Luminance and chromaticity measurement with 3D object maps

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ABSTRACT

Recent studies have proposed the method for measuring chromaticity and luminance distributions of a natural scene with a digital camera. In this method, using multiple images of the scene taken with different exposures, a high dynamic range image is created. By analyzing the created image, chromaticity and luminance distributions are acquired. By combining this method and Kinect that can acquire depth information of objects, the present study proposes the method for measuring the chromaticity and luminance distributions together with a 3D map of objects in a space. We conducted an experiment in which two images were taken by a digital camera and Kinect cameras. On the basis of point correspondences over the two images, a transformation matrix was computed. We examined the accuracy of the matching between the image obtained by Kinect and that transformed from a digital camera image.

INTRODUCTION

Recent, development of lighting technology has enabled us to create various visual environments easily according to the needs of various groups of people such as elderly people and people with eye diseases. Although illuminace is generally used to estimate brightness of the environments, many researchers and architects have often reported that the illuminance does not always correspond to observer's brightness. Instead of the illuminance, many studies have proposed various brightness indices such as Feu and reported that those indices are well matched with observer's brightness[1]. Because those indices are based on the luminance and chromaticity distributions within a space, it should be essential to measure those distributions.

A colorimeter is usually used to measure luminance and chromaticity. However, quite long time is needed for a single point measurement to obtain their distributions in a space. To resolve this problem, a camera based colorimeter has been used which can measure luminance and chromaticity distribution over one million locations of a space in a few seconds[2].

In this method, a high dynamic range image of the space is created from multiple images taken by a digital camera with different exposures. The luminance and chromaticity of each pixel is then calculated.

In the present study, we propose the method for quickly measuring the chromaticity and luminance distributions, together with a 3D map of objects, by combining a digital camera based colorimeter and Kinect that can measure depth of objects. Several studies have shown that brightness can be affected by color of objects in a space[3]. Therefore, it would be useful to create a 3D map of objects for correcting brightness indices measured in a situation with various color objects located. Kinect has two types of cameras and get two types of images: a RGB image and a depth image with depth information. Because the RGB camera of Kinect can't change exposures, it cannot be used as a camera based colorimeter. In the present study, we used a digital camera to create a high dynamic range image and computed a transformation matrix on the basis of point correspondences over the two images taken by the Kinect RGB camera and the digital camera.

METHOD

In the present study, Microsoft Kinect for Windows (Microsoft Corporation, Model:1517) and CCD camera (ARGO TXG13c) with a fish eye lens (FUJIFILM FE185C046HA-1) were used. To calculate the RGB image coordinates corresponding to depth image coordinates, we compute the Digital camera image points matched with RGB image point. When we got some points to compute transformation, we take the image of the board which has 9 points.

Coordinates and Parameters

We use four coordinates to compute corresponding points of two images: image coordinate, world coordinate, camera coordinate and normalized coordinate. Fig.1 illustrates relationships of these coordinates. Internal parameter has the focal length and center of the image. External parameter has rotation and transformation matrix. The relationship of image coordinate and world coordinate is expressed as follows.

$$s\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} & t_x \\ r_{21} & r_{22} & r_{23} & t_y \\ r_{31} & r_{32} & r_{33} & t_z \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} \tag{1}$$

where $(u \quad v)^{-1}$ is the point in images and $(X \quad Y \quad Z)^{-1}$ is the world coordinate point.

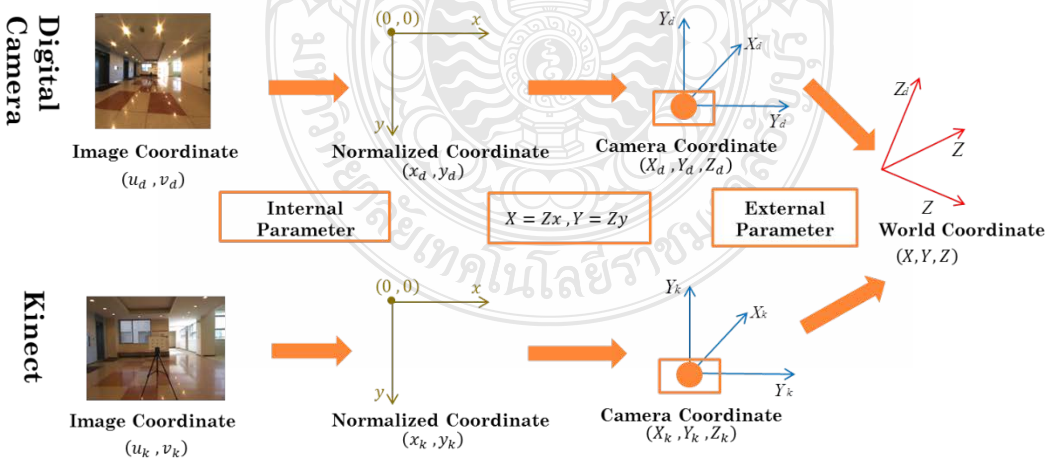

Fig.1 Relation with four coordinates

ALGORITHM

In the present study, world coordinate points corresponding to Kinect RGB image coordinate is computed and (1) by using the calculated world coordinate points Kinect RGB image coordinate are transformed into the digital image coordinate in world coordinate. We use method of Zhan[2] when we get internal parameter. About transformation from RGB camera coordinate to world coordinate, Kinect can get depth image and value of Z so we can consider Kinect RGB coordinate to be world coordinate. Therefore Kinect external parameter is unit matrix in rotation matrix and all elements in transformation matrix. Next, we compute external parameter of digital camera. We can get external parameter by OpenCV. We need depth information so we get target board images are changed about distance from camera to target board each image.

EXPERIMENT

We computed the points in world coordinate from Kinect RGB image coordinate and Digital image coordinate points which were matched. Kinect was located at the X=0 and Z=0 and we set $X \geqq 0$ in right area. We got external parameter in two cases. In first case, we got external parameter by five images were in $0 \leqq X \leqq 1000$[mm] area. In second case, we got it by fifteen images were in $-1000 \leqq X \leqq 1000$[mm] area. The 22 images to estimate errors were X = -1000, -500, 0, 500, 1000 and Z = 1000, 1500, 2000, 2500, 3000, 3500[mm].

RESULT

Table.1 and Table.2 show estimated errors. Table.1 shows the small area to compute external parameter and Table.2 shows the wide area to compute it. Colored cells mean the place of image to estimate external parameter. In small area external parameter case, the errors in $X<0$ are average 73.88, in $X \geqq 0$ are average 16.37 and in all area are average 37.28. In wide area external parameter case, the errors in $X<0$ are average 19.16, in $X \geqq 0$ are average 22.40 and in all area are average 21.22. Maximum estimated error in small area is 146[mm] and in wide area is 80[mm]. We can understand wide area external parameter is better than small area external parameter.

Table.1 Estimated error in small area external parameter

	X=−1000		X=−500		X=0		X=500		X=1000	
Z	ΔX	ΔY	ΔX	ΔY	ΔX	ΔY	ΔX	ΔY	ΔX	ΔY
3500	131	20	79	17	32	9	10	6	33	5
3000	117	16	53	10	31	5	6	7	30	4
2500	100	17	52	14	26	3	3	5	30	6
2000			38	9	10	4	4	4		
1500			21	10	8	3	2	2		
1000					5	2				

Table.2 Estimated error in wide area external parameter

	X=−1000		X=−500		X=0		X=500		X=1000	
Z	ΔX	ΔY	ΔX	ΔY	ΔX	ΔY	ΔX	ΔY	ΔX	ΔY
3500	40	9	9	7	9	9	31	7	62	6
3000	33	8	6	6	11	6	27	7	51	4
2500	5	7	6	3	12	6	20	3	33	3
2000			19	3	12	3	5	4		
1500			36	3	7	4	20	3		
1000					10	9				

DISCUSSION

In this present study, we can compute the matching RGB image coordinate and Digital image coordinate in the small error was 80[mm]. In contrast Table.1 and Table.2, in the estimated error in entire area wide area external parameter is better than small external parameter. However when we contrast them in X≧0 in which small area external parameter was computed, the average error was 16.37 in small area and 22.40 in wide area so we can understand in small area external parameter was better. Therefore we should choose parameters by situations. When we have to get chromaticity and luminance distribution in wide area, we use wide area external parameter and we use small area external parameter when we have to get it in small area.

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