Update on current research and development of autonomous inspection and repair

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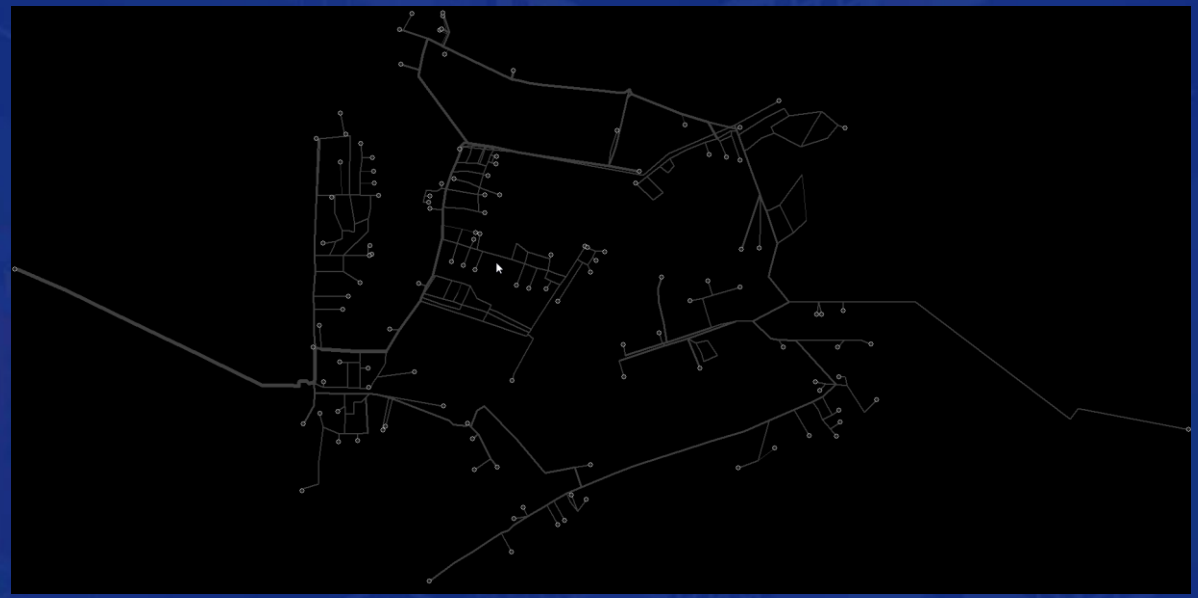
Background to project

- In the UK, there are ~600,000 km of sewers pipes in the UK.
- Sewers are “hidden underground”, difficult to access
- Sewers experience “unforeseen” failures causing:
  - flooding
  - pollution via storm overflows
  - Leak to/from groundwater
  - collapses
- There are no autonomous solutions to inspect (or maintain) buried pipes to reduce such system failures.

What is Pipebots?

Pipebots was a 6-year EPSRC Programme Grant that aims to

- develop inspection robots that work autonomously
- improve inspection techniques
- science to transform buried pipe management from reactive to proactive



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www.pipebots.ac.uk

Pipebots vision

- Robots
  - Untethered
  - Autonomous
- Permanently inside the network
- Locating and measuring defects (not condition)
  - Using a range (combination) of sensors
- Estimating system performance
  - Simulation based on defect information

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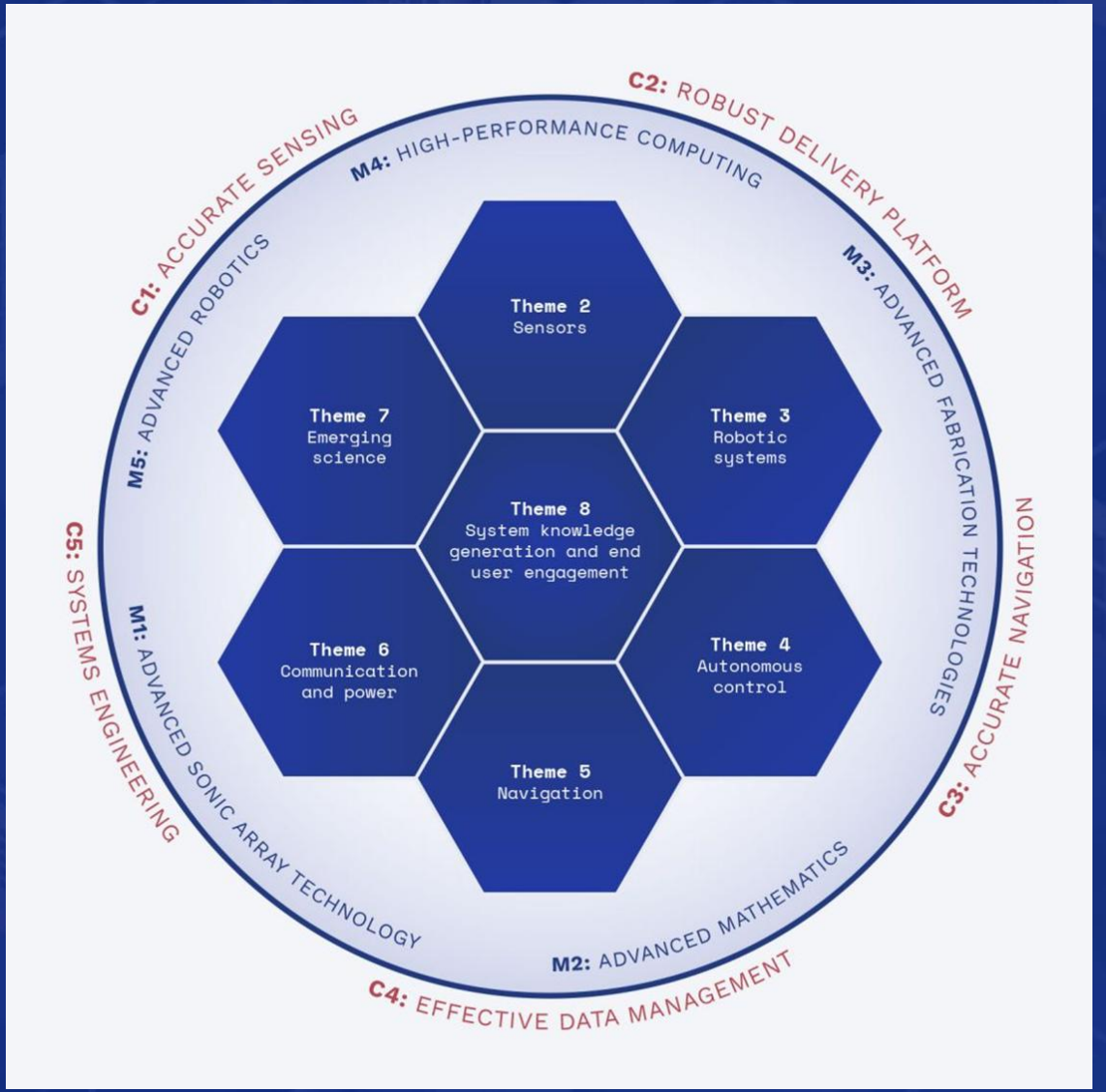
Pipebots themes

Multiple science themes



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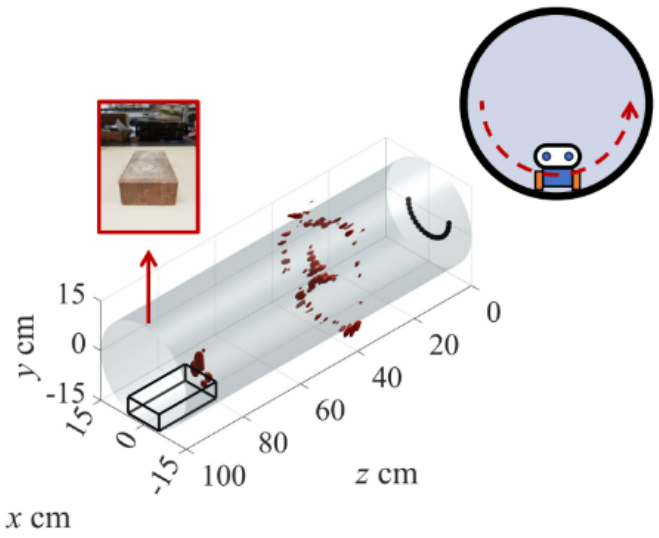
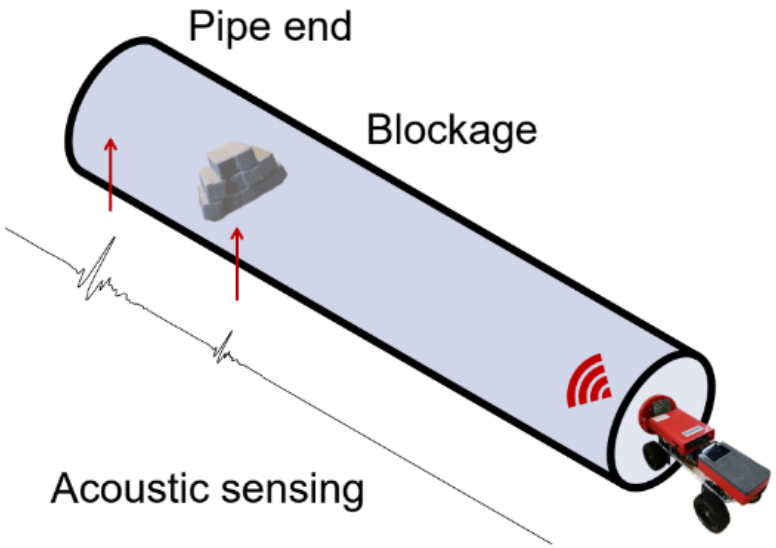
Pipebots themes - Sensing

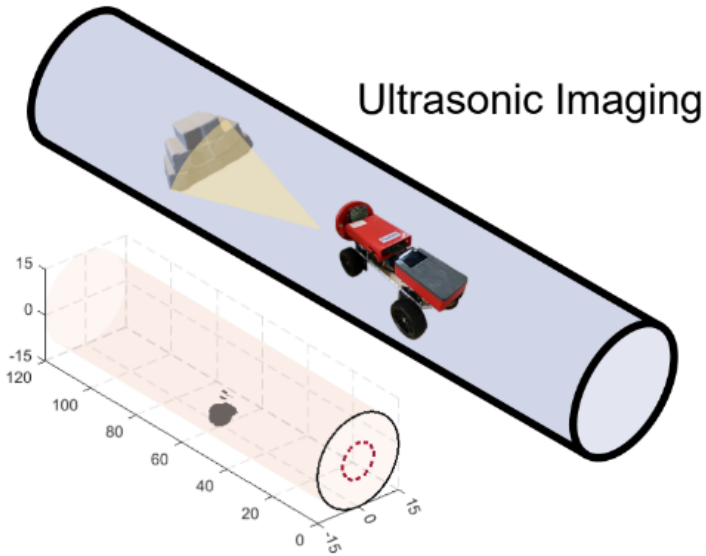
Robotic Manoeuvre Sensing



Long-range Coarse Sensing



Short-range detailed Imaging



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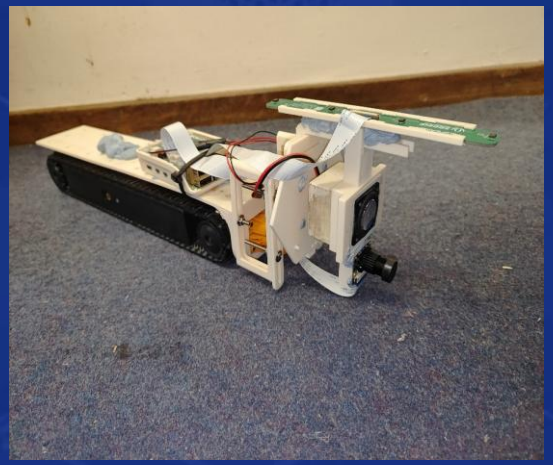
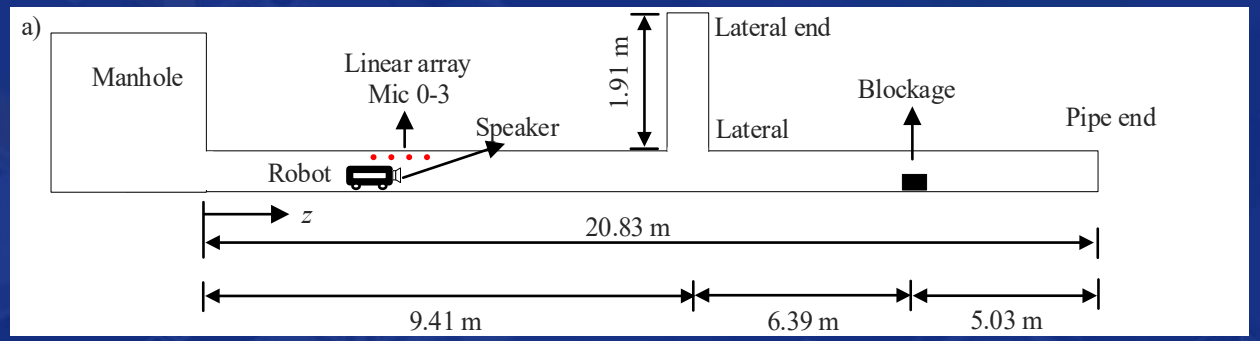
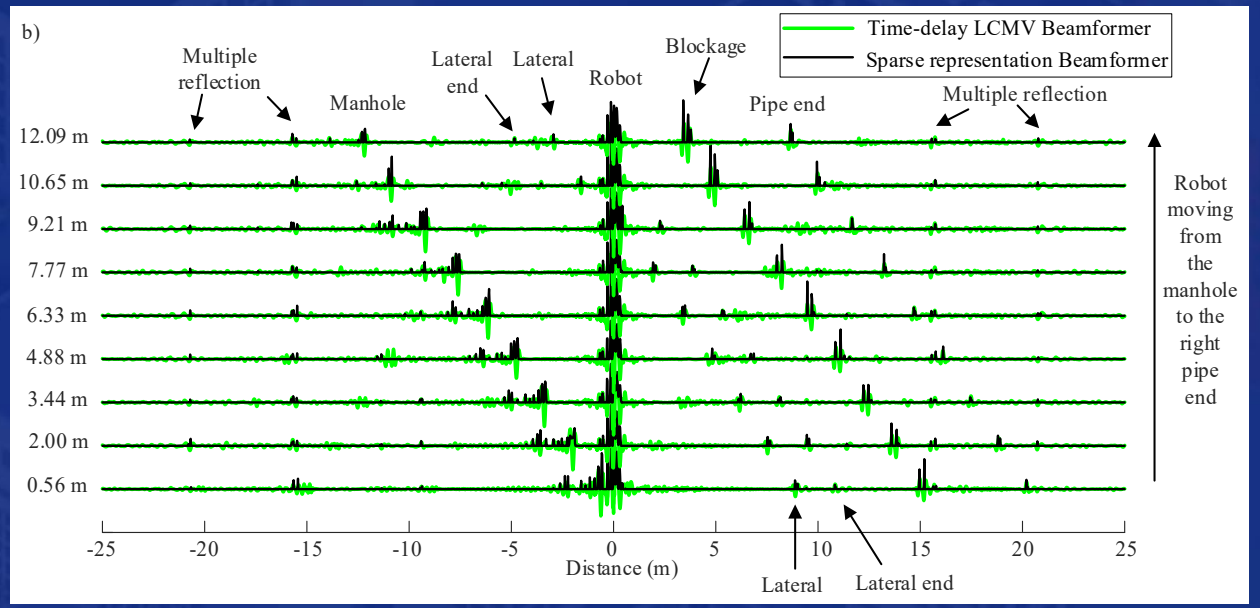
Pipebots: Long range sensing







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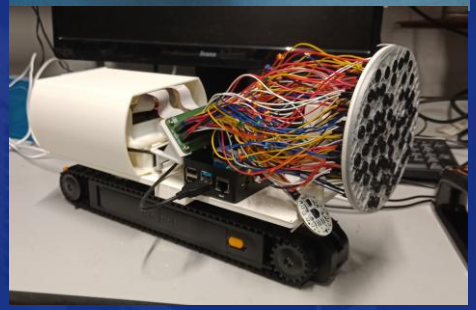
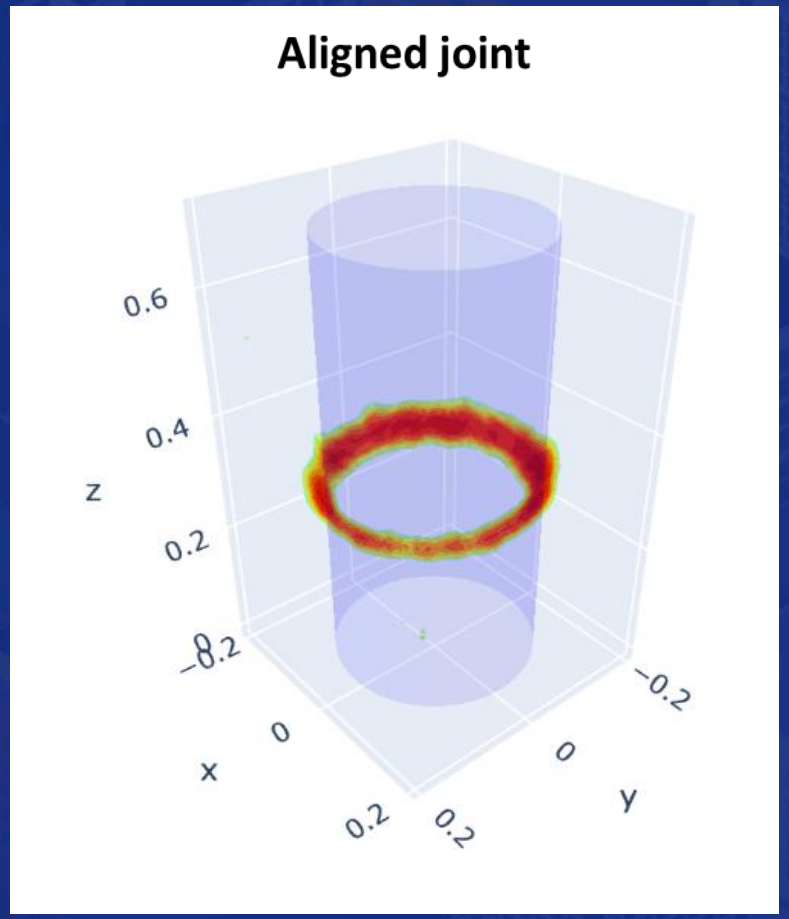
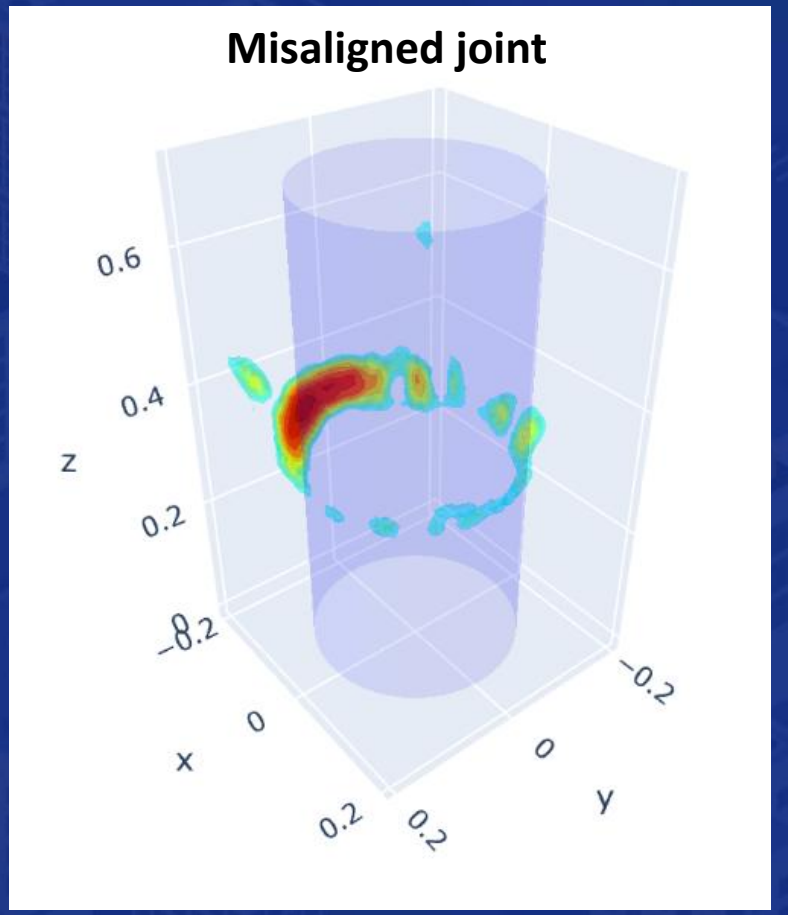
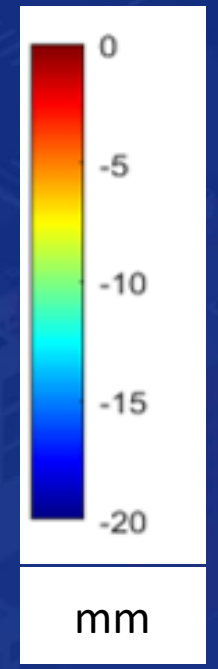
Pipebots: Ultra sonic sensing - joints









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Robotics – sensing with control

Multiple sensing modes

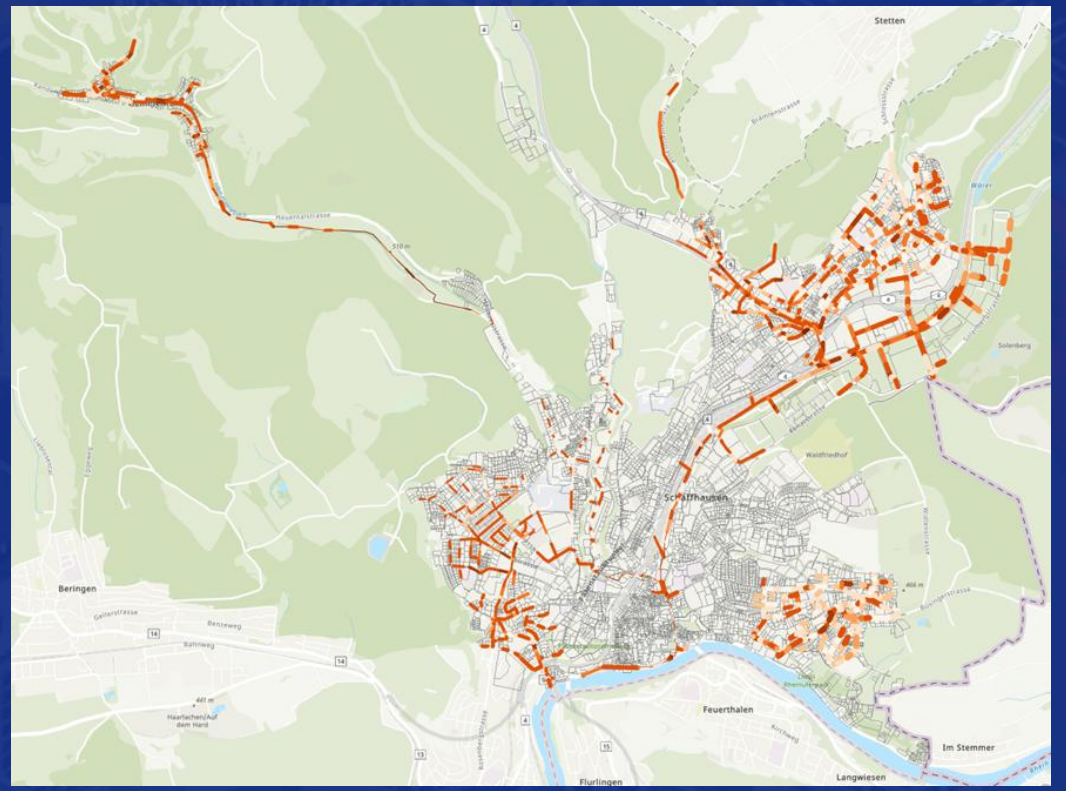
- Acoustic long range
- Ultrasonic short range

Combing with locomotion control

- Locating defects quickly
- Measuring defects exactly

An example

Estimate system performance, using simulation based on defect information



Flood risk increase based on in-pipe defects

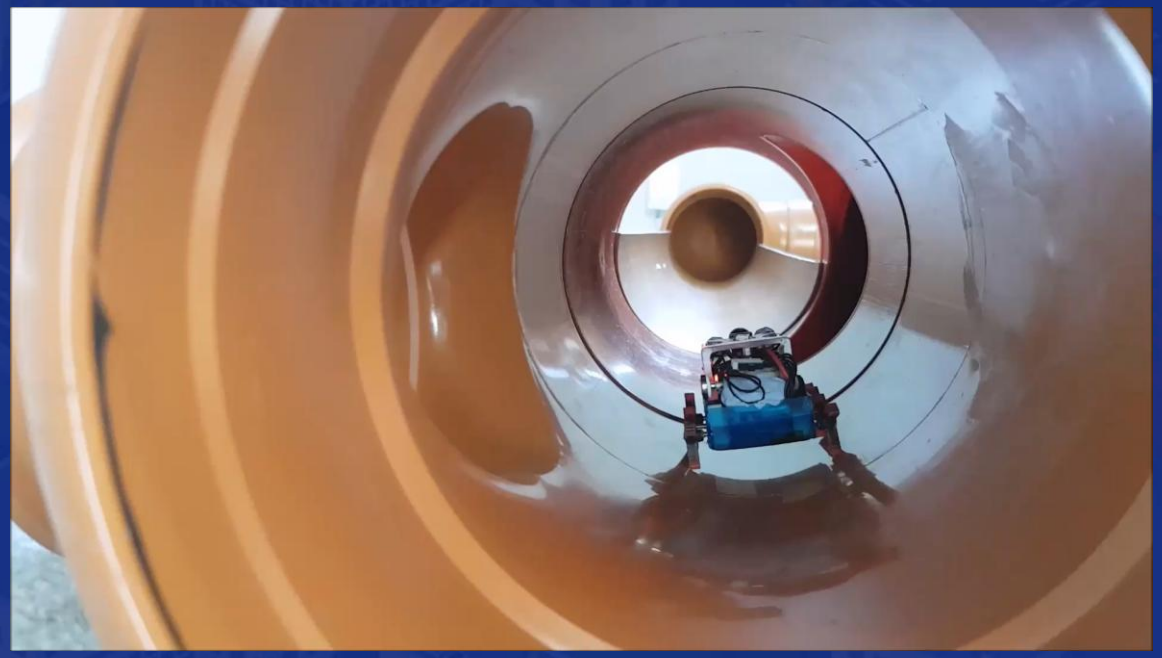
Robotics – autonomy (navigation)

Sewer network complexity

- Pipe size, materials
- Geometries, junctions, changes in level

Aim is no human control

- Need to develop on-board autonomy
- No reliable maps
- Few landmarks
- Need to collect environmental data



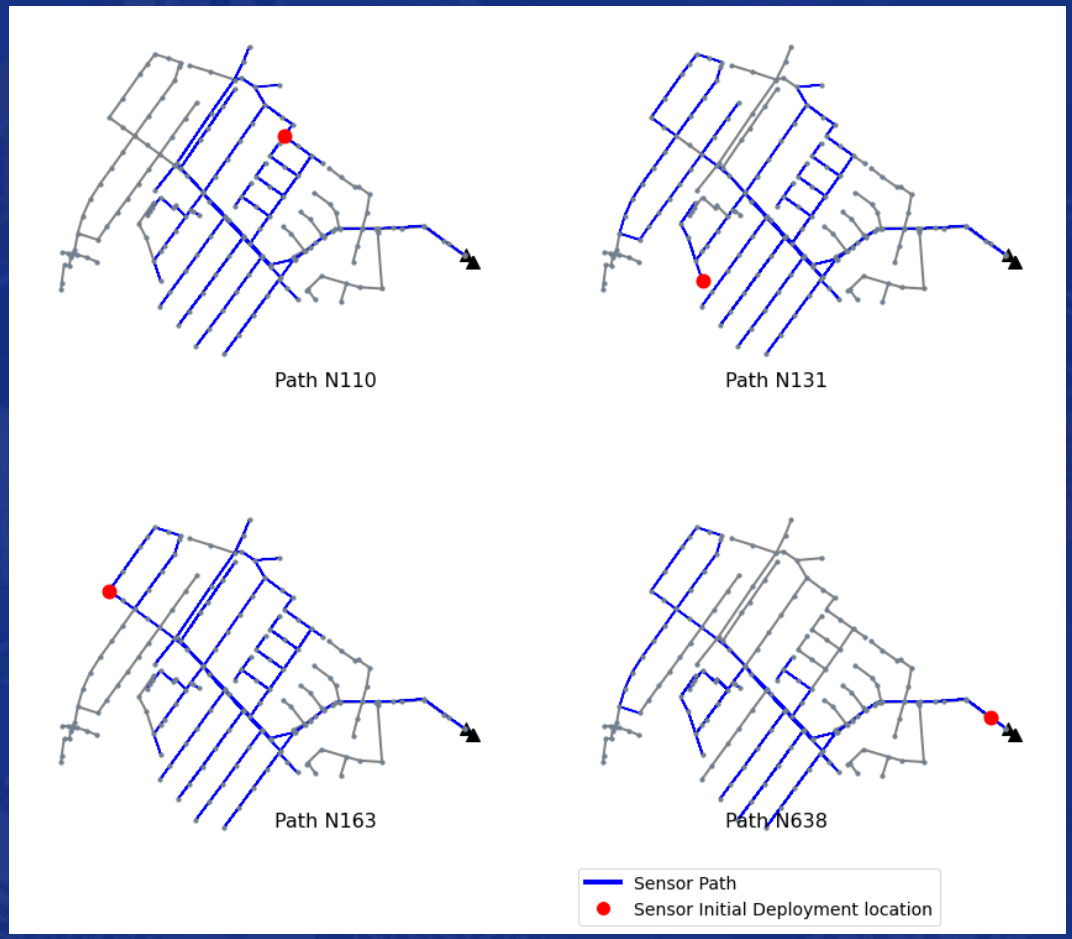
Robotics - integration

Testing in small, but realistic network in National Buried Infrastructure Facility at University of Birmingham

- Autonomy – Navigation and Mapping
- Sensing: acoustic, ultrasonic, lidar

Concept of mobile sensing patterns

- Examine if you should use mobile or static sensors at nodes/manholes
- Simulations using a hydrodynamic network model: fully calibrated, taken as “ground truth”
- Static sensors at all nodes (99)
- Mobile sensors with 4 pathways



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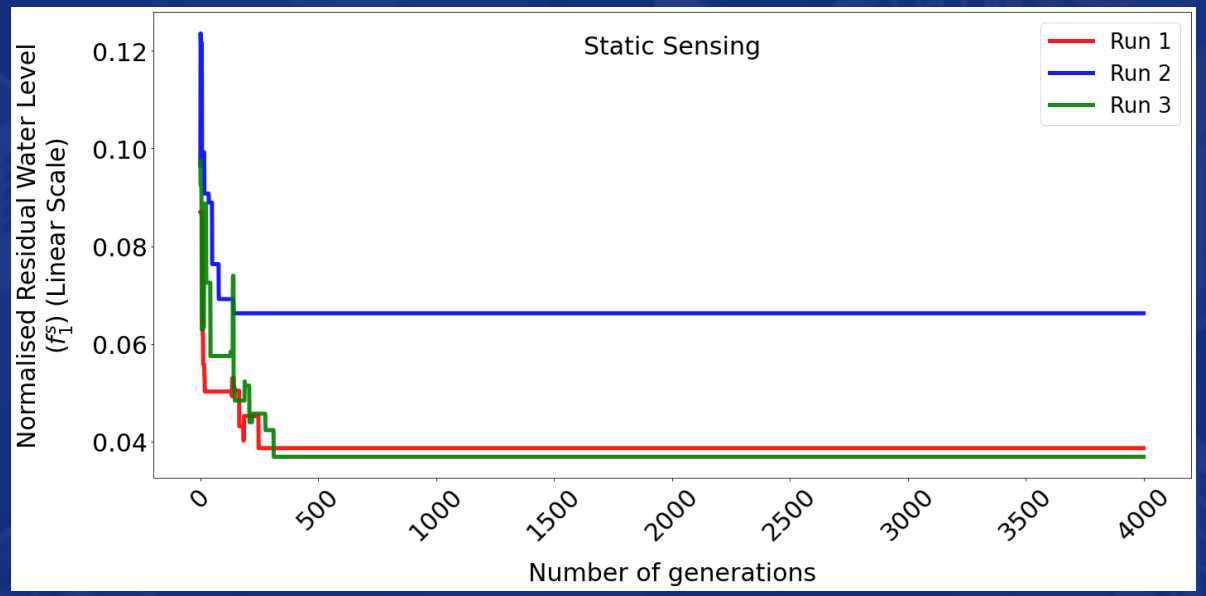
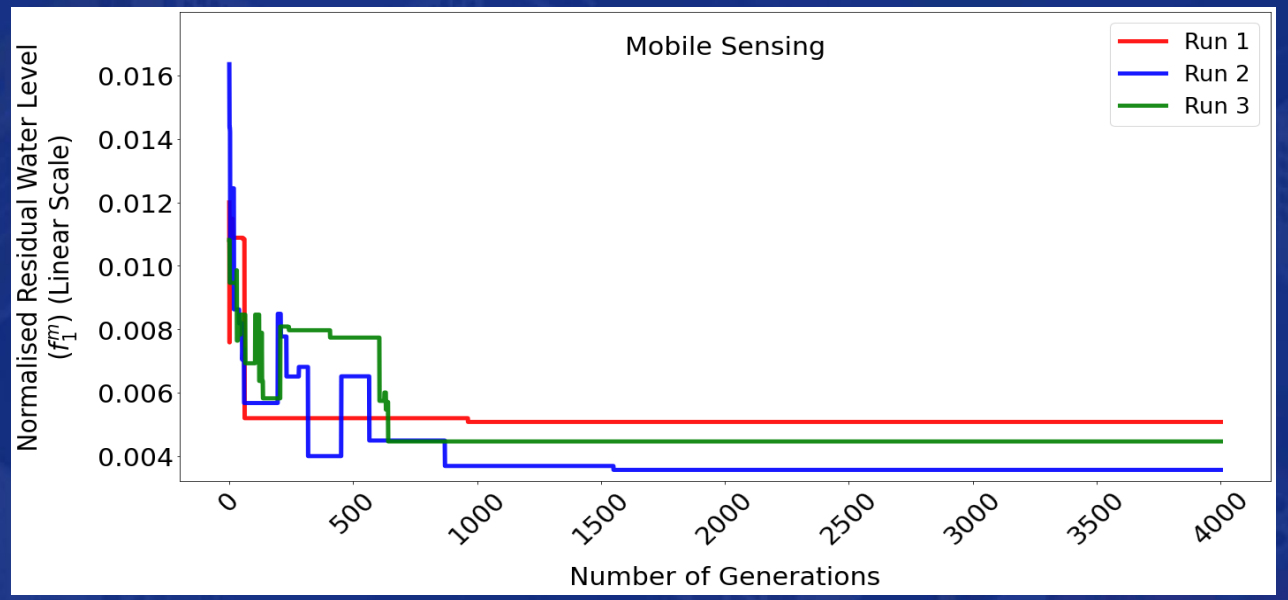
Mobile sensing patterns - Results





- Mobile sensing has model uncertainty 1/10 of static sensor network
- In this simulation one mobile sensor –v- 99 static sensors

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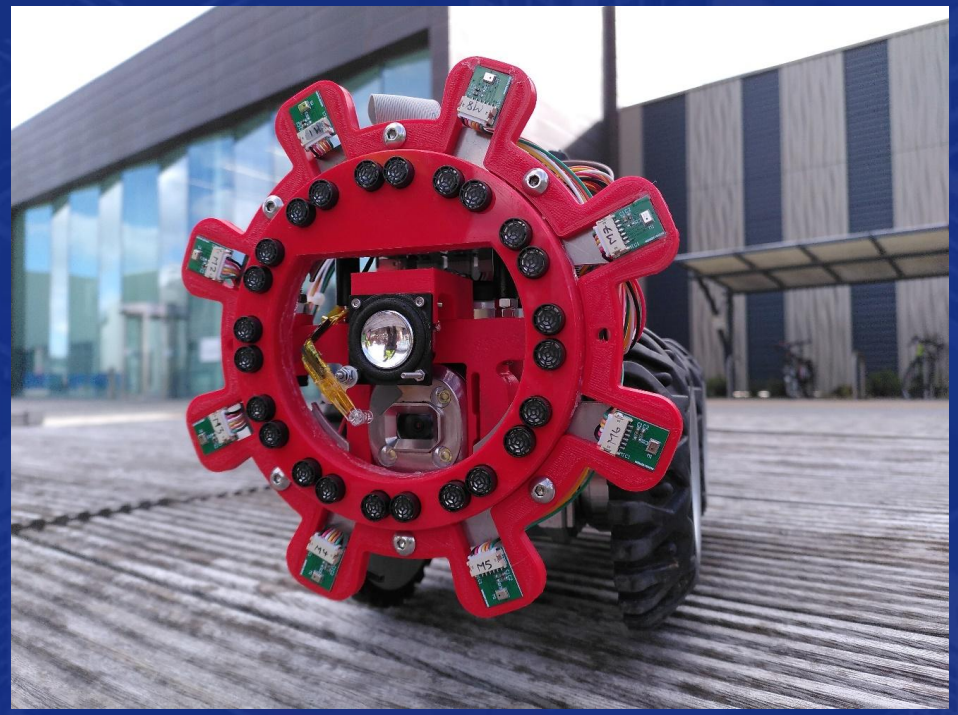
Transfer from Lab to Field (well controlled)



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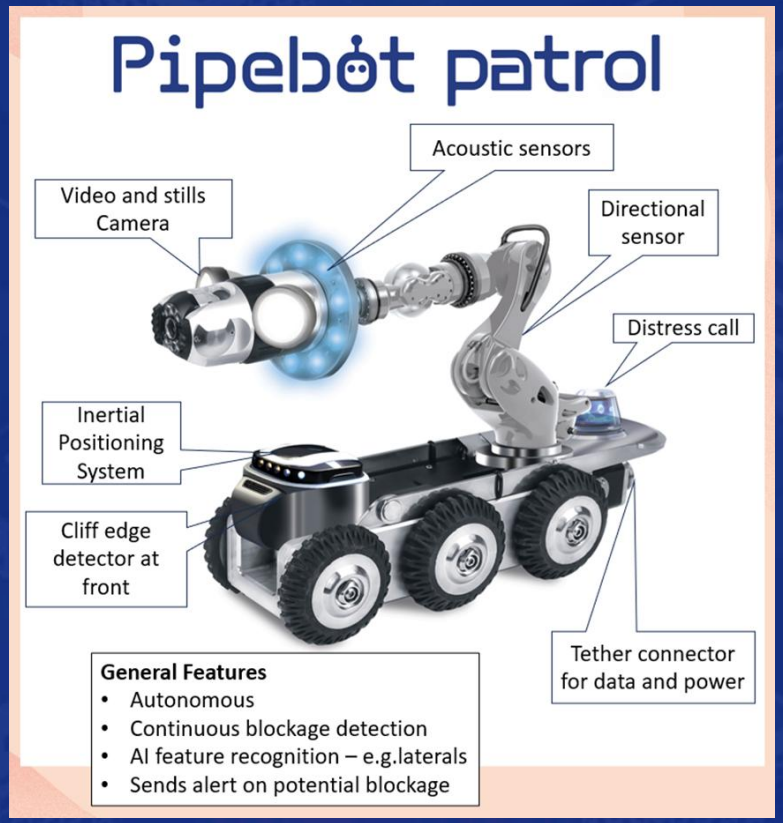
Higher-TRL Pipebots for Sewers



Pipebot Patrol is developing an autonomous sewer robot that lives in the sewer, constantly inspecting pipes autonomously and reporting the location of blockages as they are beginning to form.

Approach allows maintenance teams time to plan an intervention before sewer flooding occurs.

Sept 2024 – Aug 2026 Ofwat Innovation Fund

Led by: Northumbrian Water, with the University of Sheffield, minicam and Environmental Monitoring Solutions

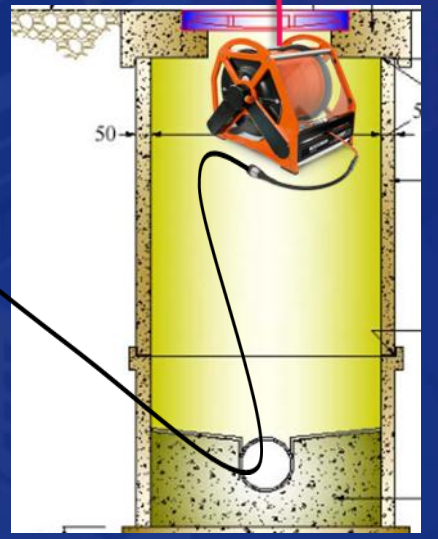
Higher-TRL Pipebots for Sewers

Current prototype

(multi sensors autonomous)

Pipebot Patrol - Control Panel

Priority	Precise Position Easting	Precise Position Northing	Make up of blockage	Criticality	Weather forecast in catchment
Critical	424125.124	568401.902	Wipes	50% blocked **Likely to cause flooding**	Heavy rain forecast in catchment
Crew rqd	424995.203	568300.222	FOG	25% blocked and building	Heavy rain forecast in catchment
Crew rqd	423500.901	571301.203	Wipes/FOG	20% blocked and building	No rain forecast for 3 days
Monitoring	424302.127	569569.902	Unknown	15% build up	Heavy rain forecast in catchment
Monitoring	423440.008	571200.999	Silt	12% build up	No rain forecast for 3 days
Monitoring	423105.105	571804.408	Wipes	10% build up	No rain forecast for 3 days
Monitoring	423220.306	571806.928	Silt	9% build up	No rain forecast for 3 days

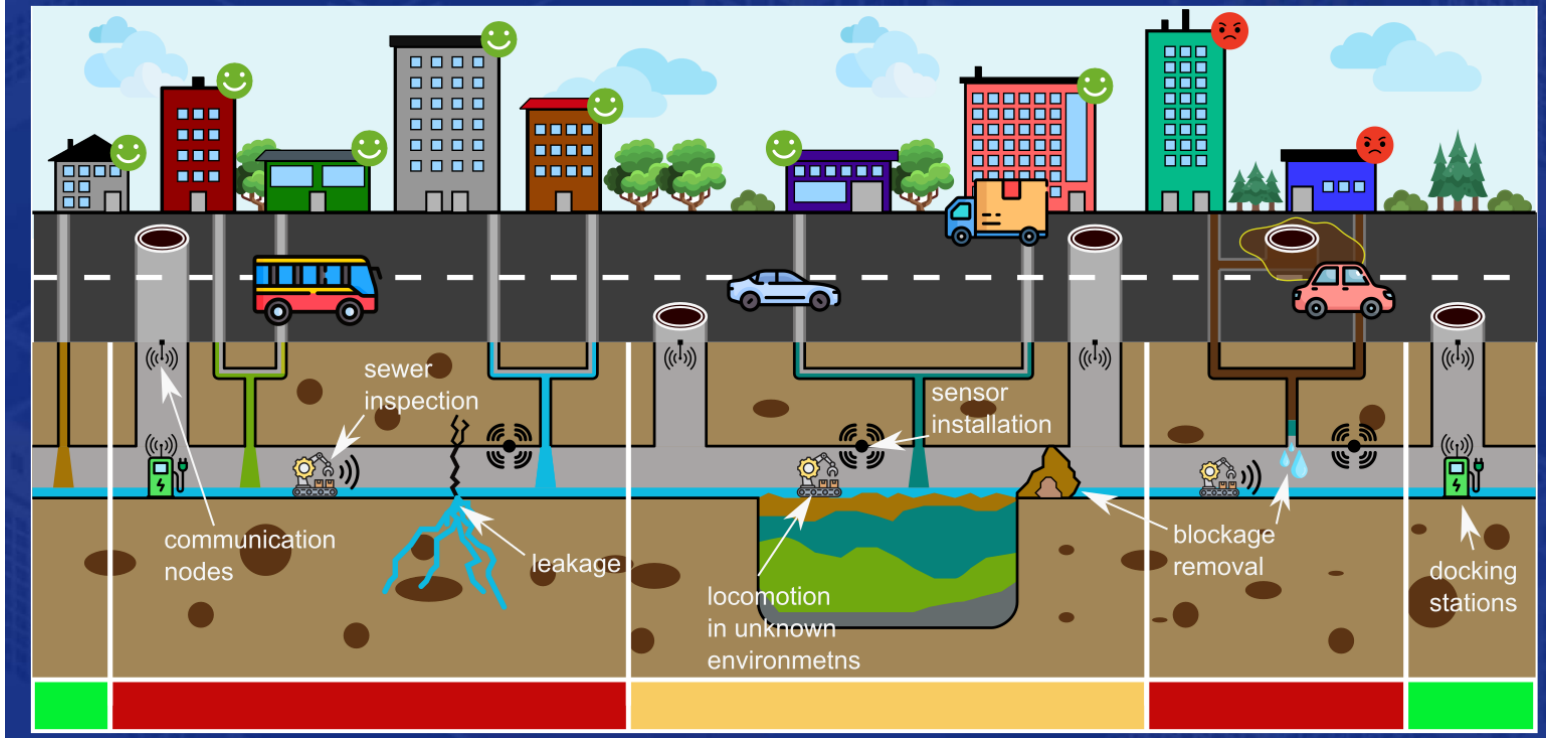


Field testing

https://pipebotpatrol.co.uk/

EU Project: Pipeon – moving to maintenance

Focus: cleaning installation of sensors and in sewers



Focus on manipulation and sewer robot reliability and robustness

Sensor installation and cleaning – rags and sediments, fats etc.

Focus on robust locomotion, manipulation

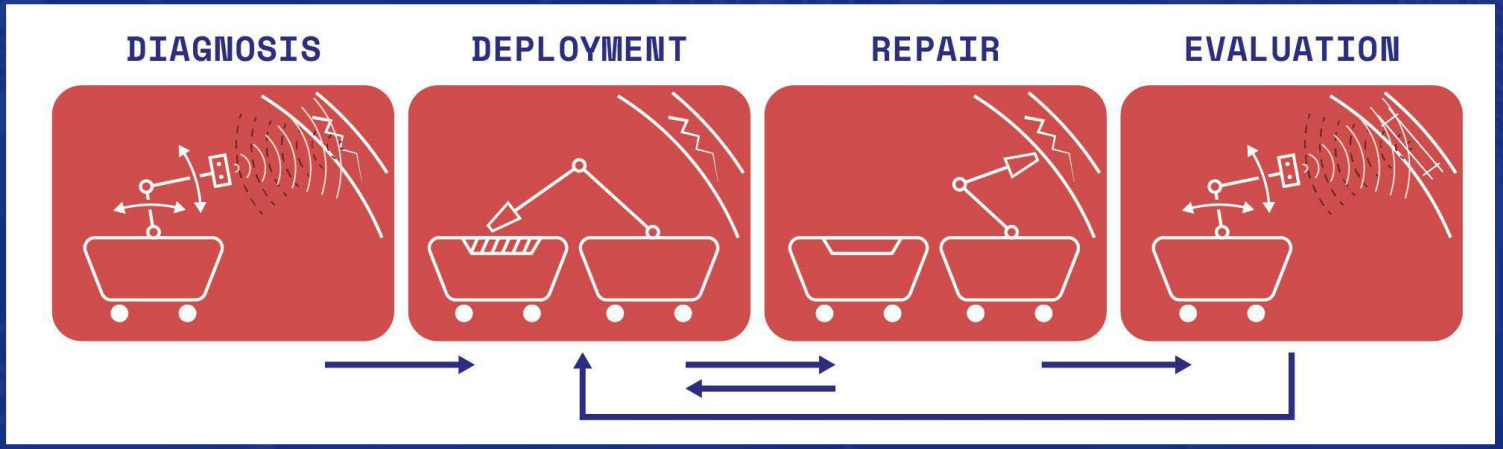
Needs underpinning pipebots technology

pipeon
Robotics and AI for Sewer Inspection & Maintenance

https://pipeon.eu/the-project//

EU Project: Pipeon – moving to maintenance

Autonomous maintenance/repair is much more difficult



Diagnosis: decide on repair approach

Deployment may involve multiple actors

Repair: a chain of tasks

Evaluation: what standards, what next?

Action primatives for repair materials and forceful actions

Sequencing of primatives for multi-stage tasks

Sensing to estimate state

Can actions sequences be made autonomous?

https://pipeon.eu/the-project//

Summary

- Basic science and technology for pervasive autonomous inspection of buried sewer and clean water pipes has been developed.
- This science and technology are at a low TRL, but it underpins the work needed to move to higher-TRL solutions that will be adopted by the industry within the next 10 years.
- Specific aspects are now close to deployment – searching for sewer blockages
- Research being extended into manipulation and control to carry out task within pipes – this is much further into the future – expect progress – step by step.

Any questions?

Interested in more autonomy and in-pipe robotics?

7th and 8th July 2025

https://www.innovationfestival.org/the-festival/sprints/pipebots-university-of-sheffield/

www.pipebots.ac.uk https://pipebotpatrol.co.uk/ https://pipeon.eu/the-project//

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