Id.: CR-78

COMPUTER VISION APPLIED IN THE DEVELOPMENT OF AN AUTONOMOUS GROUND VEHICLE FOR RADIOMETRIC SURVEYS

Gonçalves, Juliana L.[1], Azevedo, Ary M.[1], Soares, Joana B.[1], Nunes, Wallace V.[1]

[1] Instituto Militar de Engenharia, Rio de Janeiro, 22290-270, RJ, Brazil
jlimagoncalves02@ime.eb.br

Keywords: Remotely Piloted Ground Vehicle, Radiation Detection, Arduino

ABSTRACT

The project involves a Remotely Piloted Ground Vehicle (VTRP) used for radiometric surveys. The vehicle is equipped with a radiation detector that measures dose rates throughout the environment, along with a laser positioning sensor. The RadEye PRD-ER detector was used for radiation detection, with data transmitted via Bluetooth to the operator's computer. The information from the radiation detector and the positioning sensor is combined to create a radiometric survey of the location. The research was conducted in a room at the Military Institute of Engineering (IME), using radioactive sources arranged to simulate a radiological installation environment. Key aspects highlighted include operator safety, avoiding exposure to potentially contaminated environments, deployment in hard-to-access areas, and the development of Brazilian technology.

1. INTRODUCTION

Since the Fukushima nuclear accident in 2011, the use of mobile robots for radiological monitoring has increased. These devices are crucial in preventing nuclear incidents and allow entry into restricted areas, ensuring radioprotection. [1] The need for research in the nuclear field is intensified by the conflict in Ukraine, impacting both energy and radiological safety. With the cessation of Russian natural gas supply to Europe, the demand for nuclear energy may increase, accelerating the energy transition [2]–[4].

The research is justified by the need to reduce occupational exposure through the development of an ROV for Radiometric Surveying. Operator protection is crucial, and Radiological and Nuclear Defense has gained international prominence. It is vital for the Brazilian Army to be well-prepared and equipped to handle crises related to Chemical, Biological, Radiological, and Nuclear Defense, and to develop national technologies for monitoring nuclear facilities [5], [6].

In conclusion, this project aims to provide scientific support to the Brazilian Army, enabling safe operations in radiologically contaminated environments and contributing to national defense. This strengthens the ability to prevent or mitigate the impacts of radiological and nuclear incidents, promoting the safety of Brazilian society.

2. MATERIALS AND METHODS

2.1. Materials

The present work presents the development in two stages, namely the construction of the vehicle and the experimental analysis of the aforementioned environment.

The materials used in the project were: black acrylic chassis with 4 plastic wheels; 4 DC motors; 2 x Arduino UNO R3; 12V battery; 1 Radeye PRD ER; 1 L298N dual H-Bridge; 1 RPLidar A1; 1

Jozuze mini wifi camera; 2 x NRF24L01 modules; 1 joystick module; 2 x 9V batteries; battery and cell adapters; notebook with Bluetooth; 1 mobile device; jumper cables FF, MM, and FM.
The necessary software included: Arduino IDE 1.8.19 [7], FrameGrabber.exe, Excel, and Rad-Eye.exe for operating the robot.
The RPLidar A1 was not mounted on the vehicle but placed in the environment to be analyzed, and it was used to mark the measurement points.

2.2. Vehicle Development

The vehicle was built from an acrylic chassis, as shown in Figure 1, and its components have the following specifications:

- DC motor voltage between 3 6V;
- Tire diameter: 7cm;
- Tire width: 2.5cm;
- Spacing between the acrylic plates: 2.5cm;
- Total dimensions (LxWxH): 25x15x3cm;

Figure 1. Vehicle chassis and wheels

In the embedded electronics, there is a dual H-Bridge that connects the 4 DC (direct current) motors of the wheels to the Arduino Uno R3. The connections between the H-Bridge and Arduino, and connections of each wheel motor to the H-Bridgeare shown in Figure 2.

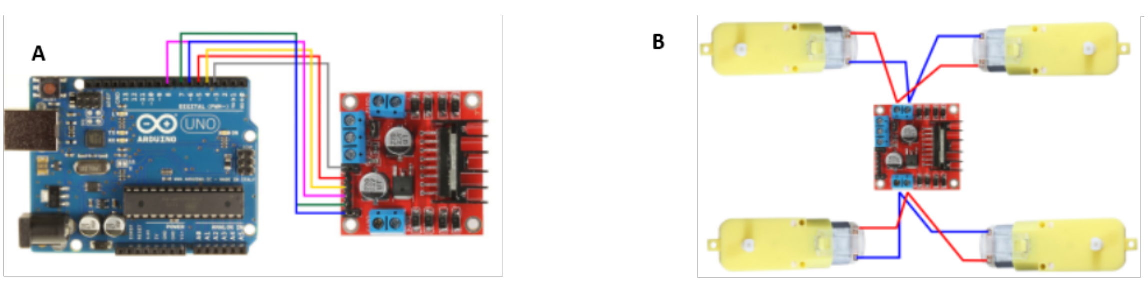

Figure 2. (A) Connections from Arduino to H-Bridge; (B) Connections from H-Bridge to DC motors

The codes used were written in C++ language using Arduino IDE 1.8.19. In short, the scripts define the Arduino inputs responsible for the car's movement. Using the H-Bridge, it is possible to modify the rotation speed of each motor according to the signal sent by the controller [7].

The vehicle's rotation, both to the right and left, is achieved by not engaging two wheels on the same side and only rotating the other two. The commands are captured by the NRF24L01 module, which has a range of up to 100 m, acting as a receiver. The sensor is also connected to the Arduino present in the vehicle, as shown in the image below.
Just like the codes used in the vehicle, the remote control has the second NRF24L01 module, acting as a transmitter. An important factor to note is that the maximum voltage supported by this sensor is 3.3V. In this context, the joystick functions as a potentiometer, controlling both the speed and direction of the vehicle. When the joystick button is pressed, the robot turns off/on.
The connection scheme for the remote control is shown in Figure 3. It uses: Arduino Uno; NRF24L01 radio frequency module; Joystick. A 9V battery was used as the power source.

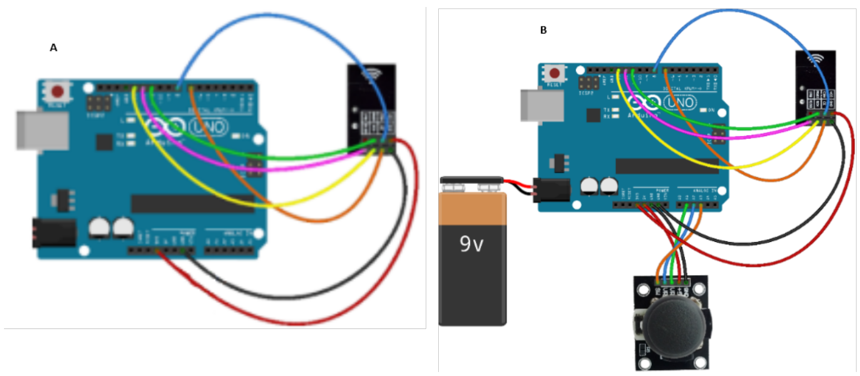

Figure 3. (A) Connection between vehicle's Arduino and NRF24L01 module; (B) Electrical scheme of the remote control

The Jozuze A9 mini camera, shown in Figure 4, is used in the vehicle so that the operator can control it and view the terrain in real-time.

Figure 4. Jozuze A9 Camera

2.3. Radiation Detection

The device that performs gamma radiation detection is the RadEye PRD-ER, shown in Figure 5, a NaI(Tl) (thallium-doped sodium iodide) scintillation detector. This detector does not use a photomultiplier in its system, but rather an array of photodiodes and its *LLD* is 0.01 to 250 μSvh^{-1} [8].

Figure 5. RadEye PRD-ER

This detector is mounted on the vehicle, and the data obtained is sent via Bluetooth to the operator's computer through the RadEye.exe software interface provided by the manufacturer. The doses measured by the RadEye at each marked position on the graph are manually combined. Thus, at the end of the survey, the mapping discriminates the dose rates at each point of the inspected environment.

2.4. Vehicle Positioning in the Room

The *RPLIDAR A1*, shown in Figure 6, is a laser triangulation scanner responsible for generating the vectors obtained from scanning the area to create the radiological map of the installation with a precision of less than 1% of the measured distance [9]–[11].

Figure 6. RPLidar A1

The information obtained is viewed on the operator's notebook through the Frame Grabber software. When saved, the information is converted to *Excel*. A file is saved for each stopping position of the vehicle. After all points are covered, the graphs generated by *Excel* are superimposed, resulting in the final map with the denoted vehicle positions.

2.5. Vehicle Test

Cs-137, Co-60, and Eu-152 sources were used in the experiment, which were placed in a room with dimensions of 617 x 421 cm. Six points were randomly designated for the positioning of the sources.
The dose rate was measured at various points in the location, with a stop time of 5 seconds. Coordinates were saved where the dose rate was higher than the background radiation for plotting the radiometric survey.

3. RESULTS AND ANALYSIS

3.1. Vehicle Assembly Results

Figure 7 shows the assembled vehicle and the remote control. These proved to be efficient in fulfilling the proposed objective. However, there are potential improvements related to movement, which will be described in the conclusions.

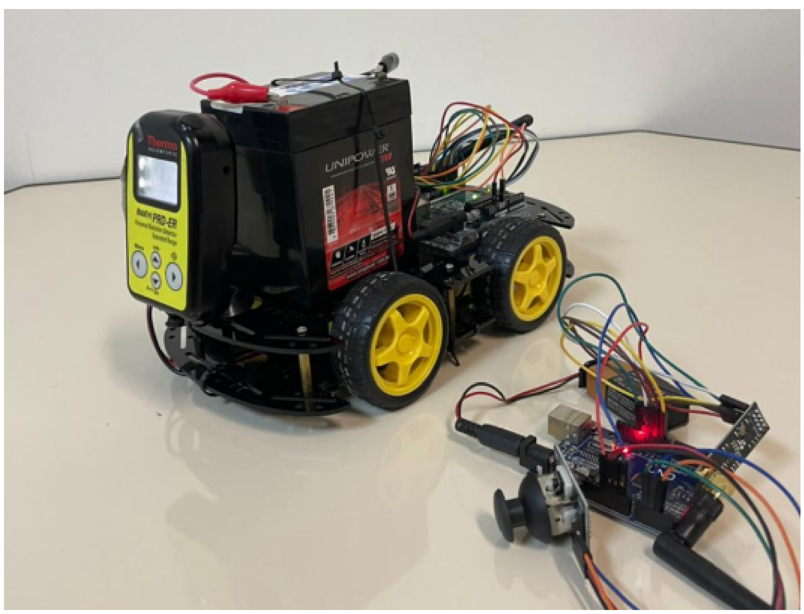

Figure 7. Vehicle and remote control

3.2. Radiometric Survey

The maps generated by RPLidar are in the format of Figure 8. A graph was created for each point and then superimposed. The dose measured by RadEye is incorporated into the graph afterward.

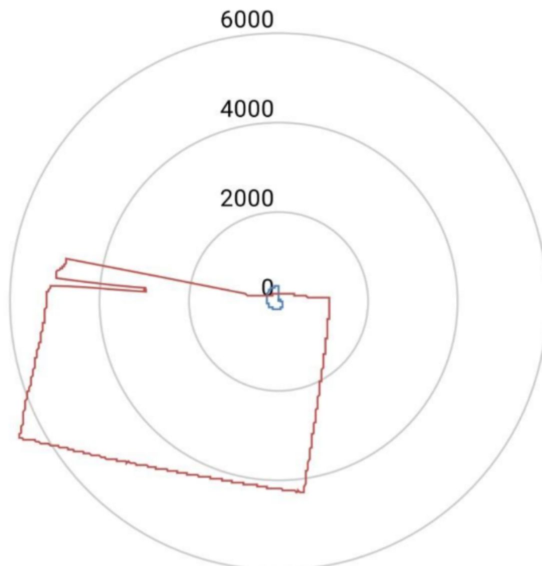

Figure 8. Mapping of Point 4

To present the radiometric survey, it was necessary to convert polar coordinates to Cartesian coordinates. The measured background radiation was 0.15 µSvh^{-1}, and it was used as a comparison base for identifying dose rates in the room. Figure 9 presents the points where the measured dose was higher than the background radiation value, and their respective dose rates.

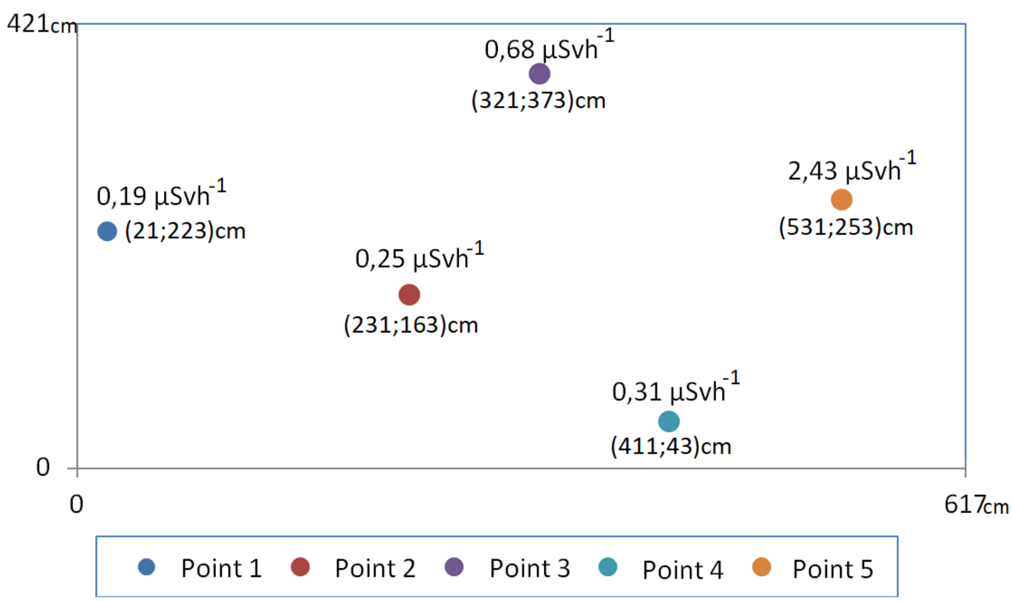

Figure 9. Radiometric Survey

4. CONCLUSION

Regarding the methodology used in the radiometric survey, it was found that it suited the purpose of the study, generating the mapping of the room along with the dose rates. Due to difficulties in integrating the RPLidar into the prototype, it was not possible to operate the vehicle autonomously but rather remotely piloted, with the scanner fixed in the room.
The vehicle was able to perform multiple measurements. However, due to the low activity of the sources, significant increases in the measured rate were observed only at points where the sources were positioned.
Finally, this project underscores the significant role that the vehicle can play in radiometric surveys, providing a safe and reliable alternative for data collection in challenging environments. Robotic technology demonstrates considerable potential to advance research and applications in areas involving radiological risks, thereby enhancing operator safety.

ACKNOWLEDGEMENTS

We would like to express our deepest gratitude to the Instituto Militar de Engenharia (IME), especially to the departments of Nuclear Engineering and Engineering and Materials Science, for their significant contribution to the advancement of science and technology in Brazil. The commitment and excellence of these departments have been fundamental to the development of innovative research and the training of highly qualified professionals.
Furthermore, we would like to thank the funding agencies, such as the Coordination for the Improvement of Higher Education Personnel (CAPES) and the National Institute of Studies and Educational Research Anísio Teixeira (INEP), for the financial and institutional support that made it possible to carry out our research projects and train high-level human resources.

References

[1] B. Bird, A. Griffiths, H. Martin, *et al.*, "A robot to monitor nuclear facilities: Using autonomous radiation-monitoring assistance to reduce risk and cost", *IEEE Robotics & Automation Magazine*, vol. 26, no. 1, pp. 35–43, 2018.
[2] M. Sethi, "Nuclear overtones in the russia-ukraine war", *Arms Control Today*, vol. 52, no. 5, pp. 12–15, 2022.
[3] S. S. Patel, R. M. Grace, P. Chellew, *et al.*, "Emerging technologies and medical countermeasures to chemical, biological, radiological, and nuclear (cbrn) agents in east ukraine", *Conflict and health*, vol. 14, pp. 1–4, 2020.
[4] F. Boulton, "The nature and consequences of a nuclear war: Lessons for prevention from ukraine 2022", *Medicine, conflict and survival*, vol. 38, no. 3, pp. 184–202, 2022.
[5] A. de Azevedo, J. Gonçalves, A. Salazar, *et al.*, "Radiometric survey with remotely piloted land vehicle in chemical, biological, radiological and nuclear defense operations", *Brazilian Journal of Radiation Sciences*, vol. 11, no. 1A (Suppl.) Pp. 01–13, 2023.
[6] P. Silveira, C. Pereira, and R. Schirru, "A prototype of a robotic research facility for nuclear applications",
[7] I. Y. Basri, D. Novaliandry, and I. M. Tania, "Design and development of inductive sensor trainer based on arduino and ide 1.8. 19 software", *Jurnal Teknologi Informasi dan Pendidikan*, vol. 15, no. 1, 2022.
[8] T. Scientific, "Radeye-prd alarming personal radiation detection", EUA, Tech. Rep. DB-087-050322 E, 2008, p. 93.

[9] A. Ikhtiar, D. Qurban, and S. Samo, "Design and control of a self-driving vehicle using rp lidar", in *2023 International Conference on Robotics and Automation in Industry (ICRAI)*, IEEE, 2023, pp. 1–5.

[10] H. Sadruddin, A. Mahmoud, and M. M. Atia, "Enhancing body-mounted lidar slam using an imu-based pedestrian dead reckoning (pdr) model", in *2020 IEEE 63rd International Midwest Symposium on Circuits and Systems (MWSCAS)*, IEEE, 2020, pp. 901–904.

[11] S. Kamble and S. Kharche, "Obstacle detection using lidar", *Int. J. Sci. Res. Eng. Trends*, vol. 7, no. 4, pp. 2537–2542, 2021.