A Novel Stereo-radiation Detection Device Calibration Method using Planar Homography

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Abstract: A radiation detection device, also known as a particle detector, is a device used to detect, track and identify the presence of radiation sources within a given area or environment. In general, a stereo-radiation detection device consists with two radiation detection devices and used to estimate 3D distances to radiation sources accurately. In computer vision, device calibration is more important and to obtain accurate results using such devices, they have to be calibrated first. Many stereo camera calibration methods have been introduced throughout the last few decades but a proper stereo radiation device calibration method has not yet been introduced. In this work, we propose a new stereo-radiation detector calibration method using planar Homography. The calibrated devices are used to estimate 3D distances to radiation sources and we obtained very accurate results with an error of less than 6%.

1 INTRODUCTION

In order to extract the metric information from 2D images in 3D computer vision, one of the most important steps we should consider is calibration. In most of the computer vision experiments, we encounter the necessity of calibrating devices, cameras especially. These devices should be properly calibrated first to acquire more optimized, higher accurate results. Many work related to camera calibration has been done throughout the last few decades (Zhang 2000; Yu and Wang 2006; Kwon et al. 2007; Wei and Ma 1993; Park and Park 2010), initially in the photogrammetry community (Feng et al. 2009).

In recent, radiation has become one of the vastly discussed topics in around the world, and the detection of radiation has also become equally important. Many conventional portable cameras with various kinds of detectors and collimators have been used to acquire 2D radiation images (Lee and Wehe 2004). But yet; proper methods to calibrate radiation detectors have not yet been introduced in computer vision society.

When pan-tilt technique (Figure 1) is used along with visualizing the radiation distribution (Yamashita et al. 2000), it is possible to obtain the radiation distribution with a 2D image (Saganti et al. 2001). The radiation level and bright light intensity values of the radiation detector can be defined by the luminance value of the image pixel in the measuring unit. Same as a projector, obtaining images of a calibration pattern from a radiation detector is not possible and most of the previous calibration methods cannot be applied in a stereo-radiation detection system.

A Proper projector-camera calibration method is introduced in (Park and Park 2010) where the projector is implicit as an inverse camera. Based on that methodology, we propose a similar inverse camera calibration technique to calibrate our radiation detection devices. The system we have implemented consists with two vision cameras and two radiation detectors, and in our approach we first generate a series of virtual calibration pattern images (converted vision camera images which are assumed to be acquired from the radiation sensors) using the Homography translation relationship between vision cameras and radiation detectors. Then we apply the Zhang's calibration method (Zhang 2000) on the converted images to calibrate the radiation sensors.

The structure of the paper is as follows. Section 2 first describes the experiment setup used along with the method used to visualize the radiation images using a pan/tilt scanning process. Then we introduce the method used to convert the vision images into

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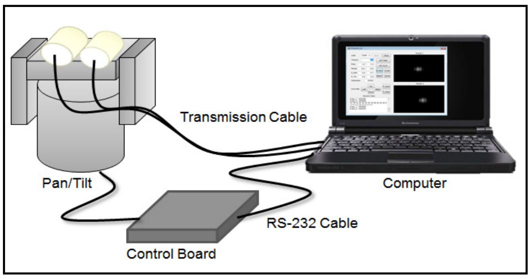

Figure 1: Experiment setup. Only two pinhole cameras are mounted on the pan/tilt table.

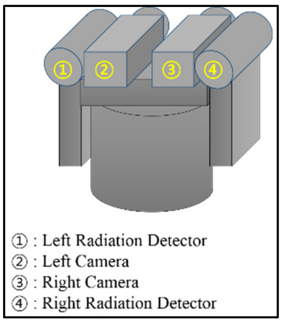

Figure 2: Stereo camera-radiation sensor setup.

radiation images using the Homography translation relationship. Next the calibration method of stereo radiation detection devices using these converted images is also described. The accuracy of the proposed calibration method is evaluated in section 3 whereas the conclusion and future works are represented in Section 4.

2 PROPOSED METHOD

2.1 Experiment Set-up

The initial experimental setup used in our proposed method to acquire images of radiation sources is depicted in Figure 1. The radiation sensors we have used in this setup are pinhole cameras and the reason that we have used them is that they manage to produce radiographs and photographs of objects that emit radiation and visible lights. These cameras are mounted on an automated pan/tilt table that is controlled by a main control board and connected to a general purposed computer via RS-232 cable. The acquisition of radiation images using pinhole cameras directly is possible, but the quality of the acquired images is extensively low. Hence, we upgraded the setup by implementing additional stereo vision cameras in between pinhole cameras (Figure 2) to obtain coincident 2D images. These coincident 2D images are then converted to virtual radiation images by applying Homography translation relationship between vision and pinhole cameras.

2.2 Homography between Radiation Sensor and Camera

The first step of the proposed method is calculating the Homography translation relationship between left and right pinhole-vision camera sets (H_crl,H_crr) whereH_crl and H_crr represent the left and right Homography translation relationships respectively. Light is a form of radiation that spreads similar to gamma rays and in our method we have used bright LED light sources displayed on a planar surface as radioactive materials. At least four known image points are required to calculate the Homography translation relationship. We used the pan/tilt scanning technique to acquire left and right image sets of LED sources from both pinhole and vision cameras. The center points of each LED image acquired are calculated using the Gaussian fitting method (Hartley and Zisserman 2003). Left and right Homography translation relationships between left and right pinhole-vision camera sets are then calculated using these corresponding feature points. Figure 3 shows how Homography translations are calculated.

2.3 Stereo-Radiation Detector Calibration

The next step of the proposed method is converting a few camera images into radiation images using previously calculated homography translation

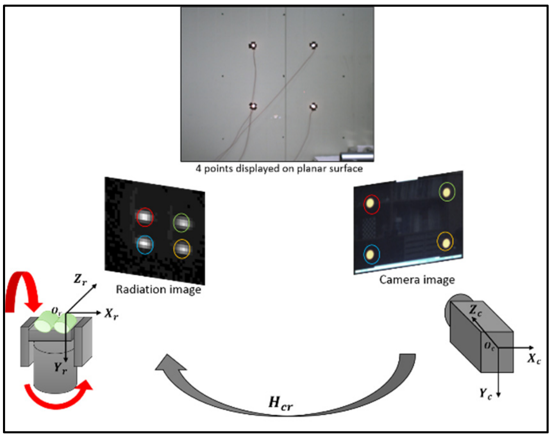

Figure 3: Experimental setup to calculate left and right Homography matrices.

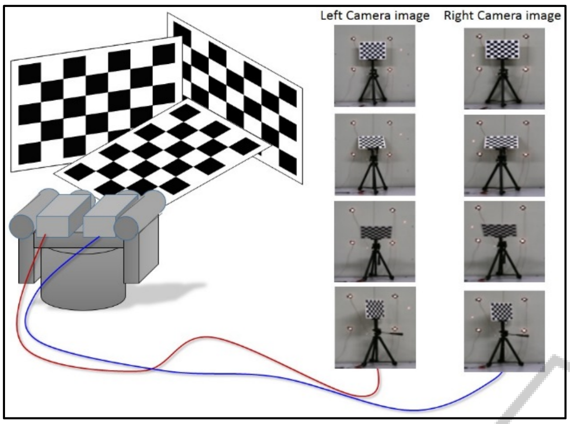

Figure 4: Capturing vision camera images of pattern board for calibration.

relationships. This proceeding requires both left and right cameras to observe a calibration pattern shown at a few different orientations as shown in Figure 4. If the orientation of stereo camera system is perpetual and the same planar surface is used, the Homography translation relationship between the acquired images is said to be constant. This special feature is used to generate the respective radiation images. For clear representation, the camera-radiation detector system is depicted in Figure 2.

After obtaining several images (at least 20 images) of the calibration pattern in different postures from left and right vision cameras, they are satisfied with the left and right Homography translation matrices (H_crl,H_crr) respectively. There the images obtained from the left camera (number 2 in Figure 2) are converted into the images that are estimated to have been taken from the left pinhole camera (number 1 in Figure 2). Similarly, the images obtained from the right camera (number 3 in Figure 2) are converted into the images that are estimated to have been taken from the right pinhole camera (number 4 in Figure 2). Finally, the Zhang's camera calibration method is applied to calibrate the pinhole camera using these converted images. The whole process is depicted in Figure 5.

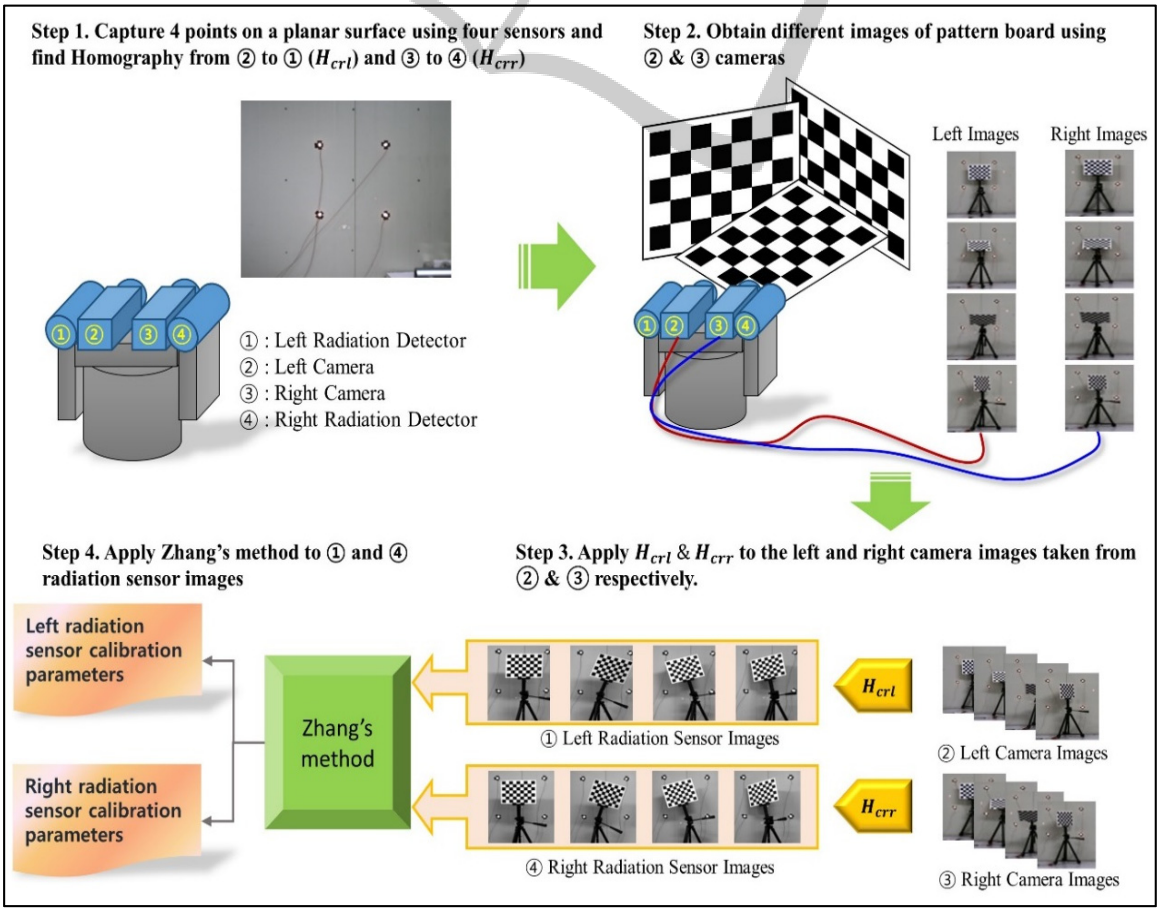

Figure 5: Overview of the whole calibration process.

Table 1: Intrinsic parameters of left and right radio sensors.

Camera	Focal length (f_x)	Focal length (f_y)	Principal point (C_x)	Principal point (C_y)
Left Camera	1048.01302	1044.52696	302.30848	297.63608
Right Camera	1048.92204	1044.95665	310.61240	302.64446

Table 2: Extrinsic parameters of the radio sensors.

R_x	R_y	R_z	t_x	t_y
0.00783	-0.04690	0.00209	-51.02962	-1.13604

Table 3: Results of experiment.

Dist (cm)	P1	P2	P3	P4	Avg	Std dev	Error
300	303.037	293.658	290.358	300.039	296.773	5.019	3.227
330	330.363	346.611	339.973	329.079	336.506	7.194	6.506
370	378.757	375.874	373.683	359.664	378.494	4.513	8.494
400	416.115	417.167	400.495	409.566	410.836	6.642	10.838

3 EXPERIMENTS AND RESULTS

3.1 Intrinsic and Extrinsic Stereo Camera Parameters

We can get the pinhole camera calibration parameters after the converted virtual images are satisfied with Zhang's method. The intrinsic and extrinsic camera parameters of both left and right pinhole cameras aredepicted in Table 1 and Table 2. R_x,R_y and R_z represent the rotation matrix whereast_x, t_y and t_z represent the translation vector. Next, we performed a 3D distance measurement experiment using these calibrated cameras to evaluate the accuracy of our proposed method.

3.2 3D Distance Estimation Test

We used a similar experiment setup what we have used to calibrate our pinhole cameras. We have displayed bright LEDs on a planar surface and captured them from different distances using our calibrated pinhole cameras. We arbitrarily varied the position and distances of the device and recorded the actual 3D distance values using a Bosch GLM 250 VF Professional laser rangefinder. 3D distances are calculated using triangulation and the results we obtained had around 5~6% error, which assured the accuracy of our calibration method. The results we obtained are shown in Table 3.

4 CONCLUSIONS

In this paper, we proposed a new method to calibrate a stereo-radiation detection system. In computer vision, device calibration is done using images of a particular calibration pattern. Since the quality of the directly acquired images of the calibration pattern using radiation detectors is considerably low, we used translation relationships between radiation sources and vision cameras to generate virtual radiation sensor images. In our process, we used two pinhole cameras as radiation detectors because they are capable of photographing radiation such as X-rays and gamma rays. Then we captured a series of left and right vision images of the calibration pattern using vision cameras, which are mounted in-between two pinhole cameras. The Homography translation relationships we found are applied to the vision images to convert them into radiation images and the pinhole cameras are calibrated using Zhang's method.

We performed a distance measurement experiment using the calibrated pinhole cameras to check the accuracy of our novel method. We used laser rangefinders to measure the actual 3D distances and compared them with estimated distance values calculated using triangulation. We managed to obtain higher accurate results with an error of about 5~6%. As future work, we are planning to improve the performance of the system by implementing enhanced image processing techniques.

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