ATU’s Advances in In-Pipe Sensing - From Inspection to Mapping of Water Infrastructure

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Water Infrastructure

Problems

- Ageing and deteriorating pipe infrastructure
- Don’t know where it is
- Increasing failure rates
- Huge cost of maintenance and repair

Need

- To survey the water infrastructure from the inside
- For effective and efficient low cost asset condition assessment and repair
- To detect faults before becoming failures
Towards an Ambitious Future Vision

Existing infrastructure
To deploy a large number of robots into the buried water infrastructure that autonomously and persistently inspect, map and repair water pipes

or

New infrastructure
To develop and install intelligent, self-healing, water pipes
Existing infrastructure
To deploy a large number of robots into the buried water infrastructure that autonomously and persistently inspect, map and repair water pipes

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New infrastructure
To develop and install intelligent, self-healing, water pipes
So how do we map, inspect and repair this?
• Initial focus on in-pipe sensing for inspection
• Realised also gave features about pipe
• Use for mapping
• Simultaneous localisation and mapping (SLAM)
Plastic Pipes – Ultrasonic Sensing

- Voids – loss of structural support
- Early indicator of onset of failure
- Ultrasonic inspection from within pipes for void detection
Experimental Proof of Concept I

Ultrasonic transducer

Soil, voids and pipe material immersed in water bath
Experimental Results I

<table>
<thead>
<tr>
<th></th>
<th>1 MHz</th>
<th>5 MHz</th>
<th>10 MHz</th>
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<tbody>
<tr>
<td>DB sand</td>
<td><img src="image" alt="Image" /></td>
<td><img src="image" alt="Image" /></td>
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<tr>
<td>Gravel 8-9.5mm</td>
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Experimental Proof of Concept II
Experimental Results II

- Actual sensor movement
- Estimate
- Estimation error
- Particle spread

Location estimate corrected by presence of void feature

Forward scan (map construction)
Backward scan (localisation)
Metal Pipes – Vibration Sensing

- Hydrophone used to excite and record pipe vibration
- 1-D map created by averaging over spectrogram
- PipeSLAM
- Inertial measurement unit
- Fused using Bayesian methods
- Prior information -> better estimates
Conclusions

- In situ inspection -> features about pipes
- Feature poor -> feature rich -> SLAM -> maps
- Plastic pipes – ultrasonic through wall sensing
- Metal pipes – hydrophone pipe vibration
- Both provide rich features to develop pipe maps
Thanks to…

Mark Ke Ma
Michelle Schirru
Gavin Sailor
Sean Anderson
Richard Collins
Robin Mills
Juanjuan Zhu
Rob Dwyer-Joyce
Ali Hassan-Zahraee
Joby Boxall