



Distribution Network Information Modelling (DNIM)

SGN Lane Rental Industry Publication




Introduction

4 million kilometres of buried assets run across the length and breadth of the UK. Ensuring they are maintained, reconditioned or replaced requires 4 million excavations to be carried out on average each year. The ability to accurately identify the location of these buried assets is therefore vital for expediting works, improving safety and reducing disruption on the road network, particularly in busy urban areas such as London.

Accurate records are key for the successful operation of gas and highway networks. Due to the age of some assets, first laid in Victorian times, current records are a combination of historical paper-based maps, along with consolidated drawings where mains have been replaced or reconditioned. Based on this, it is not possible to know the exact location of the pipe network, with current tolerances around $\pm 1\text{m}$.

The ability to accurately locate the gas network, rather than its general location, is vital for future works and keyhole access ambitions in readiness for the transition to Hydrogen. The DNIM project therefore, set out to improve the collecting and recording of the gas network.

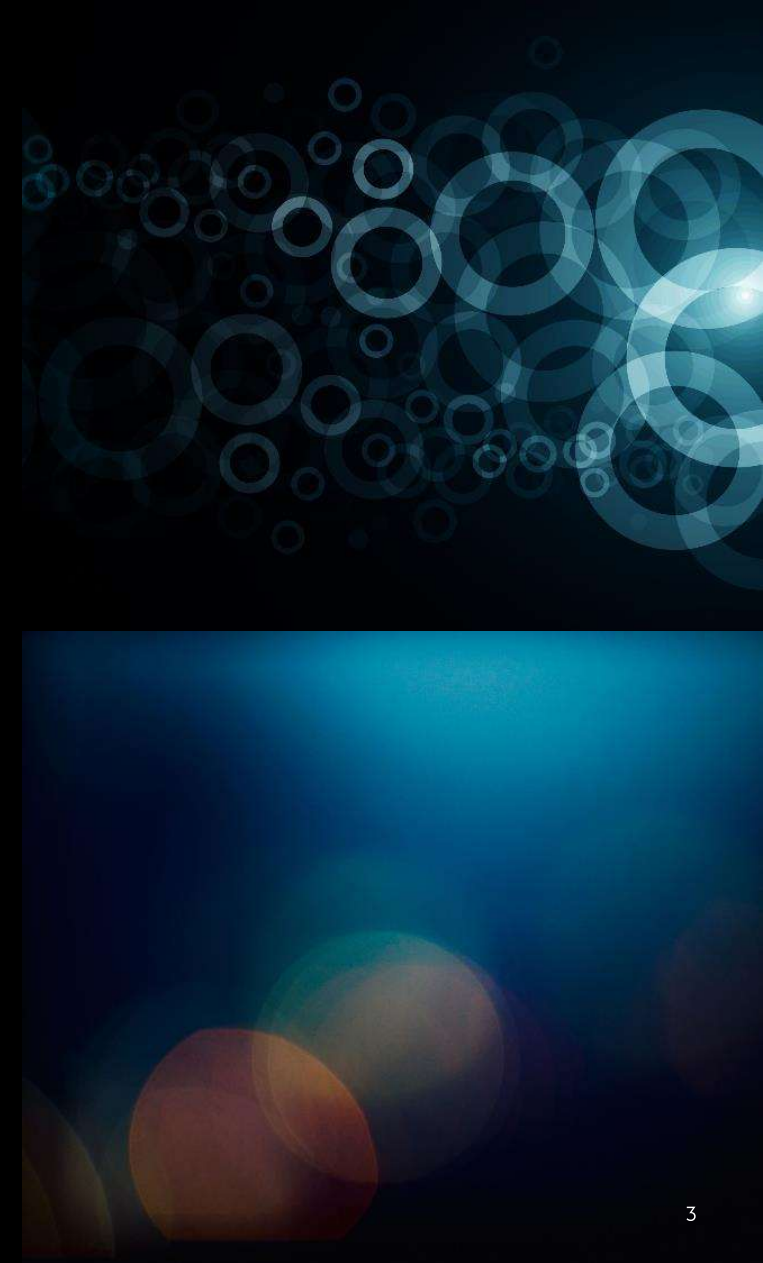


The Project

The aim was to develop technology capable of mapping and analysing the features of the pipe network from within, to enable an automated, periodic and cost-effective process. If successful, network access and subsequent works could be expedited through a much smaller footprint than current methods, decreasing the volume of excavations required, and associated social cost of delay.

A feasibility study was initially carried out to establish if a robotic system could be deployed inside the gas network and determine the limitations, capabilities and opportunities of available technologies. Based on the findings, a proof-of-concept was then developed, with a simple prototype produced for testing within a laboratory environment. Through the project sensor evaluations, mock environment testing, as well as conceptual designs and deployment scenarios were stress tested, successfully demonstrating the viability of developing this type of technology.

Accurate location and depth records could support other utilities via initiatives like the Utility Survey Exchange (USX) and the National Underground Asset Register (NUAR) will improve safety and reduce utility strikes, which the government estimates to cost the economy £1.2bn a year.





Existing in-pipe inspection technologies were established several decades ago. However, these techniques come with some substantial limitations, predominantly the size of the launch location and access into the pipe, where excavations are traditionally large.

Evolving core scanning technology has resulted in sensor heads now being mobile rather than static, increasing the scanning speed. Data processing capabilities continue to increase, providing on-board, fast cycle times from measurement to visualisation and verification.

To improve algorithm accuracy, vehicle odometry was carried out in unison with 3D laser scanning for validation of metallic main wall corrosion. Another utilised opportunity was the underground mapping/BIM modelling of major sewer networks, as it's a precursor to above ground construction and piling works in major urban areas. This has provided the capability of advanced 3D data capture techniques to be sized and housed on a tether-less internal robot which will enable future computer analysis to construct a 3D virtual network model.

Outcomes

From the market survey to examine 'off the shelf' sensor technologies, information regarding the sensory data available was collated and a high-level produced. A key element was for the robot to sense its environment and translate conditions into signals suitable for processing by the onboard computer processing system. This would be a critical component as it would determine the quantity of information available. Different sensor technologies were evaluated and summarised below:

	Sensor	Pros	Cons
1	Acoustic Sensor	Accurate, high range	One point measurement
2	Laser Range Finders	Accurate, easy to work with, high range	Costly
3	Stereo Vision Camera	Low cost	Low accuracy, needs illumination
4	RGBD	Low cost, semi-accurate	Low range

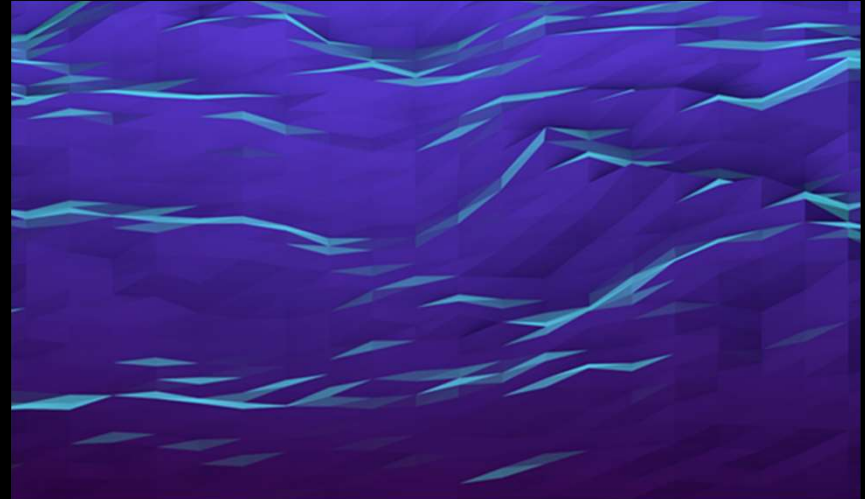
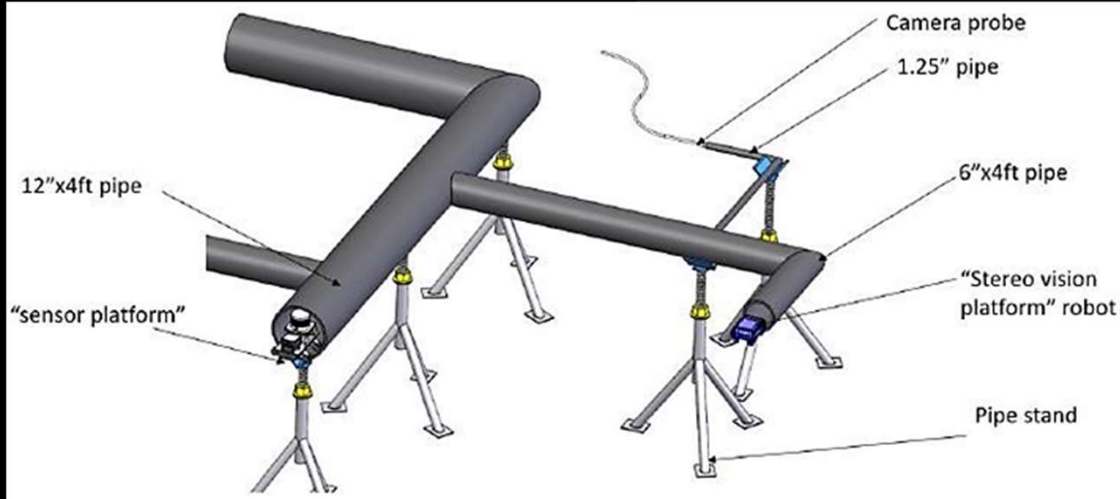
The sensor packages covered a wide range of mapping techniques (LiDAR, Stereo and Inertial) and price points. Each sensor was tested in a variety of environments to evaluate suitability and potential. Four promising sensor packages progressed to the testing stage where software and hardware validation continued. Initially, the team tested each sensor in above-ground environments where deployment was simpler and there are more visual features available to conduct data processing. In all four cases, each sensor performed well in identifying features and depths of its environment.



LiDAR Sensor

One sensors tested was LiDAR. As LiDAR mapping is done through the reflection of laser and corresponding to reflect back, the sensor performed well in pipes of larger sizes. The major restriction for LiDAR in these cases is its field of view (FOV) compared to the pipes inside diameter. On larger pipe sizes (>24"), LiDAR is a promising mapping technique however it is less effective in smaller pipes which failed in 12 inch polyethylene pipe but passed in 24" cast iron pipe. All sensors completed their in-pipe testing with varied levels of performance.

After determining the most suitable sensor and software package, the team sought to evaluate the potential in more complex use cases. As such, an unpressurised mock environment was designed and built based on pipe configurations typically seen in UK gas networks.

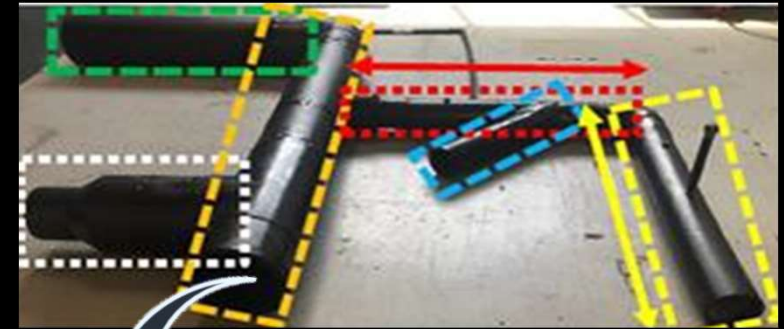


CaliCam Stereo Vision Camera

Of all four sensors evaluated during this stage, the CaliCam Stereo Vision camera proved to be the most promising for mapping operations. Its utilisation of fisheye lenses and integration with open-source software, provides a robust means of data capture. In cases where there are tighter space restrictions (eg. with smaller pipes), more narrow stereo vision cameras may be used. While wider stereos provide more accurate information, narrow cameras may hold value in specialised applications.

The findings illustrated the high accuracy when compared to the mock build with the same geometry and preservation of scale. The structured light was not able to reach reduced geometry however, this could be bypassed by the development of a 180° field of view structured light emitter which is scoped for a future phase of the project.

Furthermore, a suitable mapping system must address two fundamental factors: 1) localisation of position and 2) feature recognition and identification.. It was therefore proposed, that this would be achieved by utilisation of two robots: one for mapping gas mains and one for mapping service gas assets. Both robots would capture video footage from the inner surface of the pipes for the identification of features of interest using machine learning. Video footage will be captured at both the front and rear of the system under ambient lighting conditions.





DNIM Deployment

For deployment, DNIM will be launched into a live gas main where it can autonomously travel to its final destination in the pipe with the lasers off. During this time, data will not be collected, however, the lead camera will be used for machine vision-based guidance. Once in position, both robots will begin traveling in reverse towards the launch point. To maximise value, the hardware should be able to autonomously navigate features such as 90° elbows. To further increase the applicability of the solution, this system will be designed to be modular and easily retrofitted for larger pipe sizes.



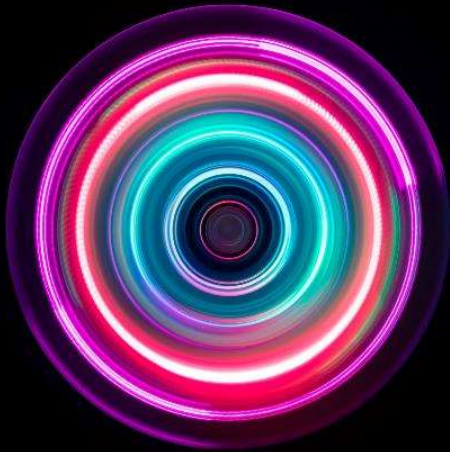
Lessons Learnt

A key lesson was the importance of rapid testing which permitted different sensing technology to be evaluated quickly and based on actual results, rather than just relying on theoretical knowledge. Using off the shelf sensor packages has allowed the project to move at pace.

As this futuristic technology can be difficult to explain, an animation was created to illustrate how this system would actually work. This helped to engage with a wide variety of stakeholders to understand the concept.

Also, a rigorous mapping environment was used for testing which helped to establish the capabilities and boundaries of different technologies. This proved to be a useful testing environment which strategically allowed the sensors to be evaluated in demanding conditions. As our existing in-pipe surveys have shown, anomalies can be found within our gas network, therefore a difficult testing environment will help DNIM prepare in localising and mapping future unknowns.





Conclusion/ Recommendations

The DNIM system has moved from feasibility to proof of concept. Through the various project stages from sensor evaluation/mock environment testing, to the development of conceptual designs and deployment scenarios, the project has successfully demonstrated the feasibility of developing a robotic system which can be deployed inside the gas network autonomously.

The project team will now establish the next phase of development and may return to the Lane Rental Governance Committee to request additional funds.

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Date Created: January 2022

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