sin(\theta).x + \cos(\theta).y + d - f}$$

After rotation motion of ., the new projective coordinates of M become

$$u_M = ex.f.\frac{-\text{Cos}(\theta+\alpha).x + \sin(\theta+\alpha).y}{\sin(\theta+\alpha).x + \cos(\theta+\alpha).y + d - f}$$

$$v_M = ez.f.\frac{-z}{\sin(\theta+\alpha).x + \cos(\theta+\alpha).y + d - f}$$

We have only projective coordinates of line segment's extremities in images sequences and their mathematical formulations.

The method of line segment matching is based only on the formalism of projective point's extremities of segments.

MATERIALS AND METHODS

Choice of the primitive: We use in this method the slope of the segment as feature tracking.

This choice is justified by the fact that the slope of the segment is robust to the noise and also it is independent from the used frame (Ait Kaci and Larabi, 1996).

Theoretical aspects of the method

- S. line segment i of IM.
- S. line segment i of IM obtained after rotation of an angle . of the camera.

Let us note v. = a. U. + b.the equation of S.with regard to the frame (PUV).

Projective coordinates on IM of every point Mi (xi, yi, zi) of the scene 3D are :

$$u_0 = ex.f.\frac{-X_{i,0}}{Y_{i,0} + d - f};v_0 = ez.f.\frac{-Z_{i,0}}{Y_{i,0} + d - f}$$

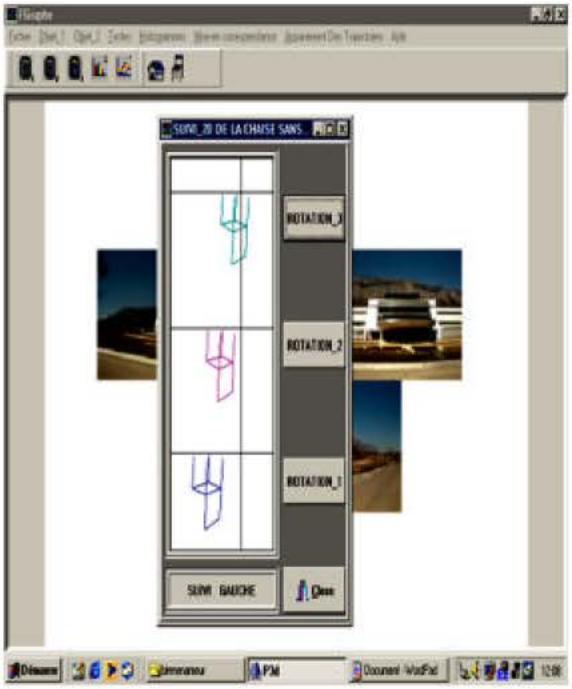

Fig. 3: Example of object in the sequence of 3 images

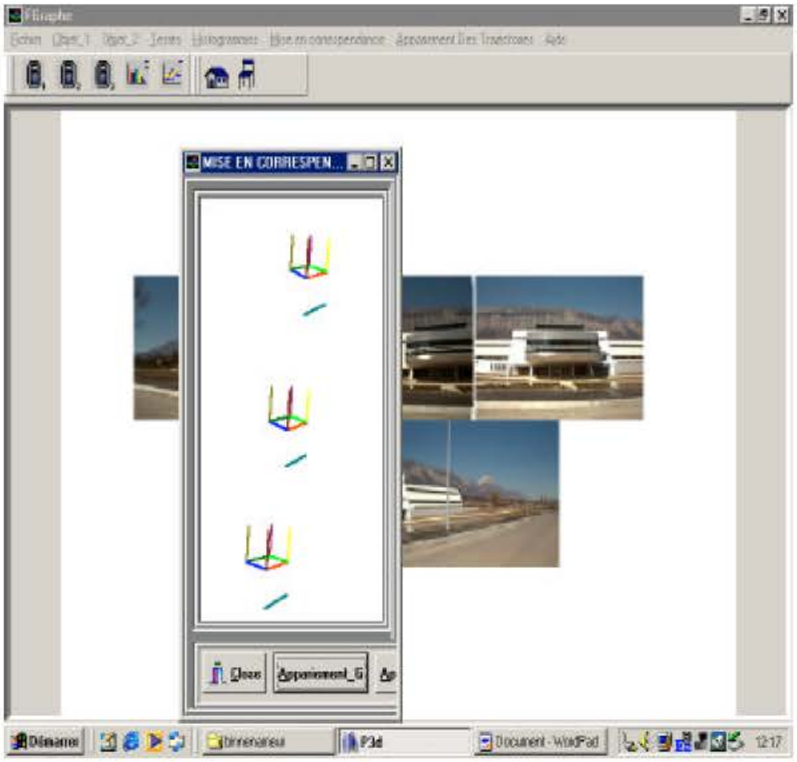

Fig. 4: Matching segments in the sequence of images (segment with same color are in correspondences)

$$\begin{cases} X_{i,0} = x_i.\cos(\theta) - y_i.\sin(\theta) \\ Y_{i,0} = x_i.\sin(\theta) + y_i.\cos(\theta) \\ Z_{i,0} = z_i. \end{cases}$$

Equation v. = a.. U. + b.of the segment S. become:

$$z_{i,0} = a_{i,0}.\frac{ex}{ez}.X_{i,0} - \frac{b_{i,0}}{ez.f}.\left(Y_{i,0} + d - f\right) \tag{1}$$

In the same way, equation v. = a..u + b.of the segment S. (homologue of S. after camera's rotation of an angle .) is as follows:

$$z_{i,1} = a_{i,1}.\frac{ex}{ez}.X_{i,1} - \frac{b_{i,1}}{ez.f}.\left(Y_{i,1} + d - f\right) \tag{2}$$

where

$$\begin{cases} X_{i,1} = x_i.\cos(\theta+\alpha) - y_i.\sin(\theta+\alpha) = X_{i,0}.\cos(\alpha) - Y_{i,0}.\sin(\alpha) \\ Y_{i,1} = x_i.\sin(\theta+\alpha) + y_i.\cos(\theta+\alpha) = X_{i,0}.\sin(\alpha) + Y_{i,0}.\cos(\alpha) \\ Z_{i,1} = z_i. = Z_{i,0} \end{cases}$$

Expressing X. and Y. according to X. and Y. give :

$$\begin{aligned} Z_{i,1} = {} & X_{i,1}\left[\frac{ex}{ez}a_{i,0}.\cos(\alpha) + \frac{b_{i,0}}{f.ez}.\sin(\alpha)\right] \\ & - \frac{Y_{i,1}}{f.ex}\left[f.ex.a_{i,0}.\sin(\alpha) - b_{i,0}.\cos(\alpha)\right] \\ & - \frac{b_{i,0}}{f.ez}\left[d - f\right] \end{aligned} \tag{3}$$

Using the Eq. (2) and (3), we obtain:

$$\frac{ex}{ez}a_{i,1} = \frac{1}{f.ez}\left[f.ex\,a_{i,0}.\cos(\alpha) + b_{i,0}.\sin(\alpha)\right]$$

where

$$\frac{a_{i,1} - a_{i,0}.\cos(\alpha)}{\sin(\alpha)} = \frac{b_{i,0}}{f.ex} \tag{4}$$

For all the same line segment in two images of sequence, the expression bellow is only defined with slopes of segment and rotation motion of camera:

Note that $\frac{b_{i,0}}{f.ex}$ = . is a constant value, for all line segment considered. This constant is estimated by using the slopes of two line segments in two images of sequence.

We can then express the following proposition:

Proposition

Note: S. the segment i inIM,, S. and S. two segment j and k in IM and IM, respectively

The necessary condition to match these three line segments is the value of . calculated from (S., S.) and the value of .' calculated from (S., S.) was the same : . (S., S.) = .' (S.,, S.) = .

The solution we propose has a way similar to that current in Hough's (1962) transformed it is a question of engendering all the possibilities for the correspondence constant . and keeping that collect the maximum of votes.

. Represent the matching factor.

Matching algorithm

```
Begin
    For all segment S. of IM
      Do
         For all S. of IM
         Do    Estimate
         $\frac{a_{j,1} - a_{i,0}.\cos(\alpha)}{\sin(\alpha)} = \sigma_{ij}$
         For all S. of IM
         Do Estimate
         $\frac{a_{k,2} - a_{i,0}.\cos(\beta)}{\sin(\beta)} = \sigma_{ik}$
            end ;
         end;
    end;
```

Search the value of . witch is engendered by the maximum of segments.

All the pairs of line segments witch engendered . are in correspondences.

End.

Results of the experiment: The matching algorithm tested on synthetically data generated by computer gives expected results on noisy and not noisy data (Fig. 3 and 4).

Table 1 present the obtained results for different slopes end noises . used. We can summarize table as follow:

- For slopes .=60° the robustness of algorithm is for .=1 pixels
- For slopes .=60° and .=45° the robustness of algorithm is for .=2 pixels
- For slopes .=45° the robustness of algorithm is for . .=3 pixels

Table 1: Results of matching algorithm

	Angle <= 45°			45° <= Angle <= 60°			Angle > 60°		
Bruit δ (pixel)	Pente a	Arctg (a) (deg)	Nombre d'appariement	Pente a	Arctg (a) (deg)	Nombre d'appariement	Pente a	Arctg (a) (deg)	Nombre d'appariement
0.1	-0.3499	-19.26	9/9	1.3251	52.96	9/9	1.7531	60.30	8/9
	-0.7004	35.01	9/9	-1.6434	-58.68	9/9	3.2404	72.85	6/9
0.3	-0.2573	-14.43	9/9	-1.0358	-46.01	9/9	2.8732	70.81	5/9
	0.84866	40.32	9/9	1.4604	55.6	9/9	-8.2514	-83.09	3/9
0.5	0.1321	7.53	9/9	1.1334	48.58	8/9	2.2705	66.23	7/9
	0.9526	43.61	9/9	-1.3013	-52.46	5/9	-4.4958	-77.46	3/9
1	0.49509	26.34	9/9	1.4207	54.86	8/9	2.2240	65.79	6/9
	0.5904	30.56	9/9	-1.5463	-57.11	5/9	-4.8673	-78.39	3/9
2	0.1387	7.9	9/9	1.2053	50.32	8/9	1.95754	62.94	4/9
	0.7096	35.36	7/9	1.6781	59.21	8/9	-2.8555	-70.39	4/9
3	0.6494	32.99	8/9	1.0398	46.12	7/9	2.09278	64.46	7/9
	0.8686	40.98	7/9	1.6479	58.75	4/9	70.31	70.31	6/9

The experiment shows that the algorithm gives better results for the oblique segments (. = 45°) and for the long segments with regard to the short segments.

CONCLUSIONS

We have proposed a method of matching line segments by using as primitive the slope of the segment which is a robust feature.

This method does not require any knowledge of the geometrical models of the camera but it need the knowledge about its motion.

The experimental results showed that the algorithm is robust until three pixels of noises, and it gives better results for the oblique segments (. = 45°) and for the long segments with regard to the short segments.

This matching process supplied as result the trajectories of the primitives which are going to be used to resolve a problem of stereoscopic matching.

After suppression of vertical segments and estimating . the matching segments are as follow:

The line segments with the same color are in correspondence. The vertical segments are matched using neighborhood constraints (Fig. 4).

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