Signal Generation for Automatic Control of a Monitoring Camera

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***Abstract*—** This paper proposes a signal generation method for automatic control of a monitoring camera. Using the control signal, the monitoring camera can track a moving object and keep it near the image center for a longer time. The proposed method is estimated in the experiments that automatically move a maker located at the specified position to the image center.

***Index Terms*—** automatic control, monitoring camera, moving object, image center

I. INTRODUCTION

Recent developments in science and technology allow cameras to continuously monitor objects. However, it is difficult for the camera to observe a freely moving object, especially when the camera is fixed or moves along a defined pattern. If the camera can track the moving object, it can keep the object in its FOV (field of view) for a longer time. Tracking of a moving object means to generate the control signal which changes a camera's viewing direction through the adjustment of its pan/tilt/zoom, and to keep the object near the FOV center [1,2]. This paper proposes a method to generate the proper control signal for a pan/tilt and zoom camera to track and properly frame an object within the camera image as viewed when viewed by a digital camera. An experimental camera generates an image of 640x480, provides data for its pan/tilt/zoom, and is controlled by RS232C.

The rest of the paper is organized as following. In Section 2, camera control parameter – pan, tilt, zoom – are presented. Experimental results will be described in Section 3. Conclusions appear in Section 4.

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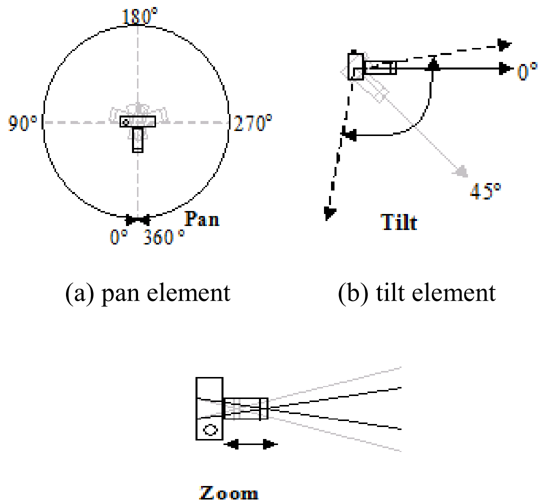
II. CONTROL ELEMENTS

Depending on the size of an object, the camera lens must zoom in or zoom out to effectively observe and monitor the moving object. In addition, depending on the direction of the moving object, horizontal or vertical shift of camera is required. These functions which change the orientation of the camera, as shown in Fig. 1, are typically referred to as pan, tilt and zoom.



(a) pan element (b) tilt element

(c) zoom element

Fig. 1 Control elements for monitoring camera

A. Pan signal

The pan function rotates camera in horizontal direction, allowing it to rate 360^{o}. This control function of the camera allows effective observation and monitoring of an object moving in horizontal direction. It detects horizontal movement of an object within a captured image in terms of pixel units and displays the objects traveled horizontal distance relative to the center point. After converting this into an angle, it converts such angle into a control signal for the pan motor necessary to reposition the camera.

In order to perform such calculation, we need to know the view angle. Then, we can calculate focal length (FL) of the camera by using the horizontal view angle, as shown below.

$$FL = \frac{320}{\tan(hViewA/2)} \tag{1}$$

where, the constant number 320 is the 1/2 the width of an image and *hViewA* refers to the horizontal view angle. Relative horizontal angle depending on the location of pixel can be calculated by using the focal length, as shown in below.

$$hReA = \tan^{-1}\left(\frac{hRePos}{FL}\right) \tag{2}$$

where, *hRePos* is the relative position of the pixel and is the horizontal distance between the location of the object and the horizontal center. Pan data of camera depending on the location of the object can be calculated as follows.

$$PanData = PanDp_1 \times hReA \tag{3}$$

where, $PanDp_1$ refers to pan data for rotating the camera in horizontal direction by 1^o.

B. Tilt signal

Tilt refers to moving the camera in the vertical direction. Unlike pan, rotation of tilt is limited to slightly over 90^o. This is a camera control function that is effective in observing/monitoring vertically moving object from an image. Method for acquiring tilt data, which is used to observe/monitor vertically moving object, is similar to the method used in acquiring pan data. However, rather than taking horizontally movement, it utilizes vertical movement for calculation. Under the presumption that, pixel is structured in square, vertical view angle can be calculated by utilizing Equation (4) and the number of vertical pixels shown. Relative vertical angle depending on the location of vertical pixel can be calculated by utilizing the focal distance of Equation (1) and vertical view angle.

$$vReA = \tan^{-1}\left(\frac{vRePos}{FL}\right) \tag{4}$$

where, *vRePos* refers to relative position of the pixel, denoting vertical distance between location of an object in the image and center of vertical line. Tilt data of the camera depending on the location of the object can be calculated as follows.

$$TiltData = TiltDp_1 \times vReA \tag{5}$$

where, $TiltDp_1$ refers to tilt data for rotating the camera in vertical direction by 1^o.

C. Zoom signal

The zoom function of the camera is a function used to reduce or enlarge an image by adjusting focal distance. This control function of camera, allows effective observation and monitoring of the target object by adjusting the object in to adequate size. Therefore, in order to observe or monitor an object through adequate ratio, the moving object must be detected, adequate ratio has to be sided depending on the size then such data should be converted in to zoom data. This paper has investigated the size of a varying object by applying the constant rate of zoom data. Then, we have derived relationship between zoom data and ratio, by utilizing polynomial curve fitting method, shown in below.

$$y(x) = p_0 + p_1x + p_2x^2 + \cdots + p_{n-1}x^{n-1} + p_nx^n \tag{6}$$

$$x(y) = q_0 + q_1y + q_2y^2 + \cdots + q_{n-1}y^{n-1} + q_ny^n \tag{7}$$

where, *x, y* refers to zoom data and ratio respectively. *y(x), x(y)* refers to ratio/zoom data acquired from independent zoom data/ratio. p_i, q_i refers to polynomial equation derived from the result of curve fitting.

III. EXPERIMENTAL RESULTS

In this paper, we have conducted an experiment to confirm validation of methods used to generate pan data, tilt data and zoom data mentioned earlier. Fig. 2 shows environment of the experiment conducted. In the experiment, we have installed dome monitoring camera in the laboratory and acquired 640x480 size images. After acquiring images, we have calculated camera control information by utilizing equations shown above. We then have transmitted calculated control signal to the camera using RS232C.

A. Pan data

To evaluate the validity of pan data, we have designated horizontal locations as shown in Fig. 2. The horizontal angle has been calculated by utilizing Equation (2) for moving each mark to the central coordinate. Then, by using the horizontal angle, the pan data has been calculated by utilizing Equation (3). After performing calculations, we have compared calculated data with the actual measurement. The result is shown in Table 1.

Fig. 2. Experimental environment

Table 1 Pan Data

Horizontal Coordinate	0	40	80	120
Calculated Angle	-26.00	-23.11	-20.10	-16.96
Calculated Pan Data	-1040	-924	-804	-678
Measurement Pan Data	-1040	-930	-800	-675
Angle of Real Data	-26.00	-23.25	-20.00	-16.88
Horizontal Coordinate	160	200	240	280
Calculated Angle	-13.71	-10.37	-6.95	-3.49
Calculated Pan Data	-548	-415	-278	-140
Measurement Pan Data	-545	-410	-270	-135
Angle of Real Data	-13.63	-10.25	-6.75	-3.38
Horizontal Coordinate	360	400	440	480
Calculated Angle	3.49	6.95	10.37	13.71
Calculated Pan Data	140	278	415	548
Measurement Pan Data	140	275	410	545
Angle of Real Data	3.50	6.88	10.25	13.63
Horizontal Coordinate	520	560	600	640
Calculated Angle	16.96	20.10	23.11	26.00
Calculated Pan Data	678	804	924	1040
Measurement Pan Data	675	800	920	1035
Angle of Real Data	16.88	20.00	23.00	25.88

As we can see from Table 1, calculated pan orientations and actual measurement of this orientation have a maximum difference of 6 pixels. Differences may be attributed to difficulties in aligning the designed marks with the desired locations. The margin of error is partially attributed to difficulties in determining the exact coordinate for the designated marks which may not be located exactly at a single pixel. This margin of error of 6 pixels corresponds to approximately 0.2^{o} in horizontal angle. That is equivalent to less than a 3 pixel difference between the actual center of the image and the detected positioned image center.

B. Tilt data

Method used to confirm validation of tilt data is similar to validation method for pan data. First, mark locations on the vertical directions. However, such procedure had been conducted in some sections only, for it was difficult to acquire data. Vertical angle of each mark has been calculated by using Equation (4) and tilt data has been calculated by utilizing result of Equation (4) in Equation (5). This is shown in Table 2.

Table 2 Tilt Data

Vertical Coordinate	240	280	320
Calculated Angle	0.00	3.49	6.95
Calculated Tilt Data	0	233	463
Measurement Tilt Data	0	235	365
Angle of Real Data	0.00	3.53	6.98
Vertical Coordinate	360	400	440
Calculated Angle	10.37	13.71	16.96
Calculated Tilt Data	691	914	1131
Measurement Tilt Data	685	905	1125
Angle of Real Data	10.28	13.58	16.88

Like the margin of error generated from pan data, tilt data has generated slight margin of error between calculated value and measured value. Here, the maximum margin of error of 9 has been shown and this is approximately 0.13^{o} in vertical angle. This is less than 2 pixel distance when converting such angle in to pixel.

C. Zoom data and ratio

In order to derive relational equation between zoom data and ratio, the study has measured ratio of 32 selected zoom data. The researcher has utilizing polynomial equation of 5^{th} degree from polynomial fitting method and acquired coefficient of Equation (8) and (9) for deriving relationship between zoom data and ratio.

$$\begin{bmatrix} p_0 \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \end{bmatrix} = \begin{bmatrix} 9.5361 \times 10^{-1} \\ 3.9403 \times 10^{-4} \\ -1.0553 \times 10^{-7} \\ 8.6191 \times 10^{-11} \\ -2.1540 \times 10^{-14} \\ 2.2527 \times 10^{-18} \end{bmatrix} \qquad (8)$$

$$\begin{bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \\ q_4 \\ q_5 \end{bmatrix} = \begin{bmatrix} -3.2584 \times 10^{3} \\ 4.1804 \times 10^{3} \\ -8.0971 \times 10^{2} \\ 7.9810 \times 10 \\ -3.7839 \\ 6.8519 \times 10^{-8} \end{bmatrix} \qquad (9)$$

Fig. 3 shows relationship between zoom data and ratio by utilizing coefficient of Equation (8). Low zoom data has shown almost uniform value between measurement value and calculated value. However, high zoom data has shown large differences. Nevertheless, the possibility of using high ratio in utilizing camera is minimal so the result of curve fitting may been seen as valid. To validate the adequacy of relational equation between zoom data and ratio, the study has applied the equation in actual system, configured ratio and performed zoom data calculation for acquiring configured ratio. Table 3 shows calculated ratio by utilizing zoom data and actual measurement ratio. Configured ratio is not generated by zoom data for zoom function of camera has staircase shaped value, rather than curved type value. That is, the ratio can be adjusted when certain zoom data increases.

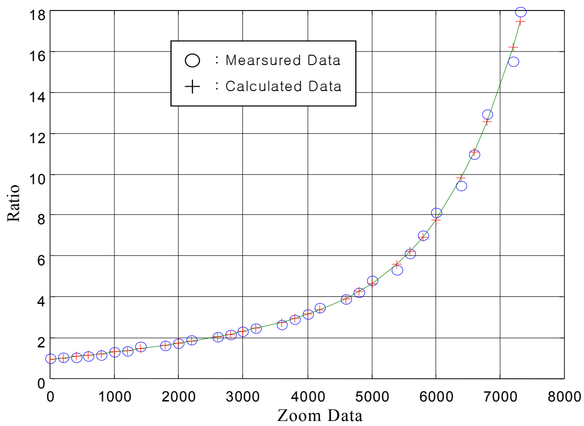


Fig. 3. Ratio as zoom data

Table 3 Zoom Data and Ratio

Ratio	1:1	1:1.5	1:2	1:2.5
Calculated Value	41	1421	2489	3296
Real Zoom Data	3684	2263	1195	388
Measurement Value	24	37	50	62
Measurement Ratio	1:1.00	1:1.54	1:2.08	1:2.58
Calculated Ratio	1:1.00	1:1.53	1:1.96	1:2.47
Ratio	1:3	1:3.5	1:4	1:4.5
Calculated Value	3893	4333	4665	4942
Real Zoom Data	65327	64887	64555	64278
Measurement Value	73	87	97	108
Measurement Ratio	1:3.04	1:3.62	1:4.04	1:4.50
Calculated Ratio	1:3.02	1:3.54	1:4.01	1:4.97

IV. CONCLUSION

This paper proposes a signal generation method for automatic control of a monitoring camera. The proposed and manual methods are compared in the experiments that move a maker located at the specified position to the image center. The performance difference between two methods is negligible and it is caused by observational error only.

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