Bird's-eye View Image Generation with Camera Malfunction in Irradiation Environment

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In this study, a gamma irradiation experiment for our proposed bird's-eye view system was conducted. Experimental results show that cameras attached to our system malfunctioned one by one in the irradiation environment, and the proposed system generated bird's-eye view images until all cameras malfunctioned.

1 Introduction

The Fukushima Daiichi nuclear accident occurred in 2011. Since then, many people have been committed to realizing the plant's decommissioning. The investigation of the plant is necessary in the process of the decommissioning, however, there are a large amount of radioactive places that are dangerous for human. In a situation as described above, investigation by teleoperated robots are highly demanded [1, 2].

Nagatani *et al.* conducted gamma irradiation tests for the electric components of their robot and described that the components have enough radiation tolerance to be used for more than 100 h at a 10% safety margin in the assumed environment (100 mGy/h) [2].

In the future process of the decommissioning, there is a possibility of investigating in a tremendous high dose radiation environment where electric devices could malfunction within hours. Therefore the systems used there need to be fault tolerant, working properly even when some of its components have failed.

When operators teleoperate robots at remote places, it is difficult to do their work with efficiency and accuracy. One of the techniques to solve this issue is the use of a bird's-eye view system. It is a system generating the virtual third person view image which shows the robot and the surroundings from the top (Fig. 1). It helps operators understand relations between the robots and their surroundings and teleoperate them accurately [3]. A fault tolerant bird's-eye view system has been proposed by our group [4]. The proposed system is based on the hypothesis that cameras attached to the system have malfunction one by one, and it can display bird's-eye view images even though only one camera works well.

In this study, a gamma irradiation experiment for our proposed system was conducted. Experimental results show that cameras attached to the system malfunctioned one by one, and that is effective for the teleoperation in the irradiation environment.

2 Fault tolerant bird's-eye view system

The way to generate bird's-eye view images with camera malfunction is described in detail in [4]. If one of the cameras does not work well, the conventional system generate bird's-eye view images that have blind spots because some regions of the floor are captured by only one camera.

With the proposed system fish-eye cameras are attached to the teleoperated robot so that every region is taken by two or more cameras, and a bird's-eye view image is generated by synthesizing images captured by cameras that are not broken.

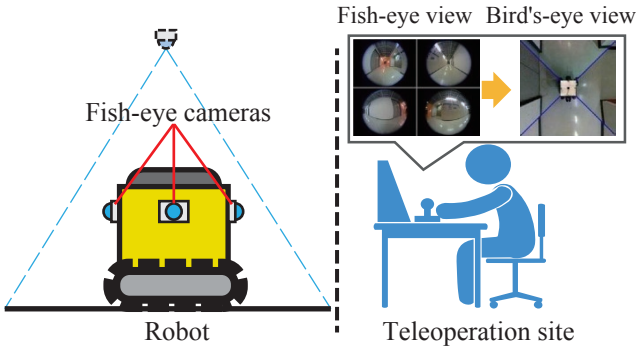


Fig. 1: Concept of bird's-eye view system

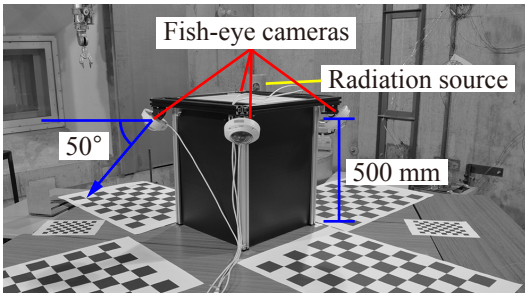


Fig. 2: Experimental environment

3 Experiments

The gamma irradiation experiment for the proposed system was conducted in the Engineering Research & Development Center of ATOX Co.,Ltd.

3.1 Experimental settings

A box made with aluminum frames was considered as teleoperated robot in the experiment. Four fish-eye cameras were attached to the box in accordance with the method described at [4] so that every region of the floor was taken by two or more cameras (Fig. 2). The cameras used (AXIS M3007-PV, Axis Communications) support Power over Ethernet (PoE),

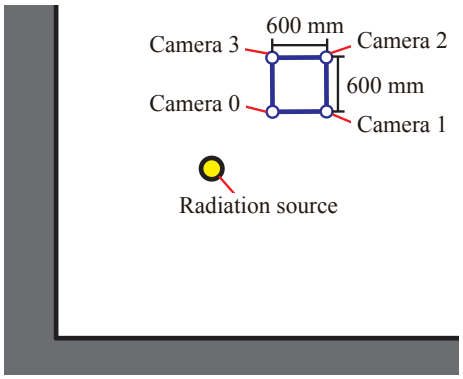
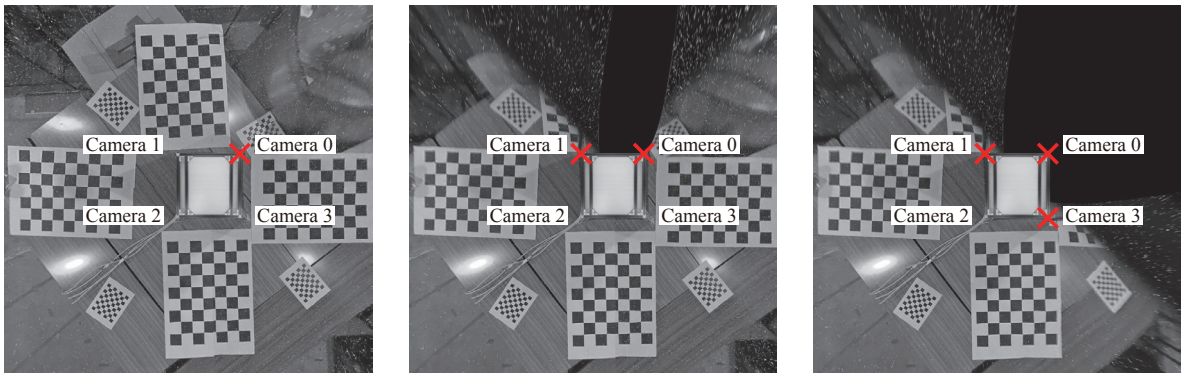


Fig. 3: Experimental layout seen from above



(a) Camera 0 (b) Camera 0 and Camera 1 (c) Camera 0, Camera 1, and Camera 3

Fig. 4: Bird's-eye view with different camera malfunction

Table 1: Result of gamma irradiation

Camera number	Air dose rate [Gy/h]	Time to malfunction	Total dose [Gy]
0	501	23 min	192.1
1	157	54 min	141.3
2	104	94 min	162.9
3	164	82 min	224.1

and it has 187° of horizontal field of view and 168° of vertical field of view.

Cobalt-60 (Co-60) was used as the radiation source. Figure 3 shows positional relationships between the radiation source and the system. The air dose rate of each camera position was measured in advance by a ionization chamber dosimeter and shown in Table 1. The gamma irradiation was carried out until all of the cameras had failed.

During the irradiation experiment for the proposed system, the images captured by the cameras were stored in a computer placed outside of the irradiation chamber via Ethernet cables, and bird's-eye view images were generated by synthesizing the images.

3.2 Results and Discussion

Table 1 shows the air dose rate of each camera position, the time to malfunction, and the total dose when each camera had failed. Time until the connection between each camera and the computer was closed was regarded as the time to malfunction.

The bird's-eye view image with one camera malfunction, with two, and with three are shown in Figs. 4(a), (b), and (c), respectively. As shown in Figs. 4(a), (b), and (c), the proposed system could show bird's-eye view images that represent the large part of the surrounding environment even though some of the cameras did not work well.

Salt and pepper noise was observed in the images immediately after the beginning of the irradiation, for example, as shown at upper part of Figs. 4(a), (b), and (c), and the more strongly the camera was irradiated, the lager amount of noise was observed in the image.

4 Conclusions

In this paper, the irradiation experiment for the proposed fault tolerant bird's-eye view system [4] was conducted in order to confirm the validity of the proposed system.

Experimental results show that cameras malfunctioned one by one at total dose of 141.3–224.1 Gy, and the system displayed bird's-eye view images even though some of the cameras malfunctioned, therefore it is extremely effective for the teleoperation of robots in a tremendous high dose radiation environment.

As a future work, we plan to remove salt and pepper noise in bird's-eye view images for the improvement of visibility.

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References

[1] S. Kawatsuma, M. Fukushima, and T. Okada, "Emergency response by robots to Fukushima - Daiichi accident: summary and lessons learned", *Industrial Robot: An International Journal*, vol. 39, no. 5, pp. 428–435, 2012.

[2] K. Nagatani, S. Kiribayashi, Y. Okada, K. Otake, K. Yoshida, S. Tadokoro, T. Nishimura, T. Yoshida, E. Koyanagi, M. Fukushima, and S. Kawatsuma, "Emergency Response to the Nuclear Accident at the Fukushima Daiichi Nuclear Power Plants using Mobile Rescue Robots", *Journal of Field Robotics*, vol. 30, no. 1, pp. 44–63, 2013.

[3] T. Sato, A. Moro, A. Sugahara, T. Tasaki, A. Yamashita, and H. Asama, "Spatio-Temporal Bird's-eye View Images Using Multiple Fish-eye Cameras", *Proceedings of the 2013 IEEE/SICE International Symposium on System Integration*, pp. 753–758, 2013.

[4] R. Komatsu, H. Fujii, A. Moro, A. Yamashita, and H. Asama, "Image Synthesis in Camera Troubles for Bird's-eye View System of Teleoperation Robot", *Proceedings of the 20th Robotics Symposia*, pp. 497–504, 2015 (in Japanese).