RECTIFICATION OF PURE TRANSLATION 2D CAMERA ARRAY

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ABSTRACT

In this paper, we propose a rectification method that can convert ray space data obtained by controlled camera array to ideal data. Here, Ideal data is obtained by getting longitudinal and transversal epipolar line between cameras vertical and horizontal. However it is actually difficult to arrange cameras strictly because we arrange cameras by hand. As conventional method, we have use camera-calibration method. But if we use this method there are some errors on the output image. When we generate arbitrary viewpoint images this error is critical problem. We focus attention on ideal trajectory of characteristic point. And to minimize the error directly we parallelize the real one. And we showed usefulness of proposed technique.
Then using the proposed technique, we were successful reducing the error to less than 0.5 pixels.

Keywords: camera array, ray-space, calibration, epipolar line, XY-Stage

1. INTRODUCTION

There are many research works about free viewpoint television system, viewer choose arbitrary viewpoint and can watch from that point. By dealing with many images captured on multi viewpoints, this system can generate images captured by virtual camera on the arbitrary viewpoint. As one of method for this system, ray space method[1] have been well studied. Ray space method is one of Image-Based-Rendering (IBR). IBR method can generate photorealistic image. In IBR, ray space data is obtained by camera array as images from multi viewpoints. Ray space is build up thickly by interpolating captured images.
On many researches, researchers often premise that ray space data is ideal condition. For example, they consider that captured ray position and direction is accurate. But, actually, there are varieties of error; the position and direction errors of camera, individual difference of camera.
So, as conventional method, we have used calibration method [2]. We can obtain internal parameter and external parameter, position and direction of camera by using this method. And, we calibrate cameras to ideal from obtained data. However, in this method, accumulation of errors influences result significantly.
At this time, when we acquire ray data we use one camera and XY-stage to avoid that. We translate camera using XY-stage. Here, translation error of XY-stage is less than a few micrometers. Benefit of using XY-stage is capturing regular ray data and we don't need to consider individual difference of camera by using one camera. By these assumptions, we don't use camera calibration and suppose to collect image by high accuracy rectification method.
The reminder of this paper is organized as follows. Section 2 explains placement of two-dimensional camera array. Conventional method and proposal technique is explained in Section 3 and Section 4. Section 5 presents Experiment. Section 6 concludes this paper.

2. PLACEMENT OF TWO-DIMENSIONAL CAMERA ARRAY

2.1. Ideal camera placement

There are many kinds of camera array placement. This time, we assume that cameras are placed on the two-dimensional plane. In this case, ideal camera placement needs to meet following requirements.

- Camera is placed at regular intervals in longitudinal and transversal direction.
- All camera faces to same direction.
- All optic axis of camera is perpendicular to camera plane.

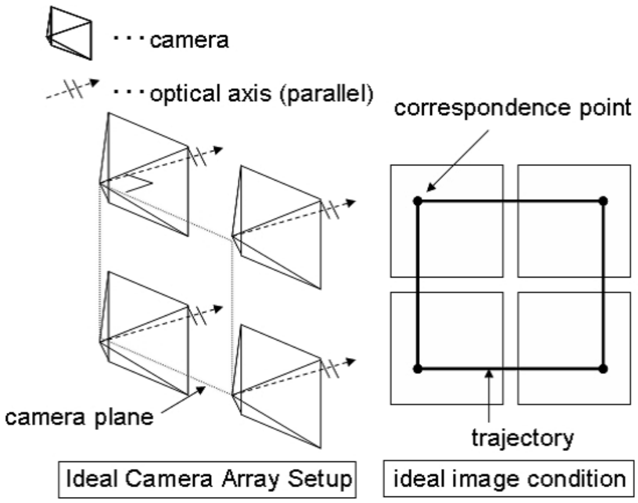

Fig. 1. Ideal condition of two-dimensional camera array

But, it is actually difficult to arrange cameras strictly meeting these conditions.

2.2. The real issue of camera arrangement

We need to arrange camera by hand. Therefore to arrange camera strictly is extremely difficult and there are following problem.

- There are back and forth and around variations of camera position.
- There are variations of camera direction.
- There are Individual differences of camera.

Here, Fig2 shows only a line of two-dimensional camera array.

3. CONVENTIONAL METHOD

As I explained in the preceding chapter, when we arrange cameras by hand we have a variety of issues. So, to solve these issues we used calibration method as conventional method. Calibration method is to estimate internal parameter, internal structure, and external parameter, position and direction of camera. And, we have calibrated cameras to ideal ones by using obtained data.

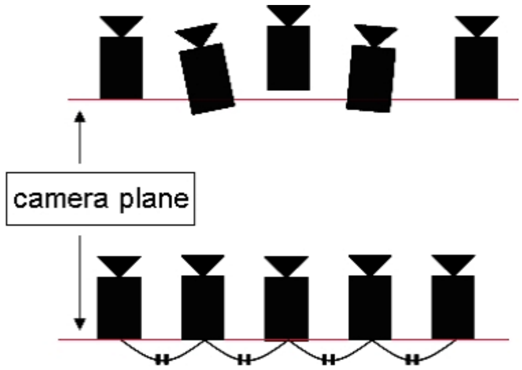

Fig. 2. Real condition and ideal condition

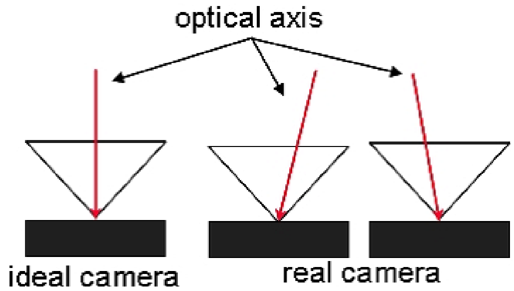

Fig. 3. individual difference

4. PROPOSAL TECHNIQUE

In previous chapter, as conventional method we explain camera calibration method. But, when we use calibration method to calibrate images captured by camera array there is an issue, a variety of error tends to accumulate to output image. To avoid this issue we control one camera by using XY-stage. We shows appearance of XY-stage in Fig.4. We can translate camera using XY-stage and translation error of XY-stage is less than a few micrometers. In this way, we can minimize the error of camera interval. And we don't have to consider individual difference of camera by capturing images using one camera.
How to collect is as follows. We move a camera using XY-stage along the lines of rectangle and capture an image at each corner of rectangle and in the middle of corner. We pay attention to correspondence point being all images, so called characteristic point. Then we transform images under the condition that trajectory of characteristic point traces ideal one. Here, we assume that ideal trajectory is rectangle. We correct images with two types of rectification method and compare precision.

4.1. The method of using vanishing point (method A)

We explains the process of method using vanishing point in this section. At first, calculate coordinate of vanishing point

Fig. 4. XY-stage

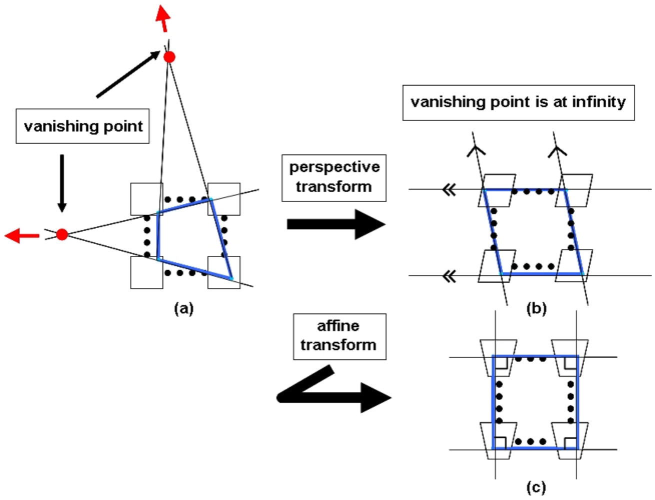

Fig. 5. Process flowchart of method A:Fig.(a) shows trajectory of characteristic point and vanishing point in input image. Fig.(b) shows trajectory of characteristic point after using perspective transformation. Fig.(c) shows trajectory of characteristic point after using affine transformation and ideal images.

from the trajectory of characteristic points. Here, we obtain two vanishing points, one is in a vertical direction and the other is in a horizontal direction. x_v, y_v is a coordinate of vanishing point in a vertical direction. x_h, y_h is in a horizontal direction. Coordinate of vanishing point is calculated from simultaneous equations (1). x_h and y_h is calculated from two horizontal lines of trajectory. In the same way, x_v and y_v is calculated from two vertical lines of trajectory.

$$y = \frac{y_i - y_j}{x_i - x_j}(x - x_i) + y_i \quad (1)$$

x_i, y_i, x_j, y_j :coordinates of characteristic point
$(i, j = 1...4$:The point in the upper left image is $i, j = 1$,upper right is 2, left below is 3 and right below is 4.)

And, we transform vanishing points to infinite distance by using projective transformation And then, we orthogonalize trajectory by using affine transformation. Hereby, trajectory of characteristic point is changed to ideal trajectory, rectangle. We show process flowchart in Fig.5. Matrix of transformation is calculated from solving equations, (2) and (3). And equation (3) is solved using assumption (4) as solution of simultaneous equations.

1. Calculate coordinate of vanishing point from trajectory of characteristic point.
2. Decide projective element of matrix by transforming vanishing points to infinite distance.
3. Decide affine element of matrix by considering ideal assumption of trajectory.
4. Transform image using calculated matrix and obtain ideal image.

$$\boldsymbol{H t_i} = \boldsymbol{t'_i} \quad (2)$$

$\boldsymbol{t_i} = [x_{v,i}, y_{v,i}, 1]^T, [x_{h,i}, y_{h,i}, 1]^T (i, j = 1...n)$
$\boldsymbol{t'_i} = [x'_{v,i}, y'_{v,i}, 0]^T, [x'_{h,i}, y'_{h,i}, 0]^T (i, j = 1...n)$
$\boldsymbol{t_i}$:Vanishing point before pespective transforming
$\boldsymbol{t'_i}$:Vanishing point after pespective transforming
$\boldsymbol{H}$:Matrix of pespective transformation(3x3 matrix)

$$\boldsymbol{A m'} = \boldsymbol{m''} \quad (3)$$

$\boldsymbol{m'_i} = [x'_i, y'_i, 1]^T, \boldsymbol{m''_i} = [x''_i, y''_i, 1]^T (i = 1...4)$
$\boldsymbol{m'_i}$:Characteristic point before affine transforming
$\boldsymbol{m''_i}$ Characteristic point after affine transforming
$\boldsymbol{A}$:Matrix of affine transformation(3x3 matrix)

$$x'_1 = x'_3, \quad x'_2 = x'_4, \quad y'_1 = y'_2, \quad y'_3 = y'_4 \quad (4)$$

4.2. Iteration method (method B)

Within method A when we calculate coordinate of vanishing points they are influenced by quantization error of image. So the outcome has instability. And so, to reduce quantization error we suppose nonlinear method using least-square method frequently. Solution is more stable by nonlinear method and we could correct image with a high degree of accuracy. We show process flowchart of method B in Fig.6. And how to calculate the transforming matrix is in equation (5). To solve equation (5) we use assumption (4) constantly.

1. Transform images using affine transformation(matrix A) and applying least-square method.
2. Transform images using perspective transformation(matrix B) and applying least-square method.
3. Iterate process 1 and 2.

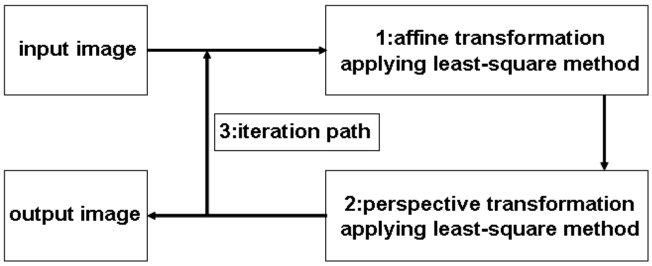

Fig. 6. Process flowchart of method B

$$\boldsymbol{PA...PAPAm_i} = \boldsymbol{m'_i} \qquad (5)$$

$\boldsymbol{m_i} = [x_i, y_i, 1]^T, \boldsymbol{m'_i} = [x'_i, y'_i, 1]^T (i = 1...4)$
$\boldsymbol{m_i}$:Characteristic point before transforming
$\boldsymbol{m'_i}$:Characteristic point after transforming
$\boldsymbol{A}$:Matrix of affine transformation(3x3 matrix)
$\boldsymbol{P}$:Matrix of pespective transformation(3x3 matirix)

5. EXPERIMENT

5.1. Experiment technique

- Use plane pattern in the background to search for characteristic point.
- Capture images using one steady camera.
- Capture static scene.
- The size of captured image is 640 x 480.
- The trajectory of camera is 10 centimeters by 10 centimeters.
- Produce image using method A and method B and compare to conventional method.

5.2. Experimental result

Fig.7 is input image and Fig.8 is output image by method B. Comparing two figures, we succeed in changing trajectory of characteristic point in input image to rectangle. And, Table.1 is average error of characteristic point in output image using conventional method and two supposed methods. Both methods reduce the error to less than 0.3 pixels. And we can see that method B brought about good results. When we considered Plenoptic Sampling[3], we need to reduce the error less than 1pixel and satisfied this condition.

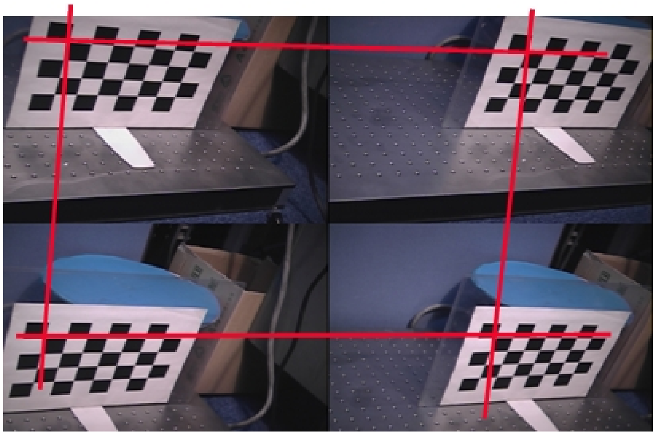

Fig. 7. Input image

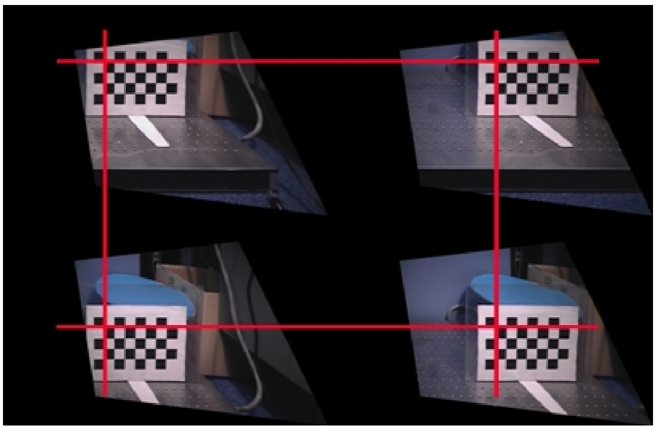

Fig. 8. Output image from method B

Table 1. Errors of existing and proposed method

	e_x(pixel)	e_y(pixel)
conventional method	1∼	1∼
supposed method A	0.134	0.236
supposed method B	0.086	0.206

6. CONCLUSION

We change input image to ideal one using only characteristic points without conventional method. Then, capturing static scene by one camera, we reconstruct two-dimensional camera array. In addition, we could correct images with a high degree of accuracy by correcting nonlinearly.
As a future work, we have to investigate difference of order between e_x and e_y. And we search for another way to correct with more high accuracy.

7. REFERENCES

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