SeeSnake: Radiological Characterisation of Complex Nuclear Spaces – 16162

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ABSTRACT

Decommissioning of retired nuclear plant can be a difficult task for many reasons. A number of locations around the world have active cells awaiting decommissioning without a clear understanding of the internal structure and possible locations of radiological sources. Furthermore, many nuclear plant drawings and models do not reflect the “as built” dimensions, and precise data required for safe and cost effective decommissioning is not readily available. This presents decommissioning teams with significant challenges when attempting to plan and execute their decommissioning programs.

Due to the complex nature and constrained environments typical of legacy nuclear plant, it is often not possible to deploy traditional remote handling/inspection technologies. Even where possible, identifying the correct sensor, or suite of sensors, to characterize the environment is problematic. To address this common issue Create Technologies Ltd (Createc) and OC Robotics collaborated on SeeSnake, a project aimed at leveraging radiometric source mapping with 3D scanning and confined space remote handling.

Createc’s imaging and sensing systems have strong capabilities in the nuclear industry, led by their N-Visage products, as do OC Robotics’ snake-arm robots as a remote deployment platform for confined and hazardous spaces.

The snake-arm robot enables access through small penetrations with the ability to navigate internal structures and other obstacles without support from the environment; whilst multiple re-positioning of the N-Visage sensor, integrated with the snake-arm system, enables a thorough 3D map to be created. The SeeSnake project demonstrates the integrated systems ability to capture valuable radiation, visual and positional data enabling the characterization of a complex active environment.

To mature the concept into an integrated, functional technology the SeeSnake partners overcame a number of challenges before demonstrating to key stakeholders in the UK nuclear industry. This paper describes these challenges and the solutions implemented, along with the results from early system trials and stakeholder demonstrations. It also addresses the next steps for the SeeSnake technology and identifies a number of applications which will may benefit from its exploitation.

INTRODUCTION

With many early generation nuclear plants reaching end of life, decommissioning is now at the forefront of minds across the nuclear industry, with safety, efficiency and cost effectiveness essential aspects of this work. Additionally, nuclear plant drawings and models are often not accurate to the physical environment and precise data required for safe and cost effective decommissioning is not easily accessible. This presents decommissioning teams with significant challenges when attempting to plan and execute their decommissioning programs.

The quality of data attainable during the planning stages of a decommissioning campaign often has a significant impact on the overall project costs. 'What are we dealing with?' is often the first question asked by the decommissioning team, with the primary challenge being to identify the location of any radiation sources in the complex nuclear environments. The ideal solution for many decommissioning projects would be a complete and accurate, high resolution, 3D map of radiation overlaid on the visible contents of the environment.

SeeSnake is a major advance in this area. As a UK collaborative feasibility project, conducted by Createc and OC Robotics, SeeSnake has developed an innovative tool for the characterization of redundant nuclear plant prior to decommissioning. Combining Createc's N-Visage radiation mapping tool with a snake-arm robot enables deployment through small penetrations and navigation of complex internal structures.

The N-Visage gamma imager and source mapping software enables the environment to be surveyed and an easy to read 3D model to be produced with accurate radiation fields and visual images overlaid. This information provides basic dose mitigation data by revealing the lowest dose area(s) from which to operate. The flexibility and dexterity of the snake-arm robot means the N-Visage tool can build up an accurate 3D map of complex environments, whilst collecting valuable radiation data.

The SeeSnake system forms part of a decommissioning tool box of technologies which have been integrated with snake-arm robots to conduct tasks including the optimization of cutting plans, in situ remote laser cutting, waste segregation and remote inspection. This toolbox not only reduces operator exposure to hazardous environments, but also improves safety and reduces costs of decommissioning projects.

METHOD

To demonstrate the concept of SeeSnake, a standard snake-arm robot was integrated with an adapted N-Visage sensor package. The work conducted to achieve this is described below:

N-Visage Sensor Package

N-Visage is an inverse-modelling software package for nuclear characterization originally developed for use in decommissioning planning at Sellafield in the UK. Many radiation measurements are fused with geometry data to produce a three dimensional activity distribution – i.e. a 3D radiation image. The concept is similar to that used by in-situ characterization systems, such as ISOCS, but using a very large number of independent radiation measurements in a single model.

The N-Visage inverse-modelling software has previously been used to make a compact gamma camera, for 3D mapping in hard to access areas such as reprocessing cells. The standard N-Visage gamma camera combines a rotating collimator with a lidar (Light Detection and Ranging 3D scanner to gather all the raw data required to generate 3D images uses the N-Visage inverse-modelling software.

The SeeSnake system develops this concept further by replacing the rotating collimator with a static collimator rigidly connected to the end of the snake-arm robot. This has several advantages relative to mounting a full gamma camera on the snake-arm robot: the sensor pack has no moving parts and can be very small and light in comparison even to a small gamma camera; the gamma sensor can translate as well as rotate, enabling an intrinsically 3D imaging process (at least 2 images from a static gamma camera are needed to build a 3D model); and the imaging process can be adapted to suit the available space.

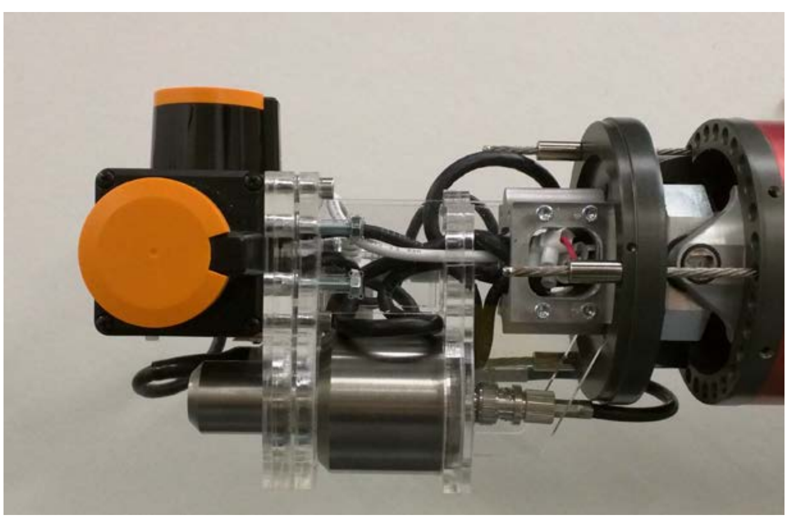

Figure 1: The prototype SeeSnake sensor pack (minus the external case)

3D Sensor Technology

A 3D sensor is an essential part of the SeeSnake concept that fulfils two distinct roles. The 3D data provides information on the absolute position of each radiation measurement through a process known a Simultaneous Localization and Mapping (SLAM). It also provides the 3D map which is used to define the geometry of the 3D image. Two options were analyzed – structured light and lidar. The advantage of structured light is its compact size and low mass, however lidar was determined to have longer range with higher precision. As Createc have experience of using lidar for their other sensor packages it was selected as the preferred option, configured with orthogonal lasers aligned with the motion axes of the snake-arm robot.

Snake-arm Robot Modifications

The SeeSnake project used an existing snake-arm robot to demonstrate the technology's abilities. The snake-arm robot was 100mm in diameter, 1.5m long and mounted on a linear axis. OC Robotics snake-arm robots have hollow cores in which services can be routed, to reduce the risk of cables snagging and to maintain a compact system. An entry point at the base of the snake-arm was created to allow the N-Visage services to be routed through the central core, to the tip of the arm. OC Robotics designed a generic mounting feature to mount Createc's tool with the existing snake-arm robot hardware. The mount allowed the services running through the center of the snake-arm robot to be passed to the tool at the tip.

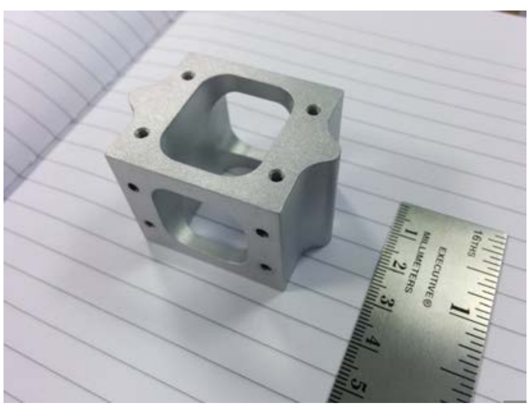

Figure 2: Universal tool mounting block

Figure 3: Mounting block attached to snake-arm robot with services

OC Robotics' Software Prototype

Tip Motion Software Development

Traditionally, Createc's N-Visage sensor packages have a positioning mechanism which allows the collimator to be re-orientated whilst collecting radiation data and mapping the environment. To minimize the mass of the sensor, the positioning mechanism was removed from the package designed for SeeSnake. To ensure the collimator could still be pointed and positioned accordingly, OC Robotics built upon an existing control mode for the snake-arm robot which allowed the tip to be re-orientated with autonomous input.

Tip motion control moves the distal three links of the arm, whilst the rest of the arm remains stationary. The algorithm bends the tip link as much as possible before bringing the other links into play. Each link can bend up to 30 degrees, allowing a tip bend of 90 degrees in total.

Control & Communication Interfacing

OC Robotics developed a software interface to allow the N-Visage tool control software to drive the snake-arm robot and re-orientate the tip appropriately. The interface also provided feedback of the approximate orientation of the arm to Createc's software. This allowed the software to calculate the position of the radiation and environmental data it was collecting, whilst negating the need for the positioning mechanism previously used by other N-Visage products.

Receiving, Sending and Visualizing Data

The ability to build up a close to real time representation of an environment is a useful asset for many use cases and applications across the nuclear decommissioning sector. OC Robotics has developed the communication protocols to send data between the N-Visage sensor and OC Robotics' snake-arm robot software, to build up a real-time point cloud of the environment. This enables the snake-arm robot to be visualized in the environment, by the operator, during deployment. Further work in this area is being conducted between Createc and OC Robotics following the successful completion of the SeeSnake project.

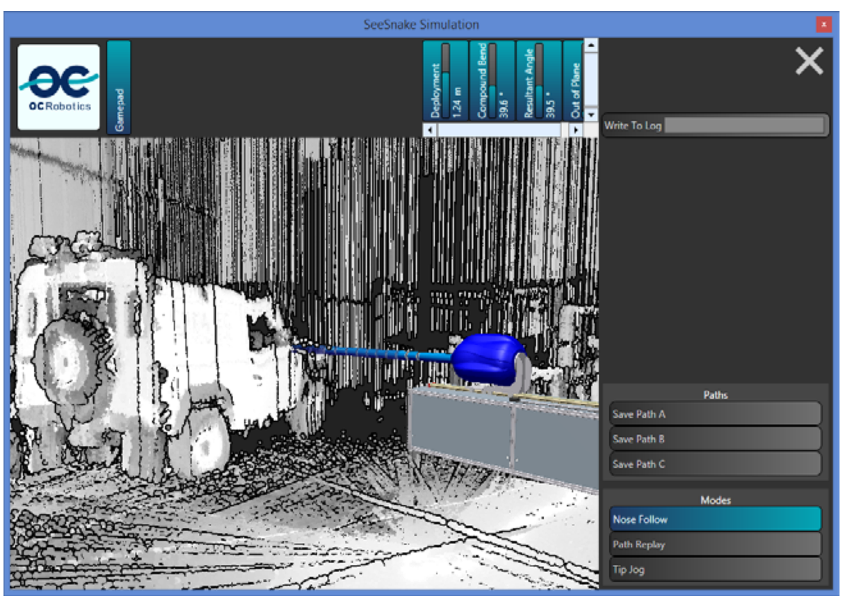

Figure 4: OC Robotics' snake-arm robot software, with visualization of snake-arm

robot within point cloud environment (based on real data collected and processed during SeeSnake project)

DISCUSSION

Testing & Trials

Figure 5, below, is from data collected during trials of the integrated SeeSnake system. It shows a 3D point cloud of a room, which has been achieved by scanning the area with the integrated snake-arm robot and sensor system. The system is able to scan along two axes, creating vertical and horizontal sets of data points. Createc's software is then able to stitch multiple data sets together to build up a clear 3D image of the room, using the location of the snake-arm robot as a positional reference and hence characterize the environment. The colored points in the center of Figure 5, indicate the location of each snake-arm robot link.

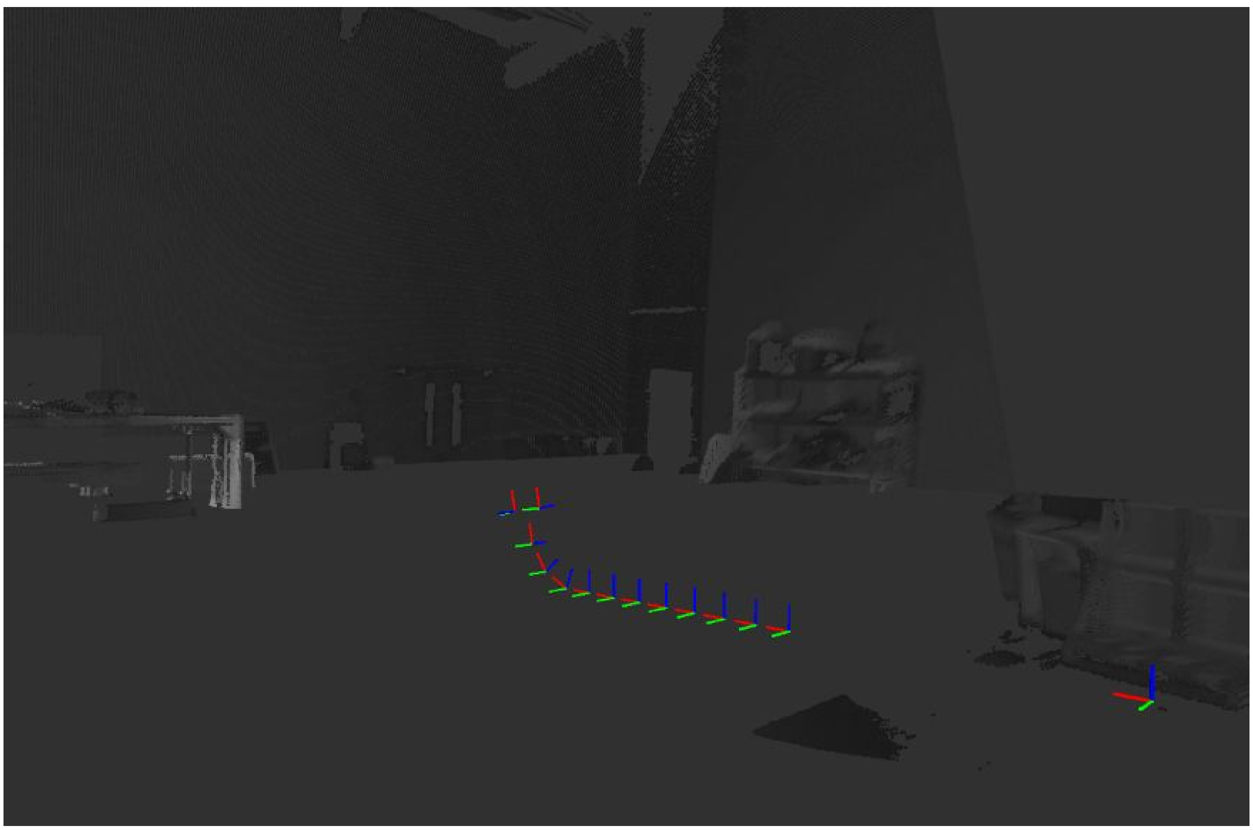

Figure 5: 3D point cloud data collected during trials of SeeSnake system.

The SeeSnake system has also been trialed radiologically characterizing an environment.

Industry Demonstration

The SeeSnake system will be demonstrated to invited members of the nuclear industry in early 2016. The purpose of the demonstration is to inform interested parties of the capabilities and uses of SeeSnake and how it can become an invaluable tool for nuclear decommissioning activities.

CONCLUSION

This paper presents the work done to demonstrate the capability of a flexible and dexterous snake-arm robot system, integrated with a complex sensor arrangement to characterize nuclear environments visually, positionally and radiologically.

SeeSnake has the ability to provide nuclear decommissioning teams with the detailed information required to safely plan and execute decommissioning activities in hazardous environments.

A number of specific use cases have been identified for SeeSnake. This includes decommissioning applications and post operation clean out (POCO) activities. Sellafield also has a number of facilities which would benefit significantly from the SeeSnake project, as does Fukushima in Japan.

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