EXPERIMENTAL TESTING OF A PROBABILISTIC-BASED RADIATION MAPPING ROBOT

Robin D. McDougall[1], Scott B. Nokleby[1] and Ed Waller[2]
[1]*Faculty of Engineering & Applied Science, University of Ontario Institute of Technology, Oshawa, ON*
[2]*Faculty of Energy Systems & Nuclear Science, University of Ontario Institute of Technology, Oshawa, ON*
E-mail: robin.mcdougall@uoit.ca; scott.nokleby@uoit.ca; ed.waller@uoit.ca

ABSTRACT
Experimental results for a probabilistic radiation mapping robotic platform are presented. Two scenarios are tested in a closed lab of unknown configuration using Cesium 137 sources. The results verify the functionality of the system.

Keywords: radiation mapping; mobile robotics.

ESSAIS EXPÉRIMENTAUX D'UN ROBOT DE SONDAGE DE RADIATION À BASE PROBABILISTE

RÉSUMÉ
Les résultats expérimentaux pour une plate-forme robotique de sondage de radiation à base probabiliste sont présentés. Deux scénarios sont testés dans un laboratoire fermé à configuration inconnue en utilisant des sources de césium 137. Les résultats vérifient la fonctionnalité du système.

Mots-clés: sondage de radiation; robotique mobile

1 INTRODUCTION

Radiation maps show how radiation intensity fields vary in a room, usually by overlaying radiation intensity contour lines on top of a physical layout map similar to the way topographical maps show altitude variations. A number of approaches have been proposed and presented in the literature, with the general approach involving moving a radiation sensor throughout the entire area being mapped using a human operator or mobile robot [1-3] and then transferring the collected radiation intensity readings directly to an existing physical layout map of the area.

The shortcoming of these approaches is their reliance on both the ability to position a radiation sensor throughout the entire area and the availability of a physical layout map ahead of time. There are, however, many situations where possession of a radiation map would be most beneficial that do not conform to these characteristics. For instance – if physical obstacles or other impediments prevent one from positioning a radiation sensor throughout the entire area then relying on direct measurements alone will not be sufficient to map the areas where the sensor could not reach. Similarly, if no physical layout map is available ahead of time, there will be no document available to transfer radiation measurements to when the map is being created.

To address these two deficiencies, a mobile robotic platform has been developed capable of both creating the required physical map itself on demand if none is available ahead of time, to employing radiation-modeling techniques to predict radiation intensities for those regions in the area where it is impossible to position a radiation sensor. The theory and proposed configuration of a mobile robotic platform, dubbed "Radbot", designed to begin to mitigate these deficiencies has been previously described in depth in [4,5]. In this paper, after a quick high-level review of the design, the first experimental results of using Radbot to generate a radiation map in a real-life scenario are presented.

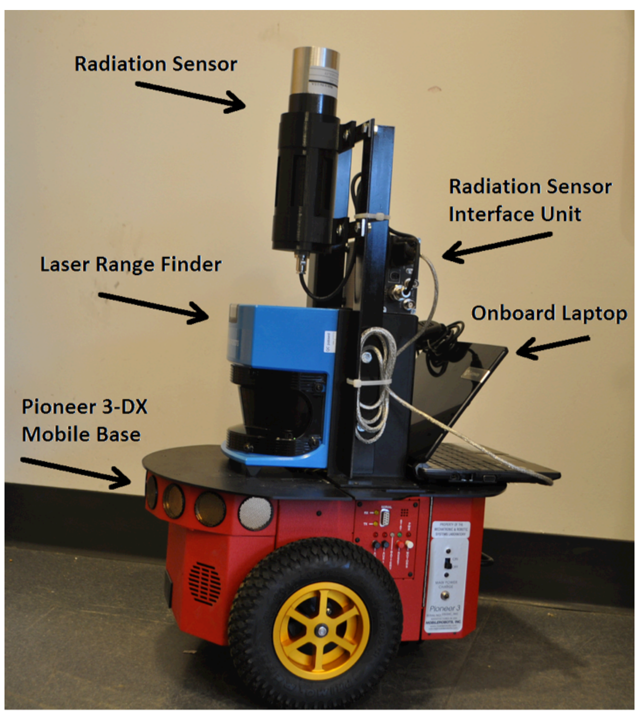

Fig. 1. Robotic Radiation Mapping Platform – "Radbot"

1.1 Radbot – An Overview

Radbot, a mobile robotic platform for generating probabilistic radiation maps is shown in Figure 1. It is composed through an integration of five functional components – a radiation sensor to measure field intensity and its corresponding data acquisition unit, a laser range finder to study the layout of the room; an on-board processor to process and analyze the sensor observations and to control the mobile robotic platform which moves the equipment through the passable regions in the room.

Throughout the entire design process; efforts have been made to preserve the options of selecting different hardware configurations appropriate to the environment being mapped while applying otherwise the same map generation algorithms. The hardware employed during this experiment is shown in Table 1 (and described in more depth in [4]) with the understanding if a more robust robot, or more sensitive radiation sensor were required they should be able to be swapped in without adversely effecting the entire scheme.

Table 1. Hardware Configuration of Radbot.

Component	Hardware Used
Radiation Sensor	2” x 2” NaI Sensor (Rexon)
Data Acquisition	URSA Radiation Alert DAQ
Laser Scanner	SICK LMS-200
Onboard Processor	System 76 – Linux Notebook
Mobile Robotic Platform	Pioneer P3-DX Robot

The operational approach of Radbot has remained very consistent with the theoretical approaches proposed and studied in [4,5]. In general, the idea is that when presented with a room or area of unknown geometry exposed to radiation sources of unknown intensity, Radbot will provide an alternative for generating radiation intensity maps to those previously proposed approaches which require taking direct measurements from the entire area being mapped.

The software platform was built using ROS (Robot Operating System). Simultaneous Localization and Mapping (SLAM) [6,7] was done using ROS’ Gmapping component to produce a physical map when none is available. The radiation models were developed in the continuous simulation software package acslX and were calibrated from data collected from a sparse portion of the entire area being mapped. By integrating these components, Radbot can provide an alternative to using human operators for creating fast that can be employed in situations where obstacles prevent moving a robot throughout the entire area.

In order to accomplish this, any available radiation readings collected will be used to calibrate a radiation model to predict the radiation intensity levels for the rest of the room for generating the radiation map. The effectiveness and accuracy of the process can be evaluated by comparing the predicted radiation levels for a set of points that were not used to calibrate the model.

2 EXPERIMENTAL STUDY

It has been shown previously in a simulation studies [5,8] that the probabilistic modeling approach for generating radiation maps for an area based on samples taken from a small portion showed promise. In this work, the goal was to put Radbot to the test, and confirm that the capabilities shown in the simulations would extend to a real-life scenario. To accomplish this, two and three source exposure scenarios were created similar to those used in the simulated studies in [5,8].

2.1 Test Space

A test environment for use in this study was assembled in a multi-purpose laboratory at the University of Ontario Institute of Technology (see Figure 2a). Three radiation source stages were constructed on which the small disk radiation sources (~1 μCi ^{137}Cesium) used to create the radiation field for measurement could be positioned. (See Figure 2b).

Fig. 2a. The Multi-Purpose Laboratory Mapped by Radbot

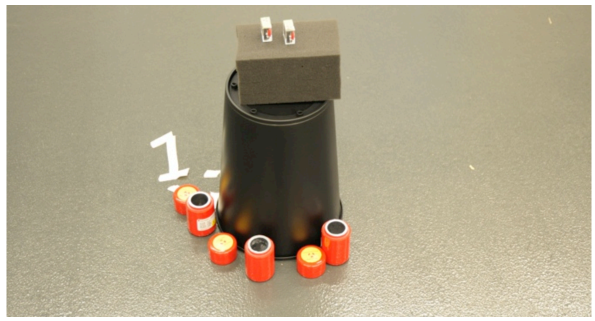

Fig. 2b. A Sample Radiation Source Stage

The first of the two test case scenarios planned involved placing two sources at Stage 1 and one at Stage 2 in the room, while the second involved placing one of the disk sources each at Stages 1, 2 and 3 (see Figure 3). In each test, Radbot was deployed into the room with no prior knowledge of the physical layout, or the locations of the sources. Radbot's objectives were to collect information about the layout of the room to generate a layout map, and to create a radiation map based on readings collected only along two sides of the room

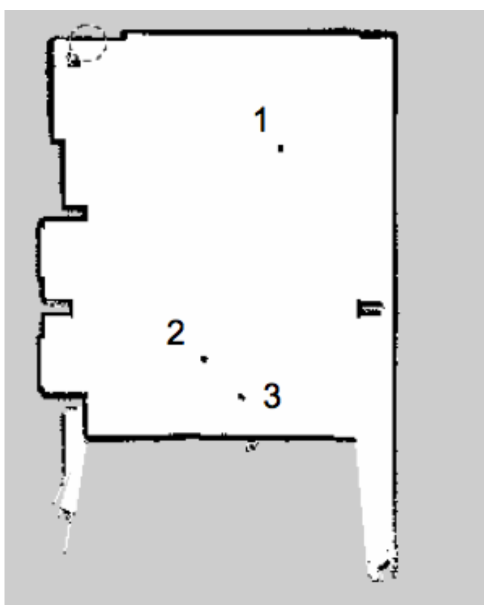

Fig. 3. Experimental Laboratory Layout Identifying Three Source Locations Used

3 RESULTS AND DISCUSSION

The two-source exposure scenario was configured first by placing two of the radioactive Cs disks at Station 1 and one at Station 2. Radbot was deployed into the room and command to conduct radiation surveys at a number of locations along two sides (See Figure 4a). These readings were used to calibrate Radbot's internal radiation model for this particular exposure scenario, based on the inverse square law as described in [5,8], and then this model was used to generate the radiation maps shown below.

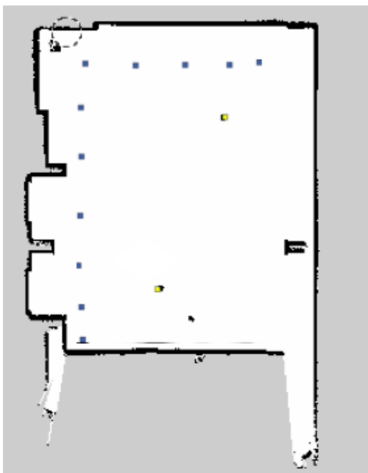

Fig. 4a. Locations Where Radiation Samples Were Collected and Used to Generate Map for the Two-Source Exposure Scenario Test

Fig. 4b. Radiation Map Generated by Radbot for Two-Source Exposure Scenario Test

Fig. 4c. Locations Where Radiation Samples Were Collected to Evaluate Performance

The radiation map generated for the two-source scenario is shown in Figure 4b – and is consistent with expectations. Two rings of higher radiation intensity centred on the locations of the sources, with the larger source (created by stacking two disks at Station one) creating a bigger ripple.

To further evaluate the performance of Radbot, radiation samples were collected at a number of other locations during the two-source exposure scenario (See Figure 4c). These readings were not used to fit the model and generate the map, but instead were used to compare real observations to the predicted values on the map. Figure 5 shows these comparisons with most locations tightly correlated as expected.

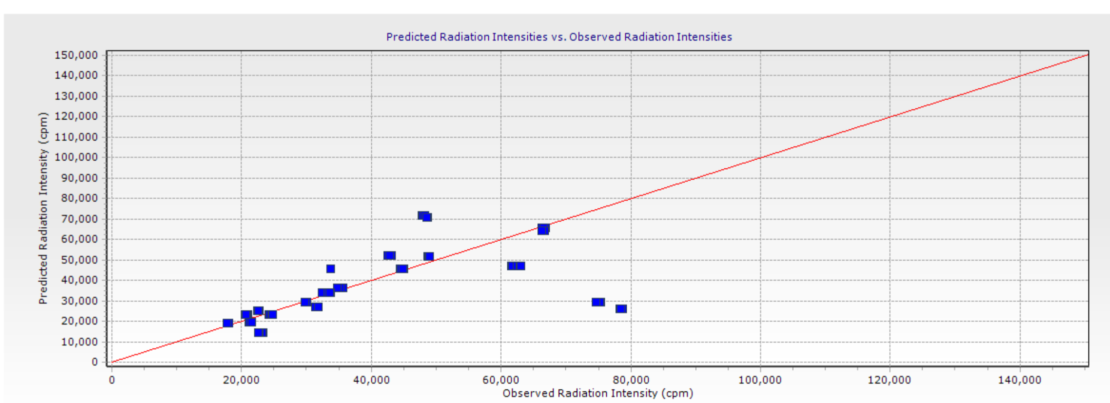

Fig. 5. Predicted vs. Observed Radiation Correlation For Two-Source Case

Similarly, a three-source exposure scenario was configured by placing a single Cs disk at Stations 1, 2 and 3. Radbot was deployed into the room and command to conduct radiation surveys at a number of locations along two sides (See Figure 6a). As before, these readings alone were used to calibrate Radbot's internal radiation model for the three-source exposure scenario, which in-turn was used to generate the radiation the second radiation map.

Fig. 6a. Locations Where Radiation Samples Were Collected and Used to Generate Map for the Three-Source Exposure Scenario Test

Fig. 6b. Radiation Map Generated by Radbot for Three-Source Exposure Scenario Test

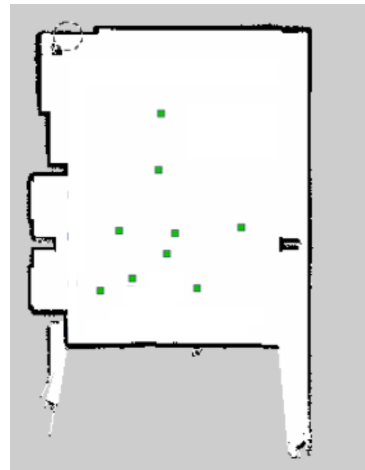

Fig. 6c. Locations Where Radiation Samples Were Collected to Evaluate Performance

Radbot was again able to generate radiation maps for a three-source scenario just as in the two-source scenario. Figure 6b shows that the map generated predicted three high-intensity regions centred at each radiation source as expected. Figure 7 shows a strong correlation between the predicted values and the observed values, again favourably showing that Radbot is an effective tool for creating radiation maps on-demand.

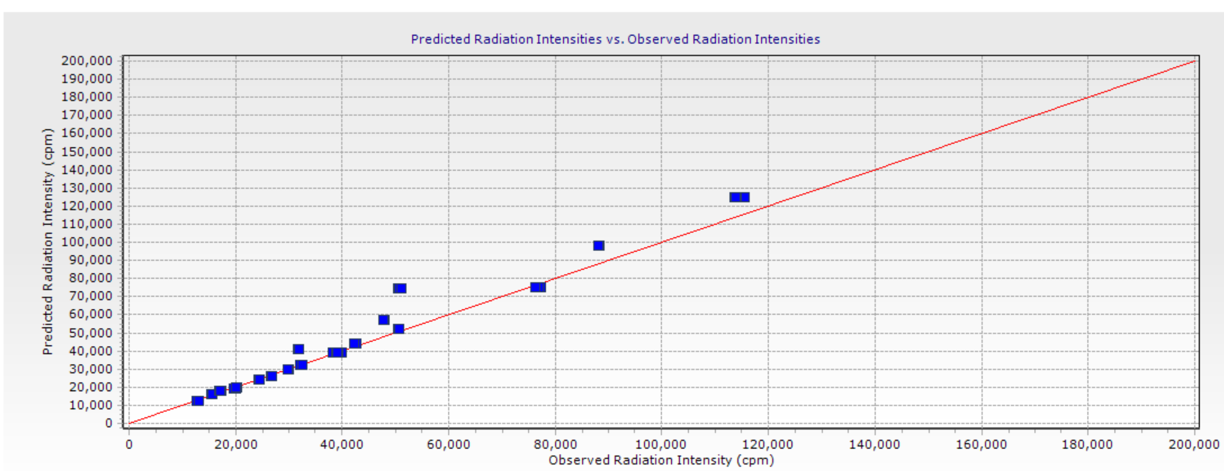

Fig. 7. Predicted vs. Observed Radiation Correlation For Three-Source Case

4 CONCLUSIONS

In this work, it was shown through real-life experimentation that Radbot can successfully generate accurate radiation maps for an area, with no prior knowledge of the area in practice at a similar effectiveness to previously published simulation studies [8].

These results in particular show that Radbot has the versatility to generate maps for both two and three source location scenarios effectively and accurately with little to no prior knowledge of the situations.

Development on Radbot continues, and its effectiveness at creating radiation maps in a room with shielding effects will be examined next.

REFERENCES

1. Cortez, R., Papageorgiou, X., Tanner, H., Klimenko, A., Borozdin, K., Lumia, R., & Priedhorsky, W. (2008). Smart Radiation Sensor Management. *IEEE Robotics and Automation Magazine*, *15*(3), 85–93.
2. Ho, C. K., Robinson, A., Miller, D. R., and Davis, M. J., (2005). Overview of Sensors and Needs for Environmental Monitoring". Sensors, 5(1).
3. Bashyal, S., and Venayagamoorthy, G. K., (2008). Human swarm interaction for radiation source search and localization". 2008 IEEE Swarm Intelligence Symposium
4. Von Frankenberg, F., McDougall, R., Nokleby, S., & Waller, E. (2012). A Mobile Robotic Platform for Generating Radiation Maps. *Intelligent Robotics and …*, *LNAI 7507*, 407–416. Retrieved from http://www.springerlink.com/index/F7656415VL2T6256.pdf
5. McDougall, R., Nokleby, S., & Waller, E. (2011). Robotic Radiation Mapping from Sparse Data. *In Proceedings of CCToMM Symposium on Mechanisms, Machines, and Mechatronics*.
6. Thrun, S.: Robitic Mapping: A survey. Tech. Rep. CMU-CS-02-111 (2002)
7. Smith, R., Self, M., Cheeseman, P.: Autonomous Robot Vehicles. In: Estimating Uncertain Spatial Relationships in Robotics, pp. 167–193 (1990)
8. McDougall, R., Waller, E., and Nokleby S.B. 2010. “A Strategy for Creating Probabilistic Radiation Maps in Areas Based on Sparse Data,” in Proceedings of the 2010 ANS Winter Meeting, November 7-11, Las Vegas, USA.