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R&D Phases of a Mobile Robot Prototype Applied to Underground Distribution Lines

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***Abstract* – This video summarizes the R&D phases of the first robot prototype designed to operate and maintain equipment in vaults for Hydro-Québec's underground distribution lines, carried out between 2003 and 2009. Detailed segments discuss project's context, proof of concept, simulations, description and design of robotic platform subsystems, prototype testing at IREQ in the lab and in an outdoor vault, field testing in Montreal on a Joslyn switch in a de-energized vault, and the future of the project.**

I. Introduction

THE aim of this video session is to present an overview of the R&D work done to robotize tasks on the underground distribution lines, illustrating each phase.

II. Exploration and Task Automation (2003–2005)

The first phase of the R&D project was to trace the history of robotics related to underground distribution lines and determine whether any system had ever been designed for this application. The technical report in [1] shows that robotic systems had been designed for overhead, but not underground, distribution grids. The video shows the kinds of vaults in Montreal where the mobile robot is intended to operate.

At IREQ, a 6-DOF Kraft TeleRobotics GRIPS II arm (see Fig. 1) was used with task-specific tools to operate a Joslyn switch in automatic mode (no teleoperation). The main tasks performed in the lab for the proof of concept were to locate a switch with a laser sensor, to remove/insert a pin on the switch's manual operating handle, to remove/replace a handle on its square shaft, and to grip and rotate the handle to change the state of the switch. A segment of this work with part of the control algorithm strategy is detailed in [2].

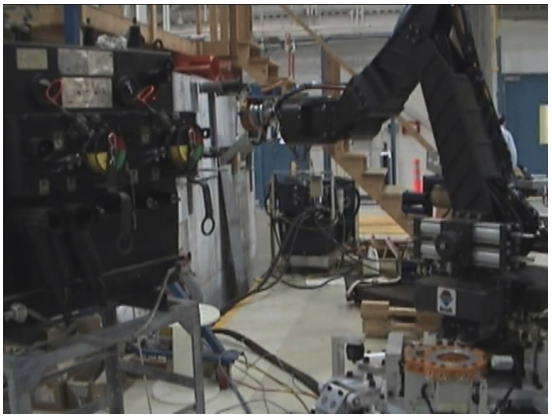

Fig. 1. Proof of concept with a Kraft TeleRobotics GRIPS II manipulator

III. Prototype Design (2005–2007)

Following the successful proof of concept using a Kraft arm, the R&D team started work on designing the complete robot system with a view to building the first prototype. As described in [3], the robotic system consists of a vehicle (the vehicle assures the mobility of the robotic platform to go on roads and sidewalks, it is operated as a regular vehicle), an articulated 5-DOF long-reach hydraulic arm, a 6-DOF electric manipulator, and task-specific tools. The video also shows that one of the special features of this mobile platform is the 6-DOF electric manipulator with integrated power and control electronics in its arms (see Fig. 2), which eliminates the need for a control cabinet; this particular work is detailed in [4].

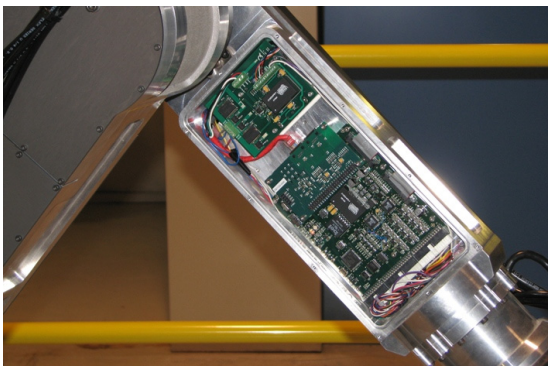

Fig. 2. 6-DOF electric manipulator with integrated electronics

To aid in the selection of components of the 6-DOF manipulator and the mechanical design, kinematics and dynamics algorithms were implemented in MATLAB to

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simulate actuator torques. Recorded forces and moments at the end-effector from tasks performed with the Kraft arm were input. An example of results generated with MATLAB simulations of rotating and pulling a switch's manual operating handle is presented in Fig. 3.

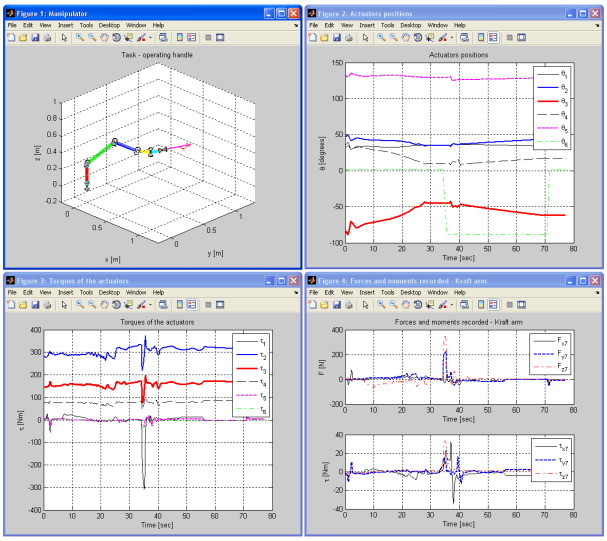

Fig. 3. Kinematic and dynamic simulations with MATLAB

IV. Laboratory Results and Field Tests (2007–2009)

The robot system prototype shown in Fig. 4 was assembled and tested in the lab for the first time in 2007. Additional tasks performed on the Joslyn switch were to unscrew/screw the cap of the SF_6 fill valve, simulate filling through the fill valve, and pull/push the insulating plug cap.

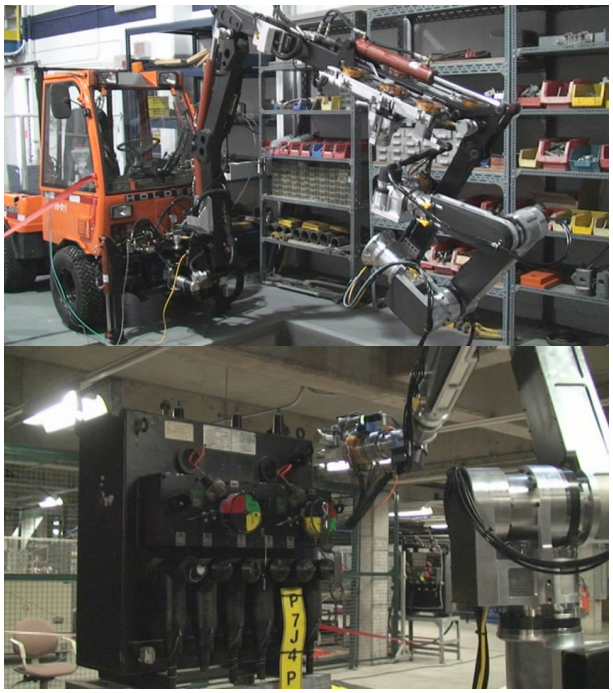

Fig. 4. First laboratory tests with the complete robot system

In 2008, a vault was built on IREQ's site to test the robot system in a realistic operating environment (see Fig. 5). The main goal was to fine-tune techniques with the manipulator and tools in order to perform tasks on a Joslyn switch in an actual vault. Unlike the proof of concept and the initial lab tests, where the manipulator was freely positioned in front of the switch, in the vault full of equipment, the robot system did not have much room to move. Tests for one vault configuration were successful. In November 2008, field tests were performed for the first time outside IREQ in a de-energized Hydro-Quebec Distribution vault in Montreal. Those tests are described in [5].

Fig. 5. Mobile robot prototype in operation in IREQ vault

V. Conclusion and Future Work

After developing the first prototype and testing it at IREQ and in Montreal, the R&D team decided to modify some aspects of the robot system. The future of the project resides in building on the first robotic platform to produce a second prototype capable of performing tasks in a confined space. A novel robot architecture for this application, currently being reviewed, is presented briefly at the end of the video with a CATIA simulation.

VI. References

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