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# A method for image processing by use of inertial data of camera

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**Abstract**

This paper is to present a method for recognizing an image of a tracking object by processing the image from a camera, whose attitude is controlled in inertial space with inertial coordinate system. In order to recognize an object, a pseudorandom M-array is attached on the object and it is observed by the camera which is controlled on inertial coordinate basis by inertial stabilization unit. When the attitude of the camera is changed, the observed image of M-array is transformed by use of affine transformation to the image in inertial coordinate system. Taking the cross-correlation function between the affine-transformed image and the original image, we can recognize the object. As parameters of the attitude of the camera, we used the azimuth angle of camera, which is detected by gyroscope of an inertial sensor, and elevation angle of camera which is calculated from the gravitational acceleration detected by servo accelerometer.

**Keyword**

Pseudorandom M-array, Affine-transform, Inertial Coordinate System, Inertial Stabilization Unit, Cross-Correlation

## 1. Introduction

Inertial coordinate system is the coordinate system which is not affected by the autorotation of the earth. So inertial coordinate system becomes a common coordinate system of vision, movement system everywhere over the earth and the coordinate system doesn't need to be fixed anywhere, and it can be applied to arbitrary movement. When a moving object is captured with a camera and tracked as real image of 2 dimension, the vision system becomes widely applicable with the use of the inertial coordinate system. In this paper, a method of image processing by use of correlation technology and pseudo-random M-array is described. 2 dimensional image processing in inertial space is to be carried out in inertial coordinate system, not in camera coordinate system. For this reason, screen image is taken by the camera which is loaded on the space stabilization unit having 2-axes gimbal mechanism. The method of image processing makes real image on inertial coordinate system affine-transformed by use of attitude data of camera. Accordingly, recognition of object is possible by use of the relative position difference between the template image and the affine-transformed image.

## 2. Inertial stabilization unit

Figure 1 shows 2-axes gimbal mechanisms of the inertial stabilization unit and Figure 2 shows design principle of perpendicular standard of inner gimbal. Control method of inertial stabilization unit is to use the space stabilization control loop where angular velocity of Y and Z-axes from gyroscope is inputed to compensation element as shown in the figure. And, the control of attitude angle is controlled by using servo accelerometer and gyroscope.

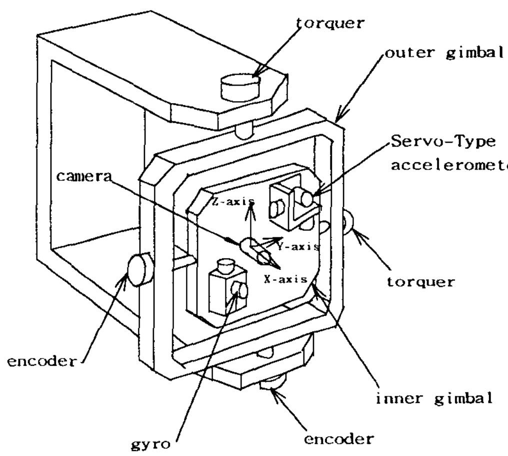


Fig.1 Schematic diagram of 2-axes gimbal mechanisms

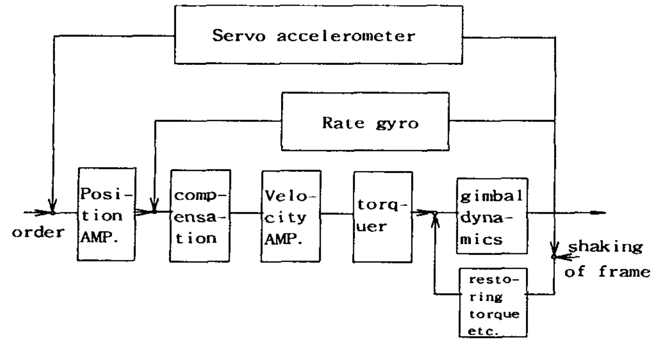


Fig.2 Design principle of inner gimbal

Figure 3 shows relationship between servo accelerometer output of X-axis of the body coordinate system and gravitational acceleration. Servo accelerometer output of X-axis takes 0 when inner gimbal becomes perpendicular. When the accelerometer is inclined, the output comes out and indicates gravity acceleration. This X-axis acceleration is detected and tilt angle is calculated from $\theta = \sin^{-1} \alpha/_{G}$ ( $\theta$ : tilt angle, G: gravity acceleration, $\alpha$ : detected acceleration).

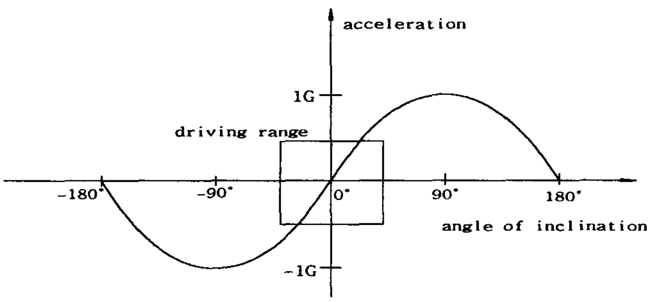


Fig.3 Relationship of servo accelerometer output and gravitational acceleration

The azimuth angle is obtained from the integration of the detected angular velocity by gyroscope. The elevation and azimuth angles are obtained by averaging 100 data among which 10 data are renewed with a certain sampling period.

### 3. Affine transformation

Affine transformation of image is performed using the elevation and azimuth angle of inner gimbal. Affine transformation processing is carried out affine transformation processing module IP90MD16. This board stores original image set to outside memory, and output the converted image in the next frame. Affine transformation procedure of this board generate converted address of output image by affine transformation as shown in Eq. (1). Secondly, the input image is read from the outside memory. And, the first-degree linear interpolation calculation is performed for the image data and the image is outputed on converted address from output port.

$$\begin{pmatrix} Dy \\ Dz \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} Sy \\ Sz \end{pmatrix} + \begin{pmatrix} E \\ F \end{pmatrix} \qquad (1)$$

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = K \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$

Sy : Y-coordinate within original image

Sz : Z-coordinate within original image

Dy : Y-coordinate within output image of output pixel

Dz : Z-coordinate within output image of output pixel

$\theta = 0^{\circ}$ : Rotation angle of X-axis

$E = Ky \cdot \tan\alpha$ : The amount of movement of the inertial coordinate origin in Y-direction, which is calculated from rotation angle $\alpha$ of azimuth

$F = Kz \cdot \tan\beta$ : The amount of movement of the inertial coordinate origin in Z-direction , which is calculated from rotation angle $\beta$ of elevation

K, Ky, Kz : Proportional constant

### 4.Recognition of object by use of cross-correlation of pseudo-random M-array

4.1 Creation of pseudo-random M-array

The method of generation of M-sequence which is used for pseudo-random M-array is as follows.

Primitive polynomial : $f(x) = x^8 + x^6 + x^5 + x + 1$

Initial value is (00011101).

The pseudo-random M-array is array of 2-dimensions which have the same property as M-sequence as far as statistical properties such as auto-correlation are concerned, and it can be easily generated using M-sequence. We used M-sequence of N=255 (N:period) to make M-array of 15 columns and 17 rows. The property used for recognition of object is that auto-correlation function $\Phi_{bb}(i,j)$ of M-sequence {bi} becomes as follows.

$$\Phi_{bb}(0,0) = 1$$

$$\Phi_{bb}(i,j) = \frac{-1}{N} \qquad 0 \le i \le M1,\ 0 \le j \le M2$$

4.2 Recognition of object by use of M-arrray

The recognition of pseudo-random M-array on the object can be carried out by seeking for cross-correlation value.The recognition of camera image while the gimbal is moving is performed as follows. The camera image is transformed into affine transformation on inertial coordinate system. Then the affine transformed image becomes possible to be compared with the reference template image. Accordingly, taking the cross-correlation function between the template image and the affine-transformed image, the relative position of both images is calculated. Thus, the position of goal object is recognized from camera image.

## 5. Experimental result

5.1 Elevation angle

Elevation angle can be calculated by two ways: one is an inclinational angle which is calculated from the detected gravitational acceleration and the other is a rotation angle with respect to Y-axis which is integrated angular velocity of gyroscope around Y-axis. The inclinational angle is obtained from $\theta = \sin^{-1} \alpha/_{G}$. Two elevation angles thus obtained are shown in Figure 4. Figure 4 shows that both angles are fairly in good agreement.

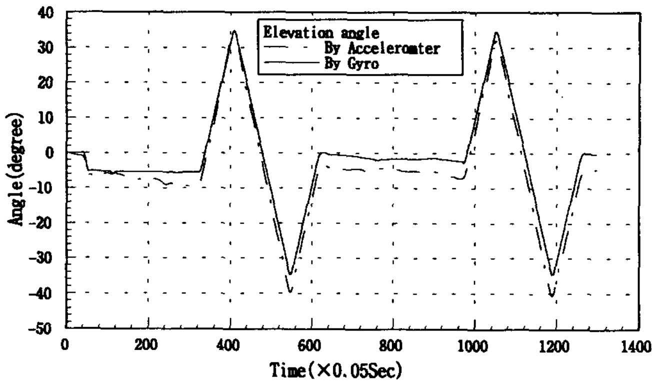


Fig.4 The elevation angle by gravitational accelerometer and by gyroscope

5.2 Azimuth angle

Since azimuth angle can not be detected by gravitational accelerometer, it is calculated as relative rotation angle around Z-axis by integrating angular velocity around Z-axis which is detected by gyroscope. The calculated rotation angle is shown in Figure 5.

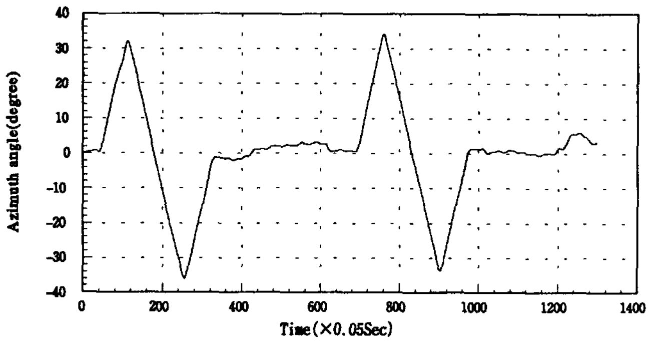


Fig.5 The azimuth angle calculated by gyro

5.3 Elevation and azimuth angle obtained by gimbal's driving command

Let gimbal's driving command value of azimuth AZ and elevation angle EL be (AZ,EL). 4 groups of command {(0° , 0° ), (0° , 5° ), (20° , 0° ), (20° ,-15° )} are applied to controller of the gimbal, every command for 15 seconds. The results of calculated azimuth and elevation angle are shown in Figure 6. From Figure 6, we see that for command (0° , 5° ), both azimuth and elevation angle are in stable condition. So, we used this region for affine transformation.

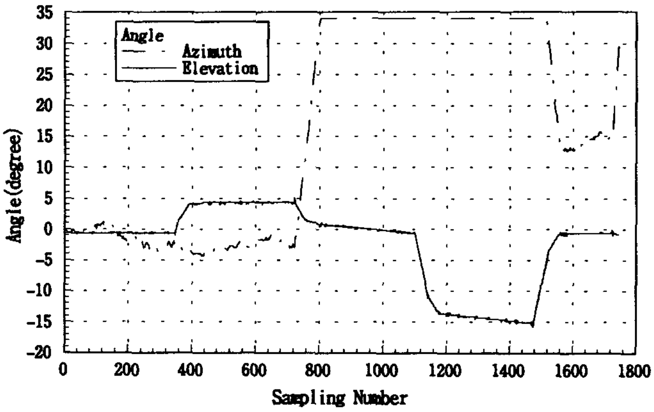


Fig.6 Elevation and azimuth angle for driving command

5.4 Affine transformation of pseudo-random M-array

In order for the object to be caught by the camera which is loaded on inertial stabilization unit to track image, the camera image is transformed into affine transformation on inertial coordinate system. Figure 7 shows the camera image which was taken when inner gimbal is in its origin in inertial coordinate axis.

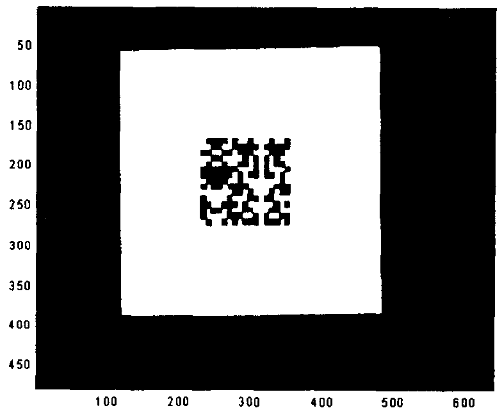

Fig.7 A camera image with inertial reference

In order for the camera image to be affine-transformed and displayed in the monitor, the template image is made by reducing the original image by 35% (Figure 8).

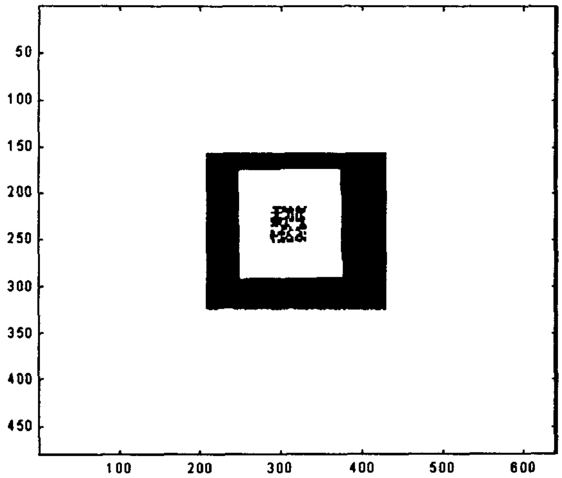


Fig.8 Template image of 35% compression

Figure 9 shows the affine-transformed camera image which is transformed into inertial coordinate system, when azimuth is 0.1 degree and elevation is 3.9 degree.

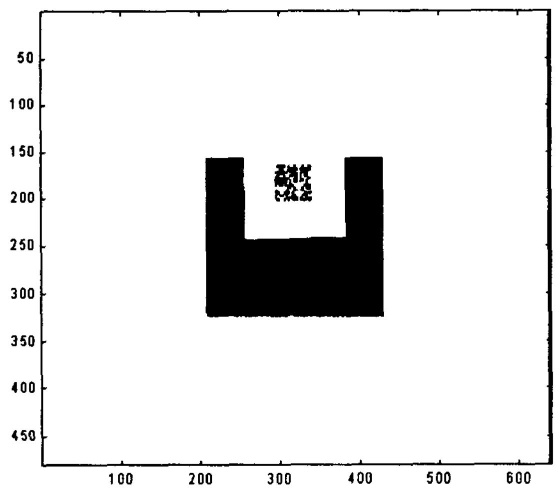


Fig.9 Affine-transformed camera image when gimbals move

5.5 Cross-correlation function of pseudo-random M-array

The reference M-array image which is extracted from M-array portion of the template image is shown in Figure 10.

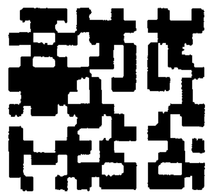

Fig.10 Observed reference M-array image

The cross-correlation function between the template image and the reference M-array image is shown in Figure 11. From the position of peak of the correlation function, we obtain the position of M-array in the template image. M-array of the template image is equal to shifted version of 59 columns 6 rows of the reference position.

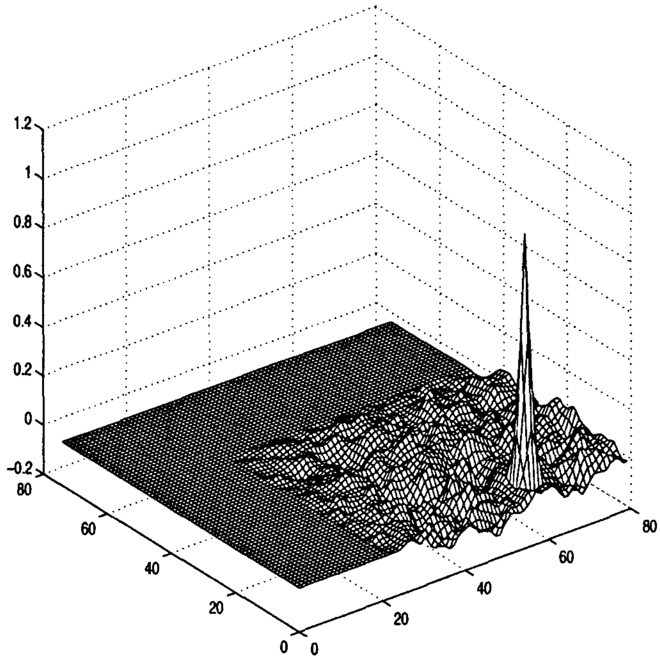


Fig.11 Cross-correlation function between the template image and the reference M-array image

The cross-correlation function between the reference M-array and the affine-transformed image is shown in Figure 12. The position of M-array in camera image is understood from the position of peak of the correlation function.

From the correlation function between the reference M-array and the affine-transformed M-array, the affine-transformed M-array is equal to the shifted 10 columns 14 rows of the reference M-array. Therefore, the position of the affine-transformed M-array is shifted by 49 columns 8 rows from the position of M-array of the template image. If difference of this pixel is converted into elevation angle, it becomes about 5.2 degree, which is a little bit larger than the value 3.9 measured with accelerometer. An effort is now being made to improve the accuracy.

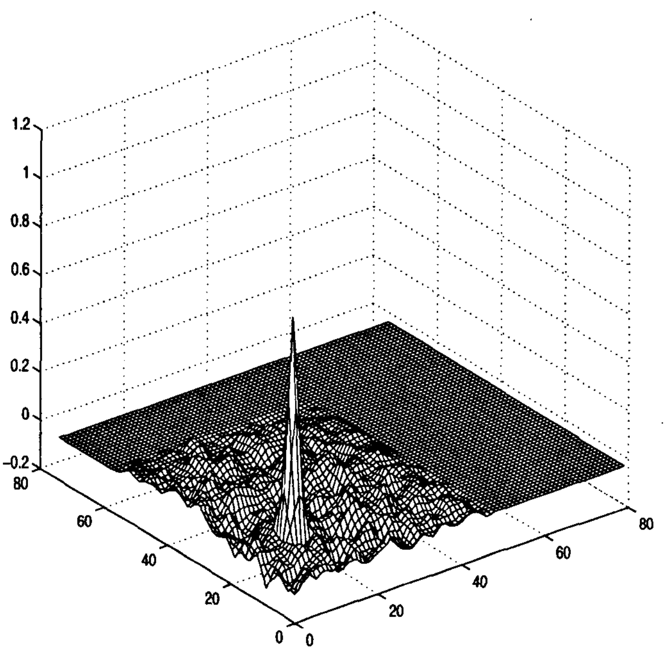


Fig.12 Cross-correlation function between affine-transformed image and the reference M-array image

## 6. Conclusions

A method for image tracking by use of inertial data of camera is described. A pseudo-random M-array is attached on the object to be tracked, and is observed with a camera whose attitude is controlled in inertial space with inertial coodinate system the observed image is affine-transformed into an image in inertial coordinate system. Tracking the cross-correlation function between the affine-transformed image and the reference image, we can recognize the position of the object. The experimental results show that this method of image processing would have wide applications in tracking a moving object with a camera.

## 7. References


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