

Robotic Systems for Remote Characterization and Decommissioning – 15102

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ABSTRACT

This paper provides an updated summary of the research being conducted at the University of Manchester, UK, in the area of remote characterisation through the use of robotic systems, in support of the decommissioning plan for the Sellafield nuclear site in Cumbria, UK. The research is being conducted in collaboration with a number of companies including Sellafield Ltd, the National Nuclear Laboratory and Forth Engineering Ltd. The progress of a number of novel mobile robotic platforms being developed at the University of Manchester is presented including the AVEXIS underwater vehicles, ground and sub-surface vehicles and alpha glove box decontamination robots. Also presented is the ongoing work on the remote sensing technologies and techniques which will be deployed on the robotic platforms.

INTRODUCTION

The UK has one of the most challenging nuclear decommissioning sites in the world at the Sellafield site in Cumbria, UK. The site has 290 active facilities in a 6km² area and is due to become the largest building site in Europe next year. The Sellafield decommissioning plan is 100 years long and there are a significant number of challenges in starting the process due to lack of accurate data regarding the facilities and their contents. The University of Manchester is leading the development of a number of robotic systems for remote characterization of these storage facilities. This paper provides an update on the robotic system development which was reported in previous work [1].

ROBOTIC PLATFORMS FOR CHARACTERISATION

The research at The University of Manchester is split into two streams; novel platform development and control, and characterisation technologies. This section will provide an update on the platform development.

Aqua Vehicle Explorer for In Situ Sensing (AVEXIS)

The AVEXIS vehicle, shown in Fig. 1, has been developed over the last 6 years for the exploration and characterization of wet storage facilities (wsf). The vehicle has been designed as a low-cost sensor platform which can be used individually, or as part of a swarm [2].



Fig. 1. The AVEXIS Prototype [1]

There are currently four ongoing projects relating to different aspects of the AVEXIS design: the AVEXIS MiniROV, design of collaborative control, analysis of the effects of radiation on the electronics and the development of an acoustic communications and positioning system.

The AVEXIS MiniROV project started in June 2014 and is concerned with the miniaturization of the vehicle for the deployment through a 140 mm access port (Fig. 2). This version of the system will be tethered and have a camera onboard and will be used to inspect very confined but uncluttered spaces. As part of the project, the hull and propulsion system is being redesigned so that there are no external protrudances. This modified hull will then be scaled back up and be incorporated into the main AVEXIS vehicle. A new embedded system is also being developed which will be used by both vehicles.

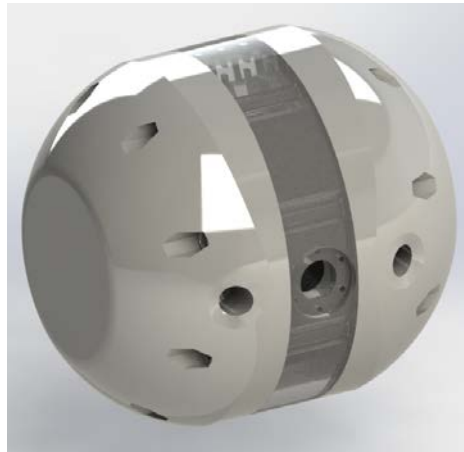


Fig. 2. The AVEXIS MiniROV Prototype

A key component of the AVEXIS system is the acoustic communications and positioning system (ACPS). The AVEXIS ACPS project also started in June 2014 and is focused on the development of a system which can be used for localization and communications in both a benign environment and a cluttered one. Frequencies ranging from 40 kHz to 1 MHz are being investigated and the main challenges are in the high multi-path components due to the enclosed nature of the facilities, and the data rate for vehicle to shore communications. When operating in a cluttered environment, non-line-of-sight issues mean that accuracy and data rate can be very poor, so collaborative formation control algorithms are being developed to allow other vehicles to act as virtual anchors.

One of the original design aims was to develop a vehicle which could be used individually or as part of a swarm. The AVEXIS Collaborative Control project is investigating the development of optimal control algorithms for the exploration of an unknown environment using a centrally controlled, power and functionality limited distributed sensor network. The initial development of the algorithms is being conducted using the e-puck robots [3] in 2D (Fig. 3). Initial work on implementing SLAM, formation control and maze navigation using the e-pucks has already been conducted [4,5,6] and this will form the basis of the future work. The algorithms will then be transferred to UAVs before being trialed on AUVs. The primary challenges in this project are related to the resource limitation of the vehicles such as power, computation and sensing capabilities.



Fig. 3. An E-puck Robot

A major concern with regards all robotic characterization systems, is their susceptibility to radiation damage. Work is ongoing at the University of Manchester to try and identify and understand the failure modes of certain electronic components that are common in most robotic systems. By understanding how and when the devices fail, mitigation schemes can be implemented and lifespan estimates of the vehicles can be generated. The AVEXIS vehicles are less susceptible to radiation than ground vehicles due to the water acting as a radiological shield, however the research benefits all of the vehicles the University is developing.

Groundwater Contamination Robots

A number of systems are currently in development for groundwater contamination analysis. As reported in [1], the Gamma Robot was being designed to remotely deploy sensors down bore holes to take radiological measurements. The prototype vehicle is shown in Fig. 4 and has the capabilities to navigate to the bore hole pipes and deploy a sensor on a winch down it to take readings. Low-resolution positioning is achieved using an acoustic positioning system, whilst the high-resolution positioning over the bore hole is done using vision and optical sensors [7].

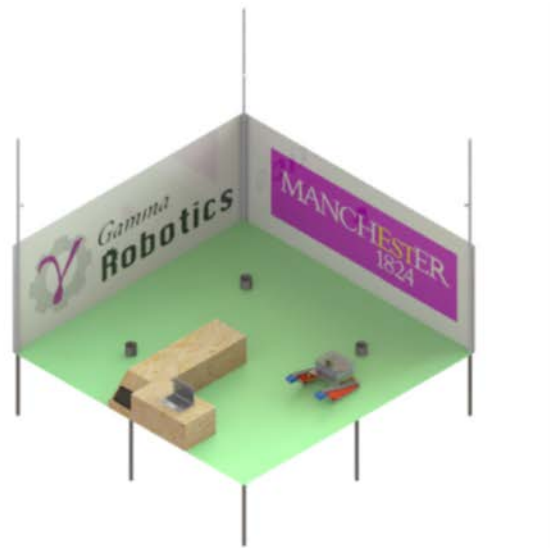
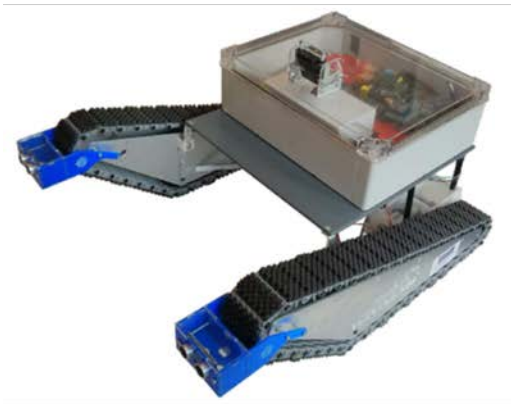


Fig. 4. The Prototype Gamma Robot for Groundwater Contamination Studies [7]

Another groundwater related project which is ongoing is to design a burrowing robot which will be able to move around underground to measure contamination levels more accurately than using bore holes. Underground motion is very challenging and the current designs use contra-rotating screws (Fig. 5) for forward and reverse motion and for turning [8].



Fig. 5. Front half of the contra-rotor screw [8]

Alpha Glove Box Cleaning System

One of the biggest challenges in the decommissioning process is the cleaning and decontaminating of alpha glove boxes. This challenge is not unique to the Sellafield site, or the nuclear industry. There are thousands of glove boxes in the chemical and biotechnology sectors which contain hazardous substances which must be removed before disposal.

On the Sellafield site, the major problem is related to logistics as well as safety. Alpha radiation is easy to block so people can wear protective PVC suits. Unfortunately the average deployment time in the suits is 2 hours, after which the suits are classified as plutonium contaminated waste and disposed of. To decommission all of the alpha glove boxes on the Sellafield site would require around 5000 man entries. There are not enough PVC suits to do this, and statistically there will be at least one fatality due to non-radiological health and safety issues. The cost of disposing of all of the suits is also very high.

To try and overcome this problem, the University of Manchester is developing a robotic system which can be deployed into the entry port of the glove box. It can then be left to clean the inside and retrieved once it has finished. The robot will also be able to validate the cleaning procedure. The initial project started in October 2014 and is a feasibility study.

Sensor Ball

The Sensor Ball project is investigating the use of small, highly mobile sensor backed devices for the cost reduction of the decommissioning characterisation and asset care problem. The principle behind the device is a small-scale, mobile, spherical sensor platform which could be deployed into a storage facility. The motion system would be internal which means that the spherical hull could be easily decontaminated and the vehicle retrieved at the end of the characterisation process. This project started in September 2014 and is in the very early stages.

Radiation Tolerance of Electronic Components

Work is ongoing at the University, through the Dalton Cumbrian Facility [1], to identify the failure modes of common electronic components used in robotic systems. Initial testing has concentrated on voltage regulators [8]. The aim is to identify and understand how the components fail and then propose

mitigation techniques. It is also hoped that a database of common-component's lifespans under varying radiological conditions can be developed.

REMOTE CHARACTERISATION SYSTEMS

This section will introduce some of the work being conducted on the characterisation technologies.

Geometric Characterization of Waste Packages

The first stage in the decommissioning process is the geometric characterisation of the waste. The data generated from this can then be used to validate the existing CAD drawings of facilities and to help plan the retrieval stage. It can also be used to plan further exploration or retrieval by remote platforms (Fig. 6) and identify optimal cutting paths.

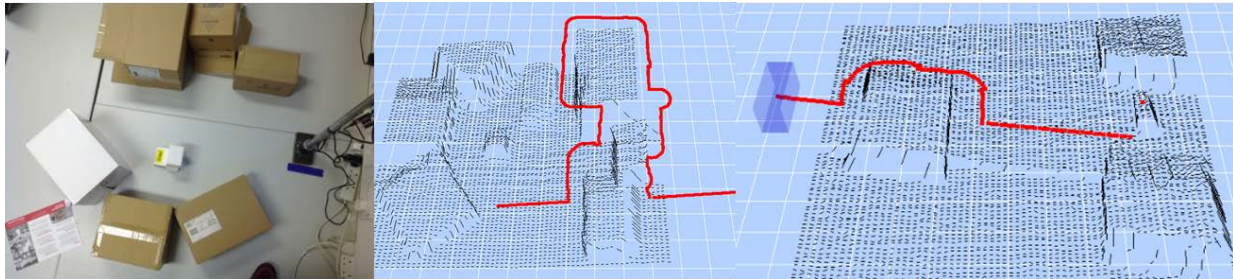


Fig. 6. Geometric Characterisation of a Cluttered Environment and Path Planning for Retrieval [9]

A number of projects are ongoing in the area of geometric and radiologic characterisation using sensors such as Lidar and stereoscopic imaging (Xbox Kinect sensor).

Tomographic Methods for In-Situ Sludge Characterization

In-situ monitoring of the legacy silos is a very difficult challenge. It is required before retrievals can begin so that any foreign objects in the sludge can be identified and worked into the removal plan. In October 2014, a project started at the University of Manchester to develop tomographic methods to characterise the sludge using invasive techniques due to the large concrete walls that surround the silos.

DISCUSSIONS AND CONCLUSIONS

The University of Manchester is at the forefront of the development of remote vehicles and characterisation technology for use in the decommissioning of legacy nuclear sites. There are many challenges surrounding the decommissioning process primarily related to the limited access entry points, hazardous environments and power consumption. The technologies being investigated could help speed up the decommissioning process and improve safety, however there are other applications in modern nuclear facilities and the oil & gas industry.

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