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Estimating the Motion Parameters of a Moving Camera from Perspective Image Sequences

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Synopsis

This paper describes the results of some experiments on estimating the motion parameters of a moving camera from two or more consecutive image frames. Our method is based on the image sequences of a scene taken from different positions and orientations using a digital still camera in static environment. We extract the motion information about the scene and camera from two image sequences of a scene by perspective transformation. Experimental results with real images are presented.

Keywords : moving camera, perspective transformation, motion parameters.

1. Introduction

The problem of estimating the motion parameters of a moving camera from a sequence of images is important for the application of image processing and computer vision in mobile robots and so on. Most methods for the detection of motion in image sequences involve the subtraction of successive frames [1], [3]. We estimate the motion parameters from two image sequences by perspective transformation. First, we find the corresponding points in two image frames of a given scene taken from different positions and orientations by manually moving a camera. Particularly, we detect the rotational motion parameters and translation parameters of the camera.

In Section 2, we review the mapping of a three-dimensional scene into a two dimensional picture from the process of optical imaging. In 2.2, we define our camera coordinate system and derive the linear equations for camera motion. Then, using this set of linear equations, we computed the camera motion parameters and experimental results with real images are presented in Section 3. Our experiment is based on two images taken from a digital camera. The image, in this experiment, contains 1528×1146 pixels.

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2. Basic Model and Equations

2.1 Imaging Transformation

Let $P(X,Y,Z)$ denote the Cartesian coordinates of a scene point with respect to the camera, as shown in Fig. 1, and let $p(x,y)$ denote the corresponding coordinates in the image plane. The image plane is located at the focal length $Z = f_c$. It can be normalized to 1 without loss of generality. The perspective projection of a 3D-point $P(X,Y,Z)$ to a point $p(x,y)$ on the image plane is express by:

$$x=\frac{X}{Z} \quad , \quad y=\frac{Y}{Z} \qquad \text{........... (1)}$$

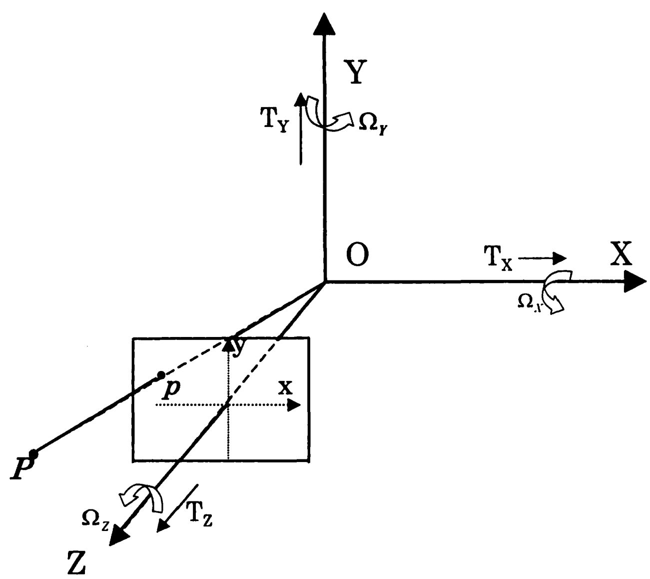


Fig. 1 Coordinate system of camera and image plane.

2.2 Camera Motion

In this section, we present a notation for describing the motion of a camera through an environment containing reference object (see Fig. 2). Due to the camera motion the 3D scene point (X,Y,Z) appears to be motion relative to the camera with rotation Ω and translation T and therefore observed at new world coordinates (X',Y',Z') express by:

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = R_\Omega \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} + T \qquad \text{.............. (2)}$$

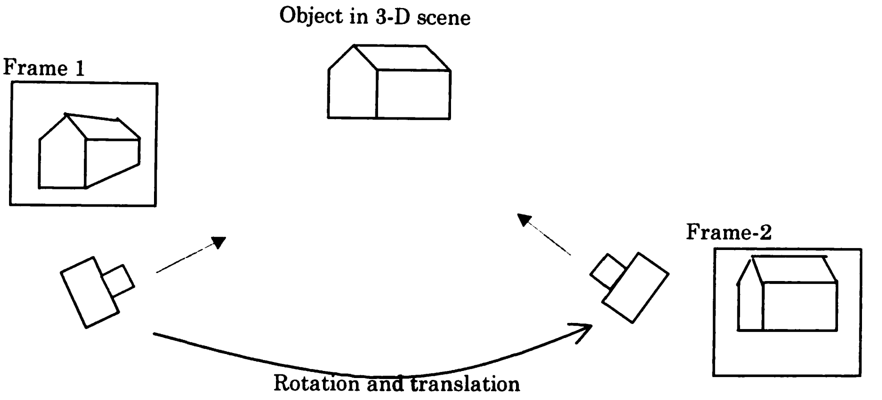


Fig. 2 Camera motion system.

Where $T = (T_X, T_Y, T_Z)$ and $\Omega = (\Omega_X, \Omega_Y, \Omega_Z)$ represent the relative translation and rotation of the camera in the scene. The rotation matrix R_Ω can be approximated, assuming a small field of view and small values of the rotation parameters.[2]

$$R_\Omega = \begin{pmatrix} 1 & -\Omega_Z & \Omega_Y \\ \Omega_Z & 1 & -\Omega_X \\ -\Omega_Y & \Omega_X & 1 \end{pmatrix} \qquad \text{..........(3)}$$

If (x, y) and (x', y') are the image coordinates corresponding to the points (X, Y, Z) and (X', Y', Z'), respectively, then

$$x' = \frac{X'}{Z'} = \frac{x - \Omega_Z y + \Omega_Y + T_X / Z}{-\Omega_Y x + \Omega_X y + 1 + T_Z / Z} \qquad \text{................(4)}$$

$$y' = \frac{Y'}{Z'} = \frac{\Omega_Z x + y - \Omega_X + T_Y / Z}{-\Omega_Y x + \Omega_X y + 1 + T_Z / Z} \qquad \text{................(5)}$$

All points (X, Y, Z) of a planer surface in the 3D scene satisfy a plane equation $Z = AX + BY + C$, which can be expressed in terms of image coordinates by using equation (1) as:

$$\frac{1}{Z} = \alpha.x + \beta.y + \gamma = u \qquad \text{................(6)}$$

where $\alpha = -\frac{A}{C}$ $,\beta = -\frac{B}{C}$ $,\gamma = \frac{1}{C}$. Substituting (6) in (4) and (5), we get:

$$\left.\begin{array}{l}(x'y)\Omega_X - (1+xx')\Omega_Y + (y)\Omega_Z - uT_X - (x'u)T_Z = x - x' \\ (1+yy')\Omega_X - (xy')\Omega_Y - (x)\Omega_Z - uT_Y + (y'u)T_Z = y - y'\end{array}\right\} \quad .....(7)$$

We can get the coefficients of T and Ω from two image sequences.

3. Computing Camera Motion Parameters and Experimental Results

First, we take the two image frames using a moving camera from different positions and orientations. We extract any three-feature points, which are projected from a planer surface in the three dimensional scene, in the first frame and their corresponding points in the second frame, as shown in Table 1. So any three pairs of image coordinates can be obtained from two pictures and substitute in (7), which is the set of linear equations in six unknowns. Each pair of image coordinates gives us two equations in these parameters, these three pairs of image coordinates yield a total of six equations in the six independent parameters. Solving these equations system we can obtain the translation parameters $T=(T_X,T_Y,T_Z)$ and rotation parameters $\Omega=(\Omega_X,\Omega_Y,\Omega_Z)$.

The camera motion parameters between two frames in **Fig. 3** are,

$T=(T_X,T_Y,T_Z)=(24.2_{cm},3_{cm},0.35_{cm}),\Omega=(\Omega_X,\Omega_Y,\Omega_Z)=(-5^\circ,15^\circ,5^\circ)$.

Ones computed by equation (7) are $(T_X,T_Y,T_Z)=(25_{cm},2.9_{cm},0.5_{cm})$

$(\Omega_X,\Omega_Y,\Omega_Z)=(-2^\circ,17^\circ,3^\circ)$. We can confirm the effectiveness of our method through this result.

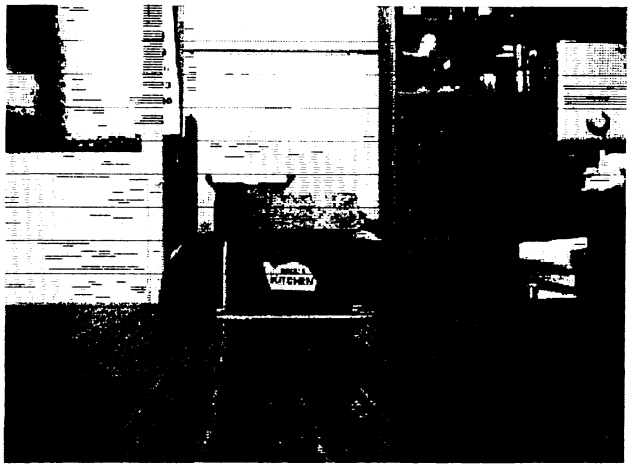
Table-1 Three pairs of image coordinates in two frames

x	y	x'	y'
933.745	758.951	851.487	767.99
635.585	768.836	541.804	769.02
631.983	571.319	539.480	573.25

4. Conclusion

In this paper we detected the camera motion from two image sequences in static scenes and we demonstrate for the real images. In the next step, we should take into consideration of the reconstruction of a 3D scene from two dimension images based on this approach.

(a)



(b)

Fig. 3 Two image frames, (a) frame-1 and (b) frame-2 are taken from different positions and orientations.

References

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