Remotely Deployed Robot and Sensor Network to Characterise 50mm Pipework

Steve Hodges
School of Computing & Communications
Lancaster University
Lancaster, UK
steve.hodges@lancaster.ac.uk

Alfie Allanach
School of Engineering
Lancaster University
Lancaster, UK
a.allanach@lancaster.ac.uk

Stephen Monk
School of Engineering
Lancaster University
Lancaster, UK
s.monk@lancaster.ac.uk

Abstract

With many hundreds of kilometres of pipework across the UK nuclear estate requiring decommissioning (and with human access usually impossible due to space and radiological dose limitations), the delivery of several sensing modules capable of characterising the inside of 50 mm pipework would be greatly beneficial. This work presents such a system which will feature several small form factor modules such as a high-resolution imaging module, using machine learning techniques to provide accurate vision data for navigation purposes, as well as providing information to the user concerning contaminants such as residual liquor. In addition, a module to measure the effects of corrosion will be included, which will most likely function utilising ultrasonic waves or fibre optics to monitor the damage. To combat any corrosion related issues, a spray delivery module will be integrated, developed using an electrically actuated syringe which utilises decontaminants such as nitric acid. The system will further include a radiological instrumentation module to determine activity using photodiodes to monitor alpha particles and neutrons, as well as a CeBr3 scintillator to monitor beta and gamma particles using a discrimination algorithm. Finally, a Raman spectroscopy module will be incorporated, intended to characterise any liquor found in the pipework. This system will be delivered to the area of interest within the pipework via a soft robotic design which is currently being developed with Dounreay. This earlier work concentrated on designing a novel locomotive stage capable of traversing 50 mm diameter pipework through junctions such as swept bends and 90-degree T junctions.

1.0 Introduction

Nuclear decommissioning presents one of the most demanding inspection challenges in modern engineering. Across the UK's nuclear estate, hundreds of kilometres of legacy pipework must be assessed and decommissioned,

yet the confined geometry of 50 mm diameter pipes, combined with hazardous radiological environments, makes direct human intervention largely impractical. This paper introduces a multi-module robotic system designed to meet that challenge. A basic diagram of the proposed modules is shown in *Figure 2*.

2.0 Related work

Current work has investigated the use of using an inchworm like locomotive in order to navigate the pipe [1]. The work conducted has achieved a successful prototype, fabricated by using silicone grippers on either end of the robot, with a silicone bellow in-between that generates linear movement through the pipe. Whilst the design does work, it would benefit from being further developed into a more robust design. In addition to this, a pneumatic control system creates a large profile for the robot which is currently inadequate for pipework with a 50 mm diameter. An image of the prototype is shown in *Figure 1*.

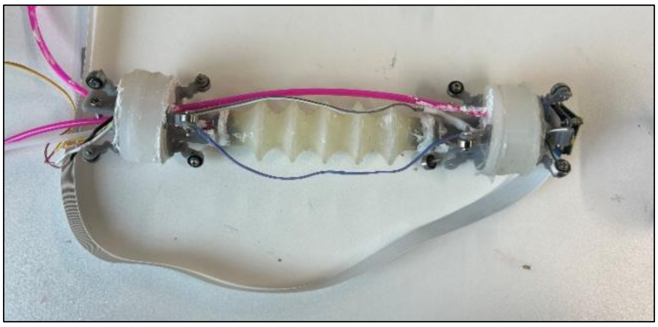

Figure 1: Current prototype progress

The development of any of the proposed modules pulled behind the locomotive has not currently been started, however, alongside the design of the initial prototype, a SLAM (Simultaneous Localization and Mapping) vision system has been developed to a high level and implemented.

3.0 Proposed Design

Whilst the basic structure of the robot will stay consistent, as shown in *Figure 2*, further design ideas have not been decided upon.

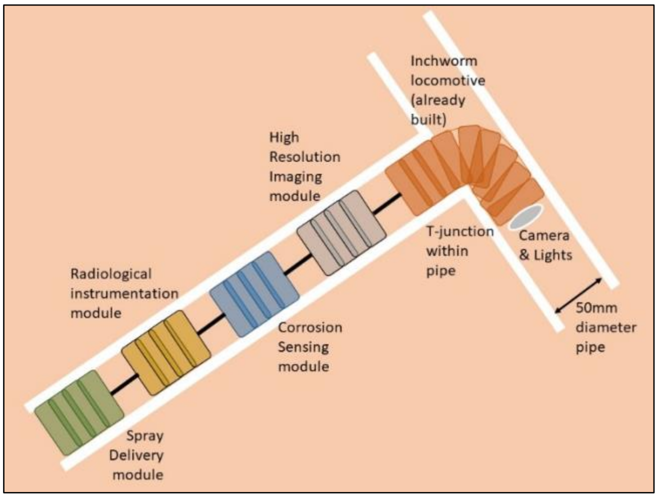

Figure 2: Locomotive with four of the modules attached

Currently, the leading idea to build upon the pneumatic locomotion proposed earlier is to use McKibben muscle actuators as they are more robust and can generate higher force outputs which will yield a higher payload [2]. A diagram of how a MKM (McKibben muscle) works is shown in *Figure 3*.

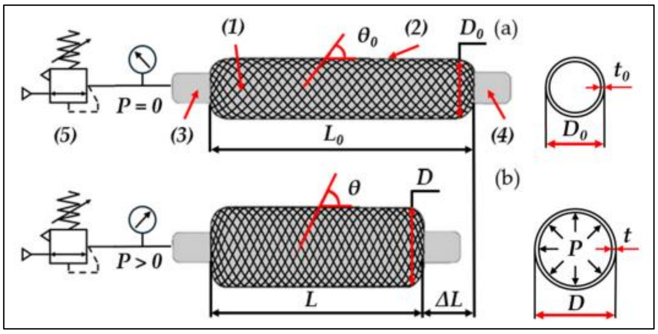

Figure 3: Schematic of the MKM: (a) at rest (P = 0); (b) actuated (P > 0). Components of an MKM: (1) inner tube made of hyper elastic material, (2) fibre reinforcement, (3) end for constraining and pressurization, (4) opposite end to exert pull force, (5) precision pressure regulator [2].

Whilst the method of actuation will be controlled by pneumatic contraction and expansion, an electronic control system will be required to regulate the robot. No schematics or designs have been created; however, it is assumed that the robot will require on board microcontrollers and PCBs in order to properly function.

4.0 Responsible innovation

This project aims to help with the effort to clean up the UK's nuclear estate. As an aspiring engineer, it is important to me that from the beginning, the post operational process of a device or system is contemplated. It is clear from sites like Sellafield that this has not been a consideration in the past. I aim to develop a device that is created from materials that can be decontaminated and recycled, so that it does not contribute to even further avoidable nuclear waste. Additionally, I am aiming to create it at a low cost so can be used anywhere and have a simple enough design that it can be used without lengthy training.

5.0 Author bio

I am postgraduate researcher at Lancaster University, working on robotics within the nuclear field. I attended Lancaster University for my undergraduate Meng in mechatronic engineering. Throughout that course I honed my technical skills such as 3D design and manufacture, as well as circuit design. Whilst my course taught me with a wide range technical skills, the nature of it being mechatronic meant I would never have achieved as much depth as a dedicated electronic or mechanical engineer in some areas. For example, whilst I have studied PCB design, it was not in much depth and infrequent. A course like this is a great opportunity to revisit those skills and develop them further.

During my master's project I, as part of a team, developed low-cost 3D printable microfluidic lab equipment which consisted of a syringe pump, a microscope, and a microfluidic chip. This was designed to be used as an accessible way to analyse microplastics within fluid samples.

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