THE URBAN FACILITIES MONITERING SYSTEM USING FISH-EYE LENS

Jin. A. Kang [a, *], Sang. Kwan. Nam [a], Tae.Hoon.Kim [a], Yoon. Seok. Oh [a]

[a] KICT(Korea Institute of Construction Technology), Repulic of Korea - (jakang, griffey, kth, ysoh)@kict.re.kr

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ABSTRACT:

The demand that we are monitoring security and crime of the urban facilities is increasing recently, but the using CCTV devices are expensive. So, we introduce the camera system using the Fish-eye Lens, which enhance the efficiency of the urban facilities monitering. First, we carry out the calibration of the Fish-eye Lens indoors, we calculate the correction parameters, and then covert the original image-point to new image-point correcting distortion. Second, the correction program with the correction parameters can obtain the real-time correcting image. Lastly, for authorization the developed program we compare correcting-image with scanning-image, it is showed the RMSE is 3.2pixel. This correct method can be monitering more effectively, economical in the urban facilities monitoring.

* Corresponding author. This is useful to know for communication with the appropriate person in cases with more than one author.

1. INTRODUCTION

1.1 Background

The CCTV and Web Camera recently receive attention, the future construction/traffic field is used in the area of u-City(ubiquitous-City) building, construction site monitoring, and facility management of the South Korea. Specially, the construction site monitoring will be used in the area of monitoring the safety of personnel management, facilities management and process control monitoring for the security management of facilities, process management, etc.

But the market is growing, the maintenance costs be sudden uprise because the equipment is not only imported but expensive. So, a fisheye lens of low-price CCTV and Web has become one of the alternatives. Generally, angle of view of a normal lens is about 45°, 60°~ 90°is the wide-angle, 90°or more is the fish-eye Lens. The fish-eye lens is used to the objects recognition, location-aware in the area of robotics.

1.2 Previous work

This paper(Ryusuke.,2005) introduce to a method to automatically calibrate lens distortion of wide-angle lens.

This project structured-light patterns using a flat display to generate a map between the display and the image coordinate systems. This approach has two advantages. First, it is easier to take correspondences of image and marker (display) coordinates around the edge of a camera image than using a usual marker, e.g. a checker board. Second, since it can easily construct a dense map, a simple linear interpolation is enough to create an undistorted image.

Also, other paper(Michal., 2008) propose a method bases on differential geometry and on determination of arc curvature in every segment of photographed test. Making regression of this curve, we obtain straight line and point laying on the straight without distortion. But this method has a weak point which need to many data.

The paper(Van den Heuvel.,2006) presents the calibration procedure developed by CycloMedia for the processing of two overlapping fisheye images into a spherical panorama: a so-called Cyclorama. CycloMedia develops the techniques and software for the production of Cycloramas and their applications in-house. But this method has a matter that a outer area distortion is not correct.

2. THEORY

This paper calibrated radial, decentering, tangential distortion of a fish-eye lens. Generally, the decentering distortion is very small compared to the radial and tangential and we mainly calibrated the radial, tangential distortion(Wolf, P. R., and Dewitt, B. A., 2000).

Basically, the orientation of single photography relied on the collinearity equation, we express by a formula (1),

$$x_{ij} = -f\left[\frac{m_{11}(X_j - X_i) + m_{12}(Y_j - Y_i) + m_{13}(Z_j - Z_i)}{m_{31}(X_j - X_i) + m_{32}(Y_j - Y_i) + m_{33}(Z_j - Z_i)}\right]$$

$$y_{ij} = -f\left[\frac{m_{21}(X_j - X_i) + m_{22}(Y_j - Y_i) + m_{23}(Z_j - Z_i)}{m_{31}(X_j - X_i) + m_{32}(Y_j - Y_i) + m_{33}(Z_j - Z_i)}\right] \quad (1)$$

x_{ij}, y_{ij} = object point coordinates of i photograph in the camera coordinate system

X_j, Y_j = coordinates of the projection centre

X_i, Y_i = object point coordinates of j point in the object coordinate system

m_{ij} = elements of the rotation matrix

Also the radial distortion generated from lens center, that can be written as:

$$x_{\text{radial distortion}} = x_j(1 + k_1 r_j^2 + k_2 r_j^4 + k_3 r_j^6)$$
$$y_{\text{radial distortion}} = y_j(1 + k_1 r_j^2 + k_2 r_j^4 + k_3 r_j^6) \quad (2)$$

The tangential distortion perpendicularily generated the radial line from lens center, this described below.

$$x_{\text{decentring}} = (1 + p_3 r_j^2 + p_4 r_j^4)[p_1(r_j^2 + 2x_j^2) + 2p_2 x_j y_j]$$
$$y_{\text{decentring}} = (1 + p_3 r_j^2 + p_4 r_j^4)[2p_1 x_j y_j + p_2(r_j^2 + 2y_j^2)] \quad (3)$$

The integrated observation equation is show below.

$$F = 0 = x_j - x_p - x_j(1 + k_1 r_j^2 + k_2 r_j^4 + k_3 r_j^6) - (1 + p_3 r_j^2 + p_4 r_j^4)[p_1(r_j^2 + 2x_j^2) + 2p_2 x_j y]$$

$$F = 0 = y_j - y_p - y_j(1 + k_1 r_j^2 + k_2 r_j^4 + k_3 r_j^6) - (1 + p_3 r_j^2 + p_4 r_j^4)[2p_1 x_j y_j + p_2(r_j^2 + 2y_j^2)] \quad (4)$$

To calibrate the correction, we need the observation 17 equation, when we assume principal(cx,cy), focuslength(fx,fy), radial distortion parameter(k1,k2,k3), tangential distortion parameter(p1, p2, p3, p4), 3 location and 3 position of lens. By the way, the object point make 2 observation equation, we need 9 object point.

3. CALIBRATION

3.1 Distortion Correction Program

When a camera calibrated distortion, there are a focuslength, location of principal point, lens distortion parameters so on. Specially, the focal length could exactly computate using 3D Target, but the 3D Target is difficult to make, the target location actual survey, and there are problem of auto-extract. For the camera calibration, this study used 2D Target sheet that fixed up the wall, and we took a picture. Also, we used the target which had regular size and repetitive lattice point. In the paper, we photograghed from serveral directions maintaining a certain distance we extracted coordinates value of lattice point and then we made lens distortion parameters with this value.

The figure 1 show is the search window to pull out the lattice point.

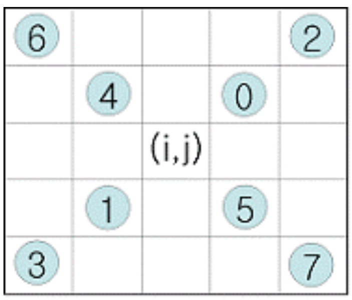

Figure 1. Search Window

To efficiently extract, we made the 5×5 search window, we recognized lattice point using two pattern. The one analyzed diagonally lattice pattern, the other made sure whether the pattern is the same diagonal. If it did not like, this point was reconized as lattice point. Namely, the lattice point had the same pattern(□□□□, □□□□) and the different pattern from a diagonal direction.

The Figure 2 is calibration program which uses the lattice point. The program is composed of setting target, add/delete, calibration, undistortion image. Also, we made full distortion (Figure 2) because the calibrated image was taller than a raw data.

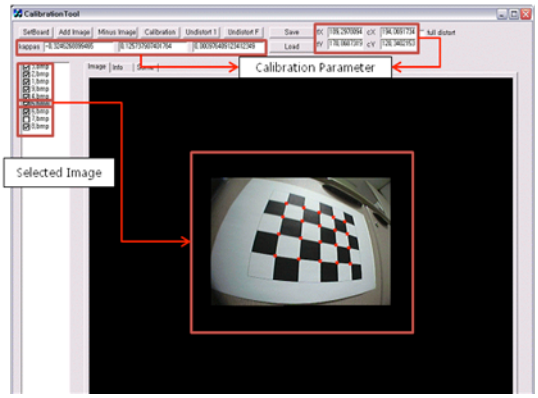

Figure 2. Calibration Program

The CCTV have ultilized in many areas, but the monitoring has a problem such narrow range and costs. We used a fish-eye lens for managing facilities, we could be effectivly monitoring the urban facilities and reducing the cost of management. The figure 3 is the calibration monitoring program with correcting parameters.

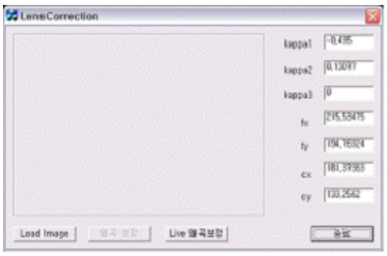

Figure 3. Monitor Program

3.2 Experiment

The calibrating experiment and anlysis developed in the Test Lab of KICT(Korea Institute of Construction Technology). This was shown Figure 9. The Test Lab is a place of experimenting and integrating the urban management techniqe.

The table 1 is VM32- B36 camera which can have the fish-eye lens. This camera can be easily replced, the installation is easy.

Focuslength	2.95mm	
CCD Size	4.8×3.6mm	
Pixel Size	9.6×7.6μm	
Weight	30g	

Table 1. Board Camera

Using the calibration program, we use the raw image. We reconized what the more the angle expands, the more radial distortion bears and focu length is short. The calibrating image is the figure 5.

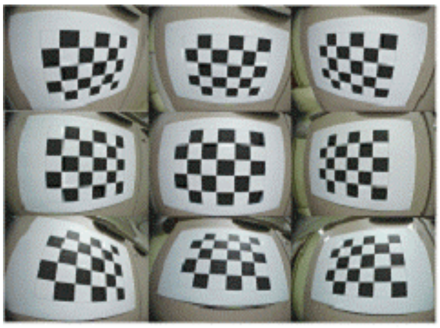

Figure 4. Before Calibrated

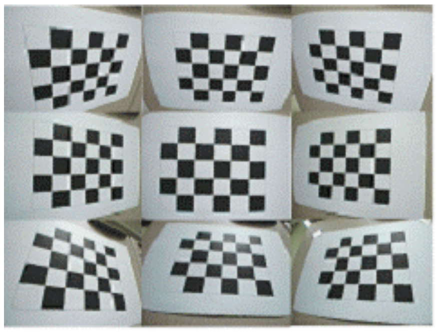

Figure 5. After Calibrated

we can know the image corrected distortion with straighten in this image by the naked eye. For the antitative analysis, we calculated the RMSE of lattice interval such as the figure 6, and for the better analysis, we compared the calibrated-image with the scanning image(Figure 7).

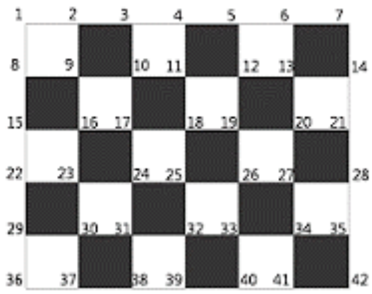

Figure 6. Lattice Number

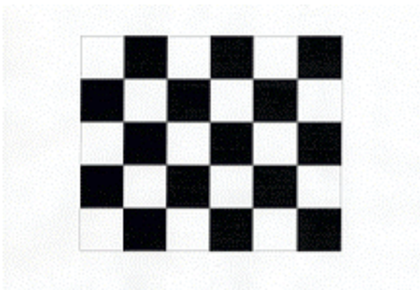

Figure 7. Scanning Image

First, we made the lattice number, and then we calulated the distance between the lattice point. The fish-eye increased distortion is increaed from the center to the outerline, the RMSE received dozens of pixels. The Table 2 is RMSE of 150° fish-eye Lens. The average RMSE was 3.2 pixels that showed the error dwindly away.

	RMSE[pixel]
x direction	2.72
y direction	1.71
2D	3.2

Table 2. RMSE after calibration

We describe the lattice point with the Figure 8 from before and after the image.

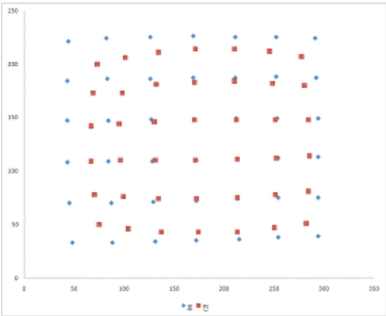

Figure 8. Lattice Pattern Graph

3.3 Application

We experimented in the Test Lab where could verified the USN for the INUF(Interlligent Urban Facilities) in the South Korea.(Figure 9.) This Test Lab were the asphalt road, guardrail, sidewalk, streetlight, gateway, control room, utility-pipe conduit ,etc.

Figure 9. Test Lab(KICT, SOUTH KOREA)

The lens has a short focus than a general lens because the fish-eye camera has the wide angle, also the more we go near, the more a distortion increase. But the fish-eye lens is taken with a wide range, the background is taken with a small range, a perspective is emphasized. This paper is use lens of 90°, 120°, 150° to compare the characteristics of angle. We shoot the utility-pipe conduit in the testlab, the we compare the view range due to angle(Figure 10).

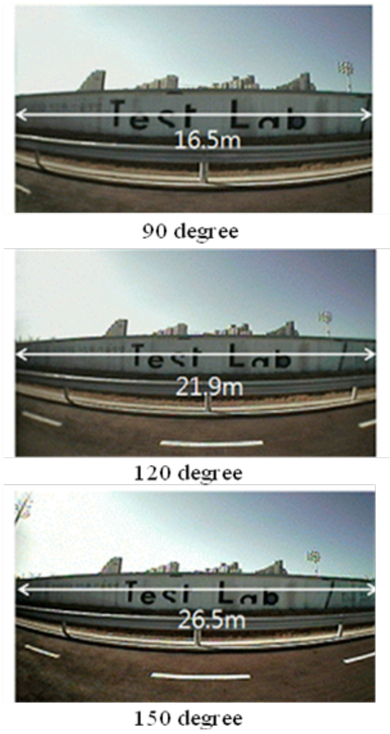

Figure 10. Views of Angle

The Figure 11 was calibrated before and after images in the Test Lab. The calibration Level is shown in a linear structure of the guardrail and road. The calibrated image was bigger than the raw image because the barrel distortion. Thereforce, this research made the full distortion. The applying image is the Figure 12.

Figure 11. Before/After Calibration

Figure 12. Full Calibration

4. SUMMARY AND OUTLOOK

Proposed a fish-eye lens utilize is efficient method that the used minimum price in urban facilities monitoring. But the fish-eye Lens had a short focal length and increased the radial distortion farther from the center of image. For the calibration, we made a mathematical model for fisheye lens camera system was developed, implemented and tested. In order to the program, we calculate the RMSE of a distance of raw and calbrated imge, the error is 3.2 pixel of the 2D RMSE. Also, we make the monitoring program for real-time detection in the management of the urban facilities.

We take the validation experiment in the TestLab of KICT (the Republic of Korea) which is about angle of view, lens calibration. And we could obtain some applicability of the system.

5. ACKNOWLEDGEMENTS AND APPENDIX

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