Introduction

- The UK has over £250 billion invested in water infrastructure (UKWRIF, Taking Responsibility for Water), with pipe networks being by far Water Companies’ greatest asset.
- This pipe infrastructure is an ageing and deteriorating asset base. Millions of holes for pipe repair are dug each year, many into the UK road network, impacting on the UK public. Failure to accurately identify the location of buried pipes can cause severe problems, costs and dangers for all stakeholders.
- A crucial aspect of water distribution pipe monitoring therefore, is to exploit the development of in situ robotics inspection to simultaneously inspect and map out the pipe network. The network map can then be used to localise defects and target excavation.
- There have been approaches to in-pipe simultaneous localisation and mapping (SLAM) based on vision [1], and inertial measurement [2], however, visual features can be sparse in pipes and inertial sensors such as gyroscopes are subject to drift.

Experimental Data

- A hydrophone was used to excite and record pipe vibration whilst travelling through 5 metres of pipe, similar to [3].
- A 1-D map along the pipe was created from averaging over a region of the spectrogram (indicated by red lines).

PipSLAM

- An algorithm was developed to simultaneously model the map and localise a robot – a PipSLAM algorithm [4].
- The algorithm was based on the Rao-Blackwellised particle filter, which uses particles to represent robot location.

Sensor Fusion

- The PipSLAM algorithm was fused with an IMU to estimate robot location in world coordinates, including an estimate of uncertainty.
- The fusion was extended to include a prior estimate of pipe location.

Summary

- Hydrophone sensing was used to transform the relatively featureless environment inside a water pipe into a more feature-rich environment – generating a new type of map.
- A novel type of PipSLAM algorithm was developed to make use of this novel type of map.
- A sensor fusion algorithm was developed to combine PipSLAM estimates of distance travelled with IMU heading estimates.
- The sensing and algorithms were experimentally tested on a 5 metre section of pipe, which demonstrated the effectiveness.

Project Aim and Objectives

The aim is to develop novel approaches to mapping water distribution pipes, using sensors that can transform the relatively featureless environment of the pipe into a feature-rich environment.

The method for robot navigation will be based on SLAM – a novel PipeSLAM algorithm.

The objectives are as follows:
1. Augment sensors such as cameras and inertial measurement units (IMUs) with sensors (ultrasonic, hydrophone) that can generate a new type of map with increased features.
2. Develop a PipeSLAM algorithm that can simultaneously model the map and localise a robot in order to estimate distance travelled along the pipe and correct drift from dead reckoning.
3. Develop a sensor fusion algorithm to combine PipeSLAM estimate of distance travelled with heading from an IMU.
4. Experimentally test and evaluate the sensor fusion algorithm.

References