Chapter 6
Safe Development Environments for Radiation Tracing Robots

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ABSTRACT

Robots can substitute for men in radioactively-contaminated areas. This is a suitable field to deploy robots for measurements, repair, or clearance, but development and test of such robots could be dangerous, because radiation sources need to be handled. To avoid these hazards in development or public demonstrations, safe alternatives to radiation samples have been sought using an already existing robot (EtaBot). One proposed solution is an optical substitution ("light follower"), the other one a fully-digital simulation of the contaminated area and the robot movement inside it using a hardware-in-the-loop simulator (HiL).

INTRODUCTION

After a nuclear disaster (e.g. Chernobyl, Fukushima) or in some military scenarios, it is too dangerous for people to enter a contaminated area. This is a suitable field to deploy robots for measurements, repair or clearance. Several fully autonomous or remote operated robots have been already built for this purpose. Before operation the robot must be developed, built and tested safely for critical missions. So it is desirable to perform these activities without handling dangerous radiation sources. A further advantage of simulated environments is a higher flexibility. This paper describes two ways of safe development. For the work a self-built, wheeled, multi-purpose robot "EtaBot" has been used. Radiation tracing and optional radiation-based navigation have been implemented in ROS.

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One simple way has been dubbed “light follower”. The radiation sensor has been substituted by a photo diode as a light sensor. For the light sensor an interface circuit emulates the signals which in true operation would come from the radiation sensor. The robot can run a given path and just measure radiation on this path, but additionally an algorithm has been implemented to follow actively the radiation source. In this mode a directive radiation source could be represented e.g. by a simple torch light, a distributed scenario by diffuse lamps.

A second, more sophisticated approach is a complete digital simulation of the contaminated environment using a hardware-in-the-loop simulator (HiL). This implies two technical core questions, on the one hand the representation of the contaminated environment and the robot motion in the HiL, on the other side the interfacing between the robot and the HiL. Depending on the interface further functionality needs to be implemented in the simulator. In the particular case of this article, the robot has been reduced to its computation platform. The ROS computer receives radiation signals from the HiL, passes motion commands to an additional microcontroller board which would control steering and the motors. The robot is jacked with its wheels free from ground, the PWM signals are intercepted and fed into the HiL to simulate the robot motion, its location and posture in the contaminated environment. With a graphical map creator, scenarios can be defined and uploaded to the HiL. Radiation exploring robots and the presented approaches are good examples where deep interaction of mechanics and electronics (mechatronics) solves problems (Habib, 2007). A very similar application is exploration for chemicals where sensors may be more complicated, but exploration is easier, because in contrast to the stochastic nature, chemical sensing delivers continuous values (Ishida, 2012).

BACKGROUND

Properties of Radioactive Radiation

Decomposition of atomic nuclei releases α-rays (particles consisting of two protons and two neutrons), β-rays (electron rays, rarely positron rays) and γ-rays (energy rich photons). The wave-particle duality allows considering these kinds of radiation also as waves. In particular γ-radiation is often considered as an electromagnetic wave with higher frequency, higher energy and shorter wavelength as X rays. All kinds are capable to damage living cells and to cause cancer and birth defects. Whereas α-rays from outside the body are absorbed by the outer skin layers, γ-rays have the deepest penetration through the body. X rays have similar properties as γ-rays, they have a longer wavelength, so the related energy of an X ray photon is lower (there is no clearly defined limit between X-rays and γ-rays, often the limit is assumed at 1 MeV or below, sometimes X-rays and γ-rays are even used synonymously).

Radiation interacts with living or dead matter by ionization. Ionization is also used to detect radioactive radiation. Typical detectors are Geiger-Müller Tubes; a typical implementation is a tube with an easily penetrated end window in which a high voltage electrode separates ions and causes a measurable current. So Geiger-Müller Tubes have a maximum sensitivity in the window direction, whereas sensitivity to radiation from the side is much lower. Further radiation sensors (not considered here) are semiconductor sensors including radiation sensitive image sensors and scintillators which turn radiation into light.