Remote Sensing of Radiation Dose Rate by a Robot for Outdoor Usage

T. Kobayashi1*, K. Doi1, H. Kanematsu2, Y. Utsumi3, R. Hashimoto4, and T. Takashina5

1 Dep. of Electronics & Control Eng., Tsuyama National College of Technology, Okayama, Japan
2 Dep. of Materials Science & Eng., Suzuka National College of Technology, Mie, Japan
3 Laboratory of Advanced Science and Technology for Industry, University of Hyogo, Hyogo, Japan
4 Collaborative Research Center, Hiroshima University, Hiroshima, Japan
5 Int. Industry Academia Collaboration Division, Hiroshima University, Hiroshima, Japan
*E-mail: t-koba@tsuyama-ct.ac.jp; +81-(0)868-24-8215

Abstract. In the present paper, the design and prototyping of a telemetry system, in which GPS, camera, and scintillation counter were mounted on a crawler type traveling vehicle, were conducted for targeting outdoor usage such as school playground. As a result, the crawler type traveling vehicle can be operated smoothly in the school grounds of brick and asphalt. The results were as follows: (1) It was confirmed that the crawler type traveling vehicle can be operated smoothly in the school grounds of brick and asphalt (running speed: 17[m/min]). (2) It was confirmed that the location information captured by GPS is visible on the Google map, and that the incorporation of video information is also possible to play. (3) A radiation dose rate of 0.09[μSv / h] was obtained in the ground. The value is less than the 1/40 ([3.8μSv / h]) allowable radiation dose rate for children in Fukushima Prefecture. (4) As a further work, modifying to program traveling, the measurement of the distribution of the radiation dose rate in a school of Fukushima Prefecture, and class delivery on radiation measurement will be carried out.

1. Introduction

In hazardous environments robots used have been studied for nuclear industry and disaster relief, military usage for long time, especially robots have been actually used for many purposes in nuclear industries[1]-[3]. The most famous robot in the fields of military and disaster relief is “PackBot” manufactured by iRobot Co. more than 3000 units in Iraq and Afghanistan [4]. However, these robots used in extreme environments can’t easily be used by anyone, further the price of a single PackBot is expensive at 120 thousand dollars [5]. The effects of the Tohoku-Pacific Ocean earthquake and tsunami that occurred on March 11, 2011, the cooling system of the Fukushima Daiichi Nuclear Power Plant, decontamination work has been carried out. However, radiation measurement has been still required in many places. A group of authors has been developed an inexpensive equipment by customizing the mass produced and commercially available robot for remote measurement of radiation dose rate. In the above system, an autonomous cleaning robot[6] and a micro computer were combined, and manual and programmed moving modes were additionally equipped to the robot which has an external signal connector[7] in order to measure the distribution of radiation dose rate in low radiation level area, such an indoor space as school house. However, by using the microcomputer SH7125, they can send the measurement results of the rumba running control, calculation of movement position, and the radiation dose data acquisition. Moreover, they were tested to measurement test in three different modes, remote manual, remote programmed, and autonomous. In this paper, I was performed prototype and performance verification of remote control robot that is intended to measure the radiation dose rate distribution in the outdoors, such as school playgrounds.
2. Prototype
2.1 Basic design
Fig.1 shows the system configuration. A crawler type dolly was selected as the driving system and the two crawlers were driven independently, since the purpose of this study is the measurement of radiation dose rate in the outdoor, with regard to the measuring system, a scintillation counter for measuring the radiation dose rate, a data logger for recording the signal and a driving recorder for capturing and monitoring the information of position visual image in real time, are equipped. It is equipped with a scintillation counter to measure an emission dose rate as system of measurement and carries the data logger together to record the measurements. In order to capture the position further information and images, to be monitored in real time, was equip with a drive recorder on a robot.

2.2 Equipment
2.2.1 Scintillation counter
There are Geiger-Muller counter, scintillation counter, and go forth, as the equipment for the measurement of the radiation dose rate. A scintillation counter, which specifications are shown in Table 1, was selected in the present study, as scintillation counter has one order of magnitude higher sensitivity than Geiger-Muller counter, further has much smaller the time constant.

![Fig.1 System diagram](image)

| Measurable Ray | γ-ray |
|----------------|-------|
| Measurable Range | From background to 30.0 μSv/h |
| Scintillater | 25.4φ×25.4mm NaI (T1) |
| Accuracy | Max. ±15% |
| Output range | DC +10mV (Full scale) |
| Time constant | 3 seconds |

2.2.2 Data logger
The measured signals in every second by the scintillation counter were recorded in a data logger. The data can be retrieved by USB memory and display the values in Excel at the present. In future, the values will be transmitted to a computer in real time.

2.2.3 Drive recorder
The movie taken by the CCD camera of the drive recorder can be displayed on a personal computer in real time. The position of the equipment captured by Global Positioning System
(GPS) can be displayed on a google map, further it is possible to import the data into the data logger in the driving recorder.

3. Measurement test

3.1 Analysis method of measurement results

3.1.1 Method for estimating the distribution of the radiation source from the measurement results

The usage of the present system is in a relatively wide playground of school, therefore it will be simplified if the position or area of the radiation source can be estimated without measuring whole area of the ground. For example, assuming a planar radiation source produced from a puddle in which the radioactive substance was deposited and concentrated, the position and area of the radiation source are deduced as shown in Fig.2 and Fig.3. The measuring robot moves toward an assumed planar radiation source along the line 2, line 1, line 0 in Fig.2. Then the distribution of the radiation dose rate will be measured as <2>, <1>, and <0> shown in Fig.3. The counter of the planar radiation source will be reduced on the line p·q where the maximum point of each distribution E, C, D is connected, and the center will be also on the line s·r which is a perpendicular bisector of the circle connected a contour constructed from the point C, B and A of each distribution <2>, <1> and <0> respectively. Next, the dimension of the planar radiation source a and b could be reduced by the spread of the distribution of the radiation dose using the equation mentioned next section.

\[ F = \frac{1}{A_1} \int_{A_1} \cos \phi_1 \cos \phi_2 dA_2 dA_1 = \frac{\hbar^2}{\pi} \int_{\pi}^{\alpha} \left[ \int_{b}^{c} \frac{1}{(x-u)^2 + (y-v)^2 + h^2} dy \right] dx \]

Fig.2 Measuring method

Fig.3 Method for measuring the position and area of the planar radiation source in which radioactive substance

3.1.2 Method calculating of the radiation dose rate distribution

A concept of the configuration factor used in the calculation of heat transfer was applied to the estimation of the distribution of the radiation source shown in section 3.1.1, since the radiation dose rate decreases in inverse proportion to the square of the distance. Definition equation of configuration factor is as follows:
(a,b: Dimensions of the planar radiation source, c,d: Dimensions of the measuring instrument, h: Height of the measuring instrument)

The configuration factor was calculated under the condition in Fig.2, and the 3 dimensional distribution of the configuration factor obtained is shown in Fig.5.

![Fig.5 An example of the configuration factor calculated under the condition in Fig.2](image)

3.2 Measurements of radiation dose rate distribution
Fig.6 shows the prototyped remote control measuring robot. Movement speed is 17[m/min]. Mileage is at about 200m, several times a test drive, I made the adjustment and confirmation of stable transmission and reception stability and stable running. Position information is captured in the drive recorder with GPS, it was confirmed that can be displayed on a google map after measurement. To chart the distribution of radiation dose rate that was loaded into the data logger, the result is shown in Fig.8. A, B, C of Fig.8 are corresponding to the position of the Fig.7. Range of scintillation counter when measured were carried out is 3 [μSv / h]. Radiation dose rate is 0.076 [μSv / h] ~ 0.104 [μSv / h], the average was 0.09 [μSv / h]. Further, in the measurement region of this distribution is considered particularly significant difference was not observed.
4. Conclusion
(1) It was confirmed that the crawler type traveling vehicle can be operated smoothly in the school grounds of brick and asphalt. (Traveling speed: 17 [m / min])
(2) It was confirmed that the location information captured by GPS is visible on the Google map, and that the incorporation of video information is also possible to play.
(3) Fig. 7 shows the results of measuring the radiation dose rate in the school grounds. The points A, B and C in Fig. 8 correspond to the symbols in Fig. 7. A radiation dose rate of 0.09 [$\mu$Sv / h] was obtained. The value is less than the 1/40 ([$3.8\mu$Sv / h]) allowable radiation dose rate for children in Fukushima Prefecture.
(4) As a further work, modifying to program traveling, the measurement of the distribution of the radiation dose rate in a school of Fukushima Prefecture, and class delivery on radiation measurement will be carried out.
References

[1] Ohmichi T 1992 Operation Robot under Radiation Environment *Proc. Japan Welding Society*, *50*, p.19-25

[2] Oka K 2003 Robot for the Nuclear Energy Disaster: Development of a Radiation-Proof Robot <Special Issue> Disaster Response Robotics *Journal of the Japan Society of Mechanical Engineers* *106*, p.765-767.

[3] D’Annucci F and Lecour E 2010 Inspection of the Steam Generator Divider Plate, ICONE18-29457 *Proceedings of the 18th International Conference on Nuclear Engineering*ICONE18, May 17-21, Xi’an, China

[4] [http://www.webcitation.org/5xPANQOLV "iRobot Delivers 3,000th PackBot"]. Archived from the original on March 23, 2011. http://www.webcitation.org/5xPANQOLV.

[5] [http://ja.wikipedia.org/wiki/%E3%83%91%E3%83%83%E3%83%88 http://ja.wikipedia.org/wiki/%E3%83%91%E3%83%83%E3%83%88%E3%82%AF%E3%83%9C%E3%83%83%E3%83%88]

[6] http://eetimes.jp/ee/articles/1109/15/news035.html

[7] Morisato K and Kobayashi T 2011 *Proc, 41th the JSME students conference, Okayama, Feb.*

[8] Kobayashi T, Nakahara M, Morisato K, Takashina T and Kanematsu H 2012 Remote Sensing of Radiation Dose Rate by Customizing an Autonomous Robot *Journal of Physics: Conference Series* *352* 012033