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Precise radioactive source installation using dual-manipulator remote mobile robot for the AD ATRAP experiment at CERN

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Abstract
Most of the maintenance activities in radioactive environments involving mobile manipulators are related to dismantling and decommissioning, in which, usually, little accuracy during the operation is needed. Mobile manipulators designed for this purpose, lack that level of accuracy necessary for accomplishing particular tasks, in which high precision and care are necessary. This lack of accuracy can be overcome using appropriate control strategies on the robot, accurate Human-Robot Interface procedures and dedicated tooling that will increase the overall operational efficiency and the safety and reduce the operator's stress. In this paper, the precise installation of a Cs-137 radioactive source for the CERN's AD ATRAP experiment using a remote mobile robot equipped with two robotic manipulators is presented. The preparation, the hardware, the tooling, the software and the operation have been implemented and executed following the guidelines of the CERNTAURO framework for remote intervention in radioactive environments. In this work will be presented an intervention procedure starting from the full custom design of the tools, operational steps needed and training for the operators, needed to archive a successful robotic tele manipulated intervention, giving an overview of the problematic of the application.

1. Introduction

Nuclear plants like Fukushima [1], as well as particle accelerator facilities, such as the European Organization for Nuclear Research (CERN) [2], present experimental facility with harsh environments condition, or underground experiment with and semi-structured accelerator areas with thousands of different items of equipment which need to be inspected and maintained. Due to the presence of human hazards mainly produced by radiation or contamination risk, for this accelerators components is need to be inspected and maintained remotely, possibly using robots. Furthermore, lack of accuracy can be overcome using appropriate control strategies on the robot, accurate Human-Robot Interface procedures and dedicated tooling that will increase the overall operational efficiency and the safety and reduce the operator's stress. In this paper, the precise installation of a Cs-137 radioactive source for the CERN's AD ATRAP experiment using a remote mobile robot1. The CERNBot [3] robotic platform (Figure 1) developed and built at CERN, it has been used in more than one hundred real interventions, which have been very successful done.

2. Intervention

For this intervention, CERNbot running CERNTAURO [4] framework, this framework it is composed of a novel bilateral master-slave control, a new robotic platform an advanced user-friendly multimodal human-robot interface, also used for the operator offline training, allowing technicians not an expert in robot operation to perform inspection and maintenance tasks. Furthermore, the CERNBot2 is equipped with an elevating stage and dual robotic arm source had a length of 20 mm and had to be removed from lead shielding radioactive transport container, taken out from its support.

Figure 1. (a. CERNbot2 in operational configuration, b. full custom fingers)

The radioactive source then being integrated into another support inside the experimental chamber and the whole assembly was put in an experimental container that is in the frame of the Antimatter Production facility [5] at CERN. For each of these tasks, a large number of robots would be needed, with sensors and tools, to satisfy every situation. Robots available on the market, both industrial and military for interventions [6], can be considered as a black box that cannot be modified and adapted to the particular needs of the intervention. Specific tools and the procedures were built following the proposed framework. Another success has been the handling of a radioactive iridium source. The

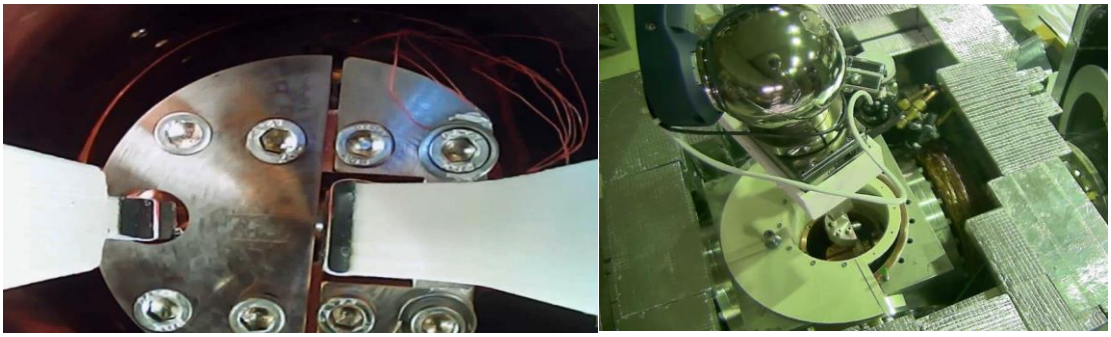

Figure 2. (a. robot friendy plastic cover set, b. point of view of endoscopic camera in gripper)

radioactive system (a Kinova robotic arm for screwing the nuts). The position of the experimental chamber as at 1.5 meter from the floor.

3. Materials and Methods

CERNbot v1.0 and v2.0 [4], novel robotic base systems, have been built at CERN with the goal of guaranteeing autonomous inspection and supervised telemanipulation in the accelerator areas. The CERNbot robotic platform has been designed to guarantee the maximum flexibility from the mechanical and electrical point of views. A commercial industrial grippers (Universal gripper PG, Size: 70, Schunk) are mounted on the robotic arms of the CERNBot2. Where the position repeat accuracy of ±0.15 mm, given from the robotic arm Schunk Powerball is able to guarantee the task precision movement needs of 0.5 mm. Since the standard fingers does not fit in the vacuum chamber, it was necessary to develop them. The fingers realized with PLA were thanks a fast prototyping 3D printed with FDM technologies. Besides, from the Human-Robot Interface (HRI) presented in [7] has been developed for remote robotic intervention in hazardous environments. The interface proposed for human-robot collaboration allows controlling a heterogeneous set of robots and the modularity and control framework. Some features for the HRI covers a series of technologies, like development to robot control, network communication, safety, Human-Robot Interaction, etc. The HRI continues to get new features and improvements broadening the use of robots in the interventions. Expert and inexperienced operators have been validated the HRI through more than hundred real interventions in CERN's facilities

4. Conclusions

Safety in the work environment is the most advantage of utilizing robotics. Employees who work in hazardous environments can delegate dangerous tasks to a robot which are possible or safe to perform for humans. CERNTAURO framework was developed at CERN to help the operators to perform robotic tasks in a comfortable way, increasing the success rate and safety, and decreasing the intervention time. The teleoperation is currently the only solution to intervene for the maintenance in extreme environments. Nevertheless, there are some types of tasks that require particular attention. In this work, two new tools was been added to the CERNbot platform in order to adapt the gripper finger and the particular point to view in order to help the operator during the manipulation. Furthermore, a new procedure it is ideated in order to avoid object dropping in the vacuum chamber. A modular set of plastic cover mask (Figure 2a) was designed to adapt the shape to each operational step avoid the possibility to drop object in the chamber, and furthermore smiley to install and remove at the end of the operation in one single movement. To avoid this problem a the combination between the two new feature and the smart fingers mounted on the gripper of the CERNBot2 platform lets the operator perform the source installation and remove, an operation safe and furthermore limiting the operational stress. The good result of the installation indicates the robustness of the robotic framework gives from the software and mechanical designed integration. Thanks to the good planning of the activities more the offline tests of all the steps needed for the intervention, give to the operators a good feeling during the real application. That indicates a good robot user interface that allows operating the robot naturally without added stress. The complete intervention was been performed in six hours of operation without any complication archived and zero doses for the persons involved.

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