A Planar Homography Estimation Method for Radiation Detection Device Calibration

Pathum Rathnayaka*, Seung-Hae Baek*, Soon-Yong Park*
*School of Computer Science and Engineering, Kyungpook National University, South Korea
e-mail : bandarapathum@yahoo.com, eardrops@vision.knu.ac.kr, sypark@knu.ac.kr

Abstract

The main idea of this paper is to present a new approach to calibrate a stereo radiation detection device by using planar homography technique. Even though, knowing the relationship between internal and external parameters of stereo vision systems is of interest in computer vision society, a few or no proper work related to stereo radiation detecting device calibration has been investigated. Gamma and CCD vision cameras, which are mounted on an independently rotating pan-tilt module, are used as the experiment setup. Since radiation cameras fail to obtain visual information directly, stereo images of a calibration pattern captured from vision cameras are transformed into the view of radiation cameras. These virtual gamma camera images are then treated with Zhang calibration method. Accuracy of the proposed method is evaluated by performing distance measurement experiments to radioactive sources, where the overall average error was around 1~2%.

1. Introduction

Throughout the past couple of years, radiation and its implementation has become one of the most renowned topics in many research areas around the world. However they are said to be having many negative corollaries, they play a significant role in many areas of science and industry (nuclear physics, nuclear medicine, non-destructive testing) [1], [2]. Radiation detectors are used to detect and track the presence of radioactive sources in a particular area. Accurate estimation of 3D position information of these detected sources is more important in above-mentioned areas. Most of the time, mono devices are used to track the presence of radioactive sources, but it is almost impossible when they are spread in wider areas. This simply broadens the necessity of implementing a stereo type setup, instead of a monotype setup. Much more work related to mono and stereo type vision camera calibration have been introduced [3]-[6], but a very little been experimented for radiation detecting devices. Therefore, we present this novel idea to calibrate a stereo set of gamma detection devices using planar homography. The experiment setup consists with a 1D-gamma sensor and a 2D vision sensor, which are mounted on a pan-tilt module that enables them to rotate in horizontal and vertical directions independently. These are very symmetric rotations so that both cameras obtain an identical baseline. However, no visual information can be taken from gamma sensors directly; therefore, we first have to transform images taken from the vision cameras to the view point of gamma sensors in-order to generate virtual gamma sensor images. These virtual gamma images are then treated with Zhang calibration method to get stereo calibration results of left and right gamma cameras.

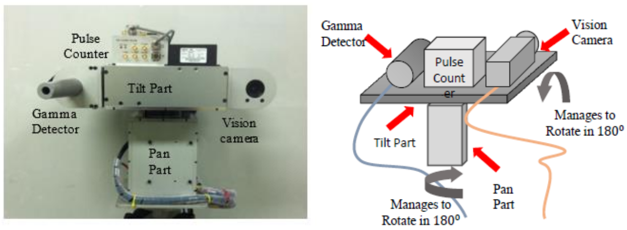

Figure 1: Experiment setup at a glance.

2. Experiment Setup

The main experiment setup is depicted in figure 1. A SPMT(Small Photon Multiplier Tube) is used as the gamma sensor, which manages to generate pulse counts of photons along with a CsI(Tl) scintillator [7]. These pulse counts are recorded and mapped as intensity values of pixel in the radiation image. The 2D vision camera is used to capture the coinciding visual information of the complete scanning area. Once stereo calibration parameters are known, viewing angles of both gamma and vision sensors can be transformed to match with each other.

3. Scanning Technique of Radioactive sources

Scanning method to visualize images using the pan-tilt module is mentioned in figure 2. Accurate motion controllers and DC motors control the rotation of the module (rotation error is 0.01^0).

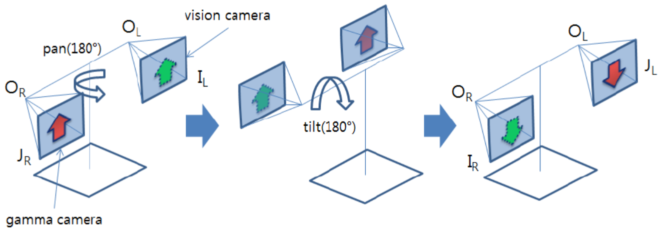

Figure 2: Panning and tilting of the setup to obtain stereo gamma and vision images.

Initially, vision and gamma cameras are mounted on left and right sides, respectively. This enables to generate left vision and right virtual gamma sensor images. Next, the module is tilted by 180^0 and the image planes are exchanged evenly. Finally, it is rotated in panning direction by 180^0 to generate left and right virtual gamma and vision sensor images, respectively.

4. Finding Homography Relationship

Two homography relationships (left-H_L and right-H_R) between vision and gamma sensors exist, and are calculated as it is mentioned in figure 3. H_L is the homography transformation from left vision image to left gamma image. Likewise, H_R represents the homography transformation from right vision image to right gamma image. We calculate the corresponding pixel intensities (at least 4 points) of both gamma and vision images using Gaussian fitting. Homography transformations are calculated using equation (1) and (2).

$$J_L \cong H_L I_L \quad (1)$$

$$J_R \cong H_R I_R \quad (2)$$

Figure (4) represents a vision image and its respective virtual gamma image.

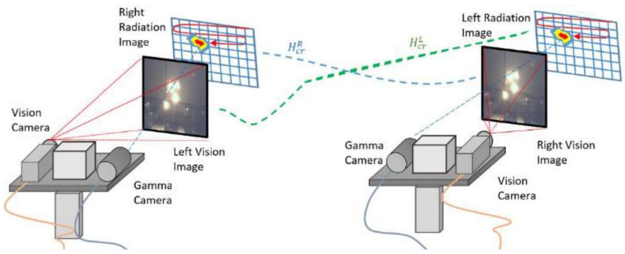

Figure 3: Homography relations.

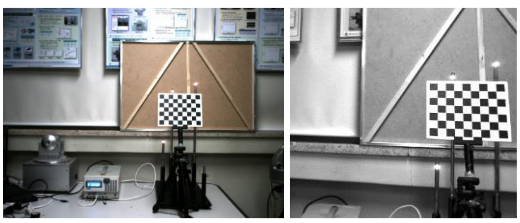

Figure 4: Vision image and virtual gamma image.

5. Stereo Calibration of Gamma Sources

After generating a minimum of 6 virtual gamma images as mentioned in the previous section, we can simply use Zhang's camera calibration method to calibrate the stereo gamma sensors. The complete calibration method is expressed in figure (5).

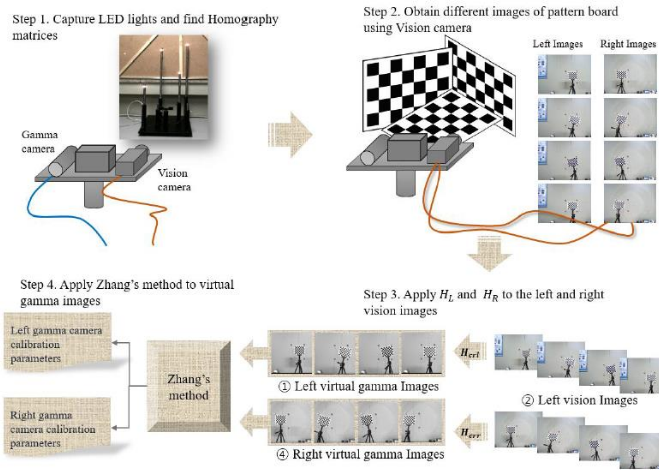

Figure 5: Full calibration process.

6. Experiment Results

After calibrating stereo gamma sensors, we performed some 3D distance measurement experiments to evaluate the accuracy of our proposed method. The experiment results showed an overall distance error of 2~3%, which simply assures the robustness of this calibration method. Table (1) and (2) show the intrinsic and extrinsic parameters of stereo gamma sensors, whereas table (3) shows some of the distance results we obtained.

7. Acknowledgements

This project was supported by the civil-military technical corporation promotion center of the defense research institute, and the Korean atomic energy research institute of South Korea.

Reference

[1] P. Rathnayaka, S.-H. Baek, and S.-Y. Park, "Introducing a New Radiation Detection Device Calibration Method and Estimating 3D Distance to Radiation Sources," in Information Science and Applications, Springer, 2015, pp. 335-342.

[2] W. Lee and D. Wehe, "3D position of radiation sources using an automated gamma camera and ML algorithm with energy-dependent response functions," in Nuclear Instruments and Methods in Physics

Table 1: Intrinsic parameters of the left and right gamma cameras.

Camera	Focal length (f_x)	Focal length (f_y)	Principal point (C_x)	Principal point (C_y)
Left Camera	1048.01	1044.52	302.31	297.64
Right Camera	1048.92	1044.95	310.61	302.64

Table 2: Extrinsic parameters of the right gamma camera with respect to the left camera

R_x	R_y	R_z	t_x	t_y
0.00783	-0.04690	0.00209	-51.03	-1.14

Table 3: Estimated 3D distance values.

Dist(cm)	P1	P2	P3	P4	Avg Error (%)
250	198	199	198	200	1.250
250	253	253	249	249	1.0
300	302	295	296	300	1.750
350	352	344	345	351	2.0

Research, Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2004, vol. 531, no. 1-2, pp. 270-275.

[3] Z. Zhang, "A flexible new technique for camera calibration," IEEE Trans. Pattern Anal. Mach. Intell., vol. 22, no. 11, pp. 1330-1334, 2000.

[4] S. Y. Park and G. G. Park, "Active calibration of camera-projector systems based on planar homography," in Proceedings - International Conference on Pattern Recognition, 2010, pp. 320-323.

[5] H. Kwon, J. Park, and A. C. Kak, "A New Approach for Active Stereo Camera Calibration," in Proceedings 2007 IEEE International Conference on Robotics and Automation, 2007, pp. 3180-3185.

[6] Z. C. Z. Chuan, T. D. L. T. Da Long, Z. F. Z. Feng, and D. Z. L. D. Z. Li, "A planar homography estimation method for camera calibration," Proc. 2003 IEEE Int. Symp. Comput. Intell. Robot. Autom. Comput. Intell. Robot. Autom. New Millenn. (Cat. No.03EX694), vol. 1, 2003.

[7] Y. . Hwang, N. . Lee, J. . Kim, and S. . Jeong, "The study for the performance analysis of the stereo radiation detector," in International Conference on Electronics, Information and Communication (ICEIC), 2015, pp. 2-6.