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# MOBILE ROBOTIC SYSTEM FOR MAPPING DOSE

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## ABSTRACT

The advancement of technology has allowed the development of ever more elaborate systems that, even, contributes to increase the life quality and safety at work. This becomes more crucial when dealing with an environment that may present some kind of danger and requires several care steps, such as the nuclear environment. In situations of radiation exposure, the use of robots has become a valuable tool.
This research aims to discuss the deployment of a mobile-robotic system capable of detecting ionizing radiation and to send important information to an operator who thus can act outside a risk area.
Through a predetermined path, the robot identifies the color that is marked on the floor of the environment, therefore, making a path that matters to the operator. Programming was done using the NXC (Not eXactly C) is a high-level programming language for the Lego Mindstorm NXT and the IDE The for NXC is the Bricx Command Center interface that provides a totally friendly and interactive interface with the Lego Mindstorm. The processing code is done completely on the robot CPU, and the information is sent (dose rate and position) to the controller positioned outside the environment via Bluetooth and through the radiation detector -PM1401K Multipurpose Radiation Monitor. Finally, information will be sent to a mobile phone, which the operator uses. This research will be tested as an aid to control and mapping the Argonauta Reactor, present at IEN / CNEN.

## 1. INTRODUCTION

Technological advancements in robotic systems have gained, increasingly, reliability and autonomy. This has been encouraged, especially by the growing need to assist human intervention in dangerous and hazardous areas.

Researches that followed World War II gave the basis of industrial robotics, when a tele-INAC 2011, operator equipment called master-slave was constructed with the purpose of handling radioactive materials.

In the mobile robotics field, the search acquired new direction since the 1980's, with the development of computational intelligence, which brought new possibilities both in treatment and data processing. Two examples are: the research developed- in the 1970's- at Stanford Artificial Intelligent Laboratory and the mobile robot produced by the U.S. Navy - the Robart I - in order to patrol indoor areas and to identify unwanted situations.

The new types of sensors appearance and the control programs development have made the robotics became the focus of several research laboratories for various applications and industrial activities.

According to S. R. Augustus, the mobile robotics field is divided into autonomous and semi-autonomous agents. In the first case, there is the ability to operate, for long periods, without human intervention.

As for the semi-autonomous, they are sub-divided into two operating regimes, tele-operated systems with continuous care, in which the operator controls all the robot movements, and the tele-robotic operation, with what the operator commands are interpreted by the robotic sensors.

In general, a mobile robot is a mechanical structure mounted on a non-fixed basis, under the control of a computer system, and also with sensors that allow interaction with the environment. Two fundamental steps define its action: information achievement from the environment, via sensors, and its processing, according to the activities to be performed.

The Nuclear Engineering Institute (IEN), located at the UFRJ campus has, in its facilities, a nuclear reactor, the Argonauta. The reactor, used for researches, is thermal, with usual operation power around 170 and 340 W. Since 1965, the Argonauta reactor has been used for research purposes and, nowadays, the main lines of activities are non-destructive testing with thermal neutrons among biology, industry, environment and public safety nationwide fields. Collaborating with universities and institutions, several disciplines and classes are taught in its various dependencies, complementing the students training, from undergraduate to doctoral.

According to safety reason, it is appropriate to measure and monitor radiation levels – inside the reactor room - periodically. As the proximity to the reactor can provide the risk of receiving radiation doses above the safe limit, a mobile robot was used to complete these tasks, therefore reducing human contact with the radiation.

Thus, this work proposes a *Mobile Robotic System for Mapping Dose*, (RMSD), to aid in the ionizing radiation detection inside the reactor room, using an autonomous robot in order to replace the human interaction.

## 2. METHODOLOGY

As noted earlier, the periodic radiation level measurements, in the reactor room, have stimulated this project, with the purpose to assist the development of new research, and to serve as a model for situations in environments with high levels of radiation.

Thus, the project consists in a mobile robotic system, to reduce the need for humans to perform tasks in such an environment. For these purposes, we have used a proportional control algorithm, used in a Lego NXT robot type. The control programming was made from the NXC language. The RMSD  e.g. Figure 1 can be divided into two parts: the robot and the radiation detector.


**Figure 1. The RMSD.**

## 2.1 Lego Mindstorm NXT

Composed by a 32-bit microprocessor and several lego pieces that make the robot manageable, and thereby providing a variety of possible programming, the robot has the basic elements that can be used to construct an integrated system with electromechanical pieces, controlled by a computer. The micro-programmable computer, in the form of a Lego large piece, is known as brick. It can process a control algorithm to read data from sensors and activate the engines. With four sensor inputs and three outputs for motors, the Brick also has a small LCD screen and a speaker. Its communication with a PC can be done via a USB cable or Bluetooth. Its feeding is made by six AA batteries, so it is clear that batteries changes are a routine task with the NXT, but that does not cause delay in the research development.

The robot was fitted with two independent drive wheels - but located on the same axis  - and a third free wheel as a fulcrum. This configuration is called "differential drive" that defines a robot with two independent engines that drive two wheels on the same axis. To ensure the robot balance, a third free wheel is used only as support. It is a common configuration, due to its simplicity.

This configuration allows the robot to rotate around the wheel axle center. So, it was assumed that there is space for its rotation and thereby orientations changes can be done without the center position modification. Thus, the path planning has been simplified to the extreme, where the robot, via sensors, receives the guidance to follow the path. To help the guidance needed, we used two sensors: the light and the touch ones.

The touch sensor is a switch, that detects whether it is being pressed, sending a Boolean output. It can be used attached to a bumper, acting, then, as a collision detector. When the robot touches an object forward, this sensor delivers a command to stop the robot.

The light sensor reads the light intensity reflected in an object or an environment. The sensor output can be considered as a color representation in shades of black and white, depending on the software, this value can vary between 0 and 1023. This sensor is also called color sensor and it is used to distinguish colors through shades of gray. For this, the colored object must be close to the sensor.

This sensor was used on the robot to guide it, in a path that was put in front of the reactor; a black strip, followed by the robot that distinguishes different tones of black. A white stripe was used to help the robot with the curves

### 2.2 The PM1401K Multipurpose Radiation Monitor Detector

The PM1401K is a multipurpose equipment, compact and easy to use, designed to detect Alpha, Beta and Gama radiation sources, and also neutron emission sources, in a precise and reliable way.

Among its many functions, the PM1401K is able to distinguish between naturally occurring radioactive materials such as uranium, medical isotopes, industrial sources of radiation (particularly harmful to the population) and heavy radiation sources, such as nuclear weapons.

At RMSD, it is used, for measuring, gamma radiation besides its transmission. Its position, in the environment is, also, provided, via Bluetooth, to a mobile phone that uses the Windows Mobile operating system. In this phone, it is possible to view, in real time, what is being measured and the stored data, for future reference.

## 3. APLICATION

After the proportional control algorithm was well executed, tests were performed at the Argonauta reactor. A pre-determined path was drawn, making use of a black and white stripe glued to the ground in front of the reactor e.g. Figure 2. The robot stops for five seconds at points selected by the operator. This path was selected because it has been observed, in previous experiments, that there is, at this area, a greater concentration of radiation, especially at the main channel exit (J9).

**Figure 2. An operator receiving data while the RSMD is passing in front of the main channel.**

Even with the reactor shut down, it was possible to perform tests with the background radiation. The operator received, via Bluetooth, different levels of radiation, taken along the path made by the robot.

The algorithm viability was, then, certified as well as the robot functionality, in addition to the data receiving. There was no route deviation.

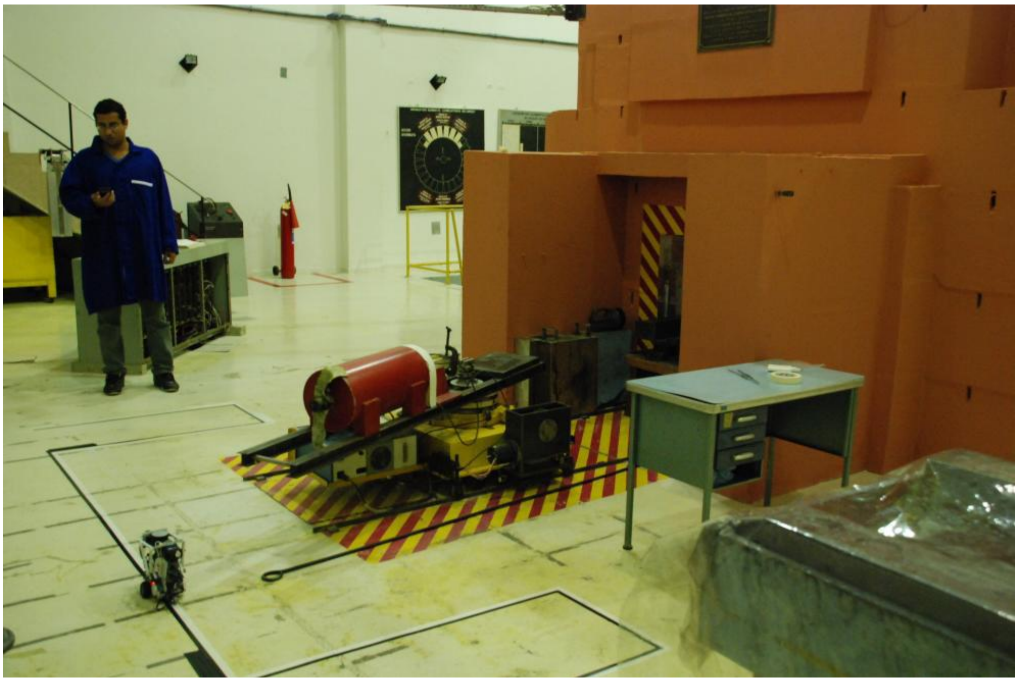

**Figure 3. The operator is receiving the data and the RMSD is passing in front of the main channel.**

## 4. RESULTS

For the RMSD system validation purpose, it was chosen, only, the front path to the reactor main channel J9. If the system efficiency can be attested in just a part of the way, it may be validated for any predetermined way. The coordinate axis starts at the figure left portion origin and its path goes by the main channel J9. All tests were done on the x axis e.g. Figure 4 .

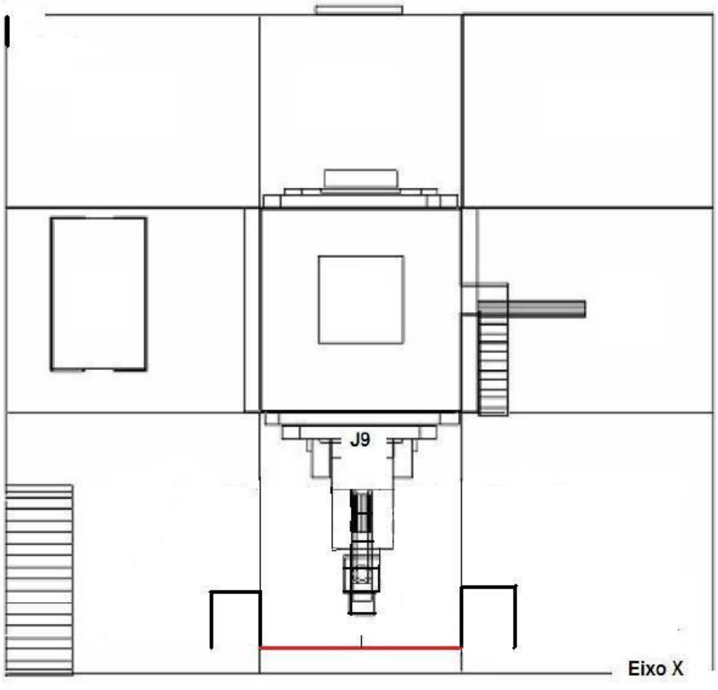

**Figure 4. The Argonauta reactor plant with a red band where the radiation measurement was made with the RMSD.**

The red band, where the robot has made the measures, has 3.3 meters and it was divided into small pieces of 30 cm where the RMSD stops during small breaks of 5s, to obtain the data measurement. The table below shows this gamma radiation information along the axis:

**Table 1. Numerical results**

| Position | 0.0 m | 0.3 m | 0.6 m | 0.9 m | 1.2 m | 1.5 m |
|---|---|---|---|---|---|---|
| Gama radiation | 0,780 μSv/h | 0,770 μSv/h | 0,810 μSv/h | 0,870 μSv/h | 0,910 μSv/h | 0,980 μSv/h |
| Position | 1.8 m | 2.1 m | 2.4 m | 2.7 m | 3.0 m | 3.3 m |
| Gama radiation | 0,980 μ Sv/h | 0,890 μ Sv/h | 0,820 μ Sv/h | 0,810 μ Sv/h | 0,780 μ Sv/h | 0,780 μ Sv/h |

a. 12 spatial cells in x direction in front of J9.

As we can see, on the table, even with the *Argonauta* reactor out of operation, it is possible to find that between the points 1.5 m to 1.8 m, the dose level is bigger than at the other points, what is explained due to their location, in front of the hot runner J9 main channel.

## 5. CONCLUSIONS

The system demonstrated one of the many successful applications that robotics can bring into the nuclear energy field. No wonder, nuclear power has contributed, over the years, to the robotic development researches. The RMSD was the first step in a project that aims to reduce the need for operator and researchers direct exposure to radiation doses.

In such a field, one of the key issues is to combine a robust programming and the electronic devices resistance to the radiation exposure. Therefore, the future goals, at IEN, is related to the use of a more reliable robot, which includes the electronic components shielding to the radiation effects, and also the use of more powerful engines as well as sensors more sensitive to the environment, allowing the automation development in nuclear environments.

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