Are you ready for RoboNavvy?

Could a robotic system that performs keyhole surgery on underground pipes change the face of streetworks for good? **Helena Russell** reports

Mention streetworks to anyone – be that utility company, local authority highways engineer, motorist or pedestrian – and you are almost certain to be met by a rolling of the eyes, possibly worse. Such reactions are hardly surprising given that the standard procedure for repairing or replacing buried services has not changed for decades and is notoriously slow and disruptive, with poor-quality reinstatement an unwanted legacy.

A jumble of brightly-coloured plastic barriers leaning drunkenly around an open trench, with a pile of asphalt and hardcore scattered nearby and no work visible for days on end is the all-too-common sight that confronts inconvenienced drivers or pedestrians, and it's an image that utility companies are desperate to shake off.

Reputational damage, service outages and traffic delays are not the only unwanted side effects that traditional streetworks generate. By their nature they are resource-intensive, often requiring at least some manual excavation, and staff are put at risk by working next to live highways for extended periods and by using power tools when the exact location of services may not be known.

Programming is unreliable given the high probability of unexpected problems being unearthed, exacerbating inefficient working practices and increasing the already poor emissions footprints of such works.

But a three-year research and development programme now in its final months could spell the end for disruptive streetworks – if trials currently being undertaken prove successful.

As this issue of the magazine went to press, a prototype multi-function robot, designed to be capable of doing almost any streetworks job from start to finish, had just started full-scale tests in New York state.

And although the trails are being conducted on the other side of the Atlantic, development of the Robotic Roadworks & Excavation System (RRES) was made possible by funding from the UK gas and electricity regulator Ofgem's Network Innovation Competition funding pot.

In 2018 a collaborative project by UK utilities company SGN and US robotics specialist ULC Technologies to develop and test the RRES was awarded £6.3m towards the total £7.4m cost of the project.

The RRES project is a joint venture between UK-based utilities firm SGN and US-based robotic specialist ULC Technologies. Much of the funding is from Ofgem's Network Innovation Competition scheme

If all goes to plan, streetworks using the RRES unit will look very different from the shambolic scenes we are familiar with. Instead of digging up huge areas of tarmac, the RRES will perform 'keyhole surgery' in precisely-targeted locations. SGN's aspiration is that the machine will simply trundle on to site with a series of interchangeable tools and carry out all the operations that are usually performed by various teams of workers.

Furthermore, the work will be completed in a matter of hours rather than days or weeks.

At the heart of this battery-powered wonder is an autonomous robotic arm with a 2.7m reach, mounted on a 3m by 1.8m tracked undercarriage. Custom-developed software controls the arm and the tools it manipulates, making decisions based on the data it gathers at the site.

The unit starts by scanning and mapping the below-ground landscape to identify the target asset. This data is analysed by the system's software to establish the size and position of the keyhole it should cut in the road surface, what depth to excavate to and what other assets it needs to work around.

A custom-designed tool can then be employed to carry out whatever repair or replacement work is required on the gas pipe, before the robot switches to another tool to compact the backfill. It then lifts back into place the section of pavement that it originally cut out, ideally leaving little sign of the intervention.

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On completion of the works, the 'keyhole' is backfilled and plugged again

After scanning and mapping the site, the robot cuts a neat 'keyhole' in the pavement surface

Having all these operations carried out autonomously by the same machine clearly saves a lot of time, but according to ULC Technologies project manager Ali Asmari, the benefits don't stop there. The software that controls the system also employs artificial intelligence so that the robot learns how best to apply each tool to achieve the best outcome – to work faster or more accurately, to reduce wear on tools, to prevent damage to other assets and so on.

An important part of the real-life trials is to start gathering this data and testing the machine-learning elements of the system.

Before the outbreak of Covid-19, the plan was that the RRES would arrive in the UK this spring and be put into action by SGN on its own closed sites before being trialled on live streetworks contracts.

The restrictions on travel prompted a rethink and testing was relocated to highway mock-ups that ULC has specially created at its plant in Suffolk County, New York.

While SGN project lead Oliver Machan is confident that RRES will be put through its paces on UK streets later this year, Asmari gets to test out the full-size unit first, and clearly relishes the task.

"The fun is just about to begin," he says with a big grin. "We have a system that has all the necessary tools and components, but it was designed in the lab environment and hasn't really been tested in the real world. Once it starts collecting data we will be able to further modify and develop the AI modules and the software that enables it to adapt to the conditions.

"We've tried to simulate the environment that the robot will experience, to enable us to trial end-to-end performance," he continues. "We start by scanning the ground, processing and analysing the data to try and identify the location of the assets and establish the ground conditions."

The first sweep of the road surface with ground-penetrating radar enables the software to map what is below the asphalt and identify the target asset while building up a picture of the type of ground that needs to be removed.

Once the machine gets below the surface, it will feed back what Asmari refers to as 'ground truth' – the actual ground conditions and the exact locations of the assets identified by the radar – validating the results generated by the initial surveys and allowing the software to iterate its procedure as necessary.

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Conventional streetworks are notorious for the mess and disruption they cause road users and pedestrians

TRIAL AND ERROR

Much of the physical technology that the RRES exploits is tried and tested – the key difference being that it is all deployed by a robotic arm with machine-learning capabilities.

SGN already had a long-standing relationship with ULC Technologies, having previously developed a robot that crawls through cast-iron pipes to seal the joints from the inside and investigating how to automate other techniques such as the 'core and vac' excavation process.

Creating a system that could do this through keyhole incisions – 'core-hole' as SGN project lead Oliver Machan dubs it – fitted with wider aspirations to minimise disruption to the public.

"A lot of these technologies were already in the market," agrees ULC's project manager Ali Asmari, "but one of the challenges was to get all the different sensors, technologies and devices working together to complete a single operation.

"They all come from different vendors who use different standards; the software packages are written in different languages and so on. We integrated the latest and the best technology that is on the market. However we also had to develop the missing pieces – for example the use of artificial intelligence to interpret the data from certain sensors," he adds.

Some technologies had to be developed or adapted to suit the way the robot applies them. For example the road-cutting tool is recognisably a chainsaw – not the option that would naturally spring to mind for cutting asphalt.

"The chainsaw went through four different variations," reveals Asmari. "We started out with a small hand-held tool and found we were able to safely scale it up to improve the efficiency, speed and repeatability. Now at the fourth iteration we can cut a 600mm-diameter, 300mm-deep keyhole through reinforced concrete in less than an hour, which is exceptional for this type of operation in this type of environment. If the road surface is any softer than that, we will be saving time. We hadn't initially considered it because the idea of cutting the road with a chainsaw just didn't make any sense. But when backed up by the control and AI systems, and the accuracy of the robotic arm, it provides the right solution."

Similarly, Asmari recalls that the excavation system, which deploys air jets to agitate and loosen the soil before it is removed through a vacuum tube, went through about 30 different iterations. "A lot of the prototypes were just not stable, but eventually we locked down on something that effectively agitates and pulverises the soil and removes it."

Machan adds: "It's a high-tech piece of kit that uses supersonic air nozzles to loosen the ground – we are not just sticking something into the ground and trying to suck out the loose material. The system can control the pressure and direction of these air nozzles, so as we carry out more trials it will learn the most effective way to apply them."

The RRES excavation tool incorporates a specially-developed chainsaw designed to cut through reinforced concrete

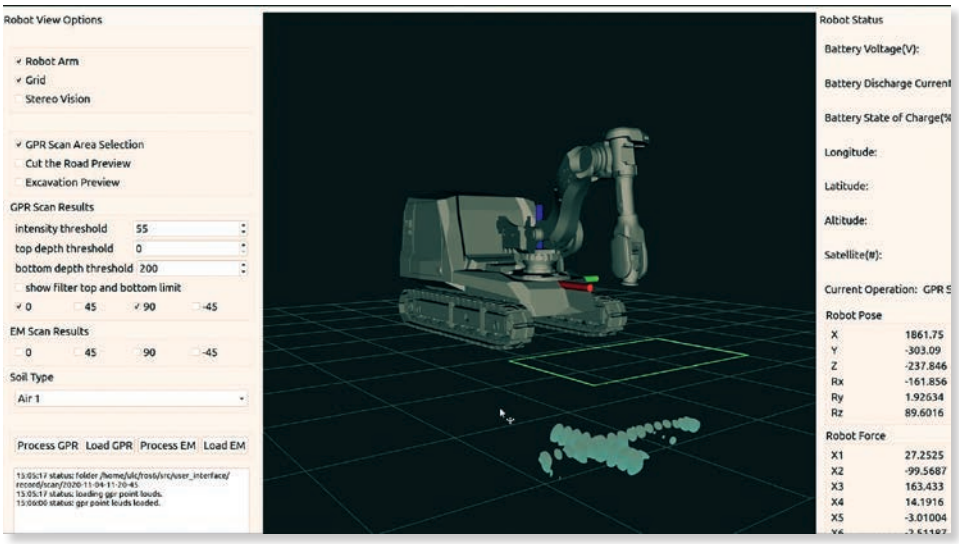
The robotic arm carries a whole host of sensors, the data from which will be used to guide its autonomous decisions on factors such as what pressure to apply to the road-cutting tool and where and how hard to direct the air jets from the excavation nozzle. The sensors also detect changes in resistance that indicate that a different type of material has been encountered, prompting the robot to pause cutting so that the operator can assess how to proceed.

"All of these features will be tested in the field and we will log the data and try to identify any patterns that can help with its future operation," says Asmari.

SGN's Oliver Machan is hopeful that the RRES will make it to the UK within a few months (the current plan is to bring it here in late May) at which point it will be deployed by SGN on one of its own sites by way of continuing the machine learning process in the live working environment. SGN is also planning to host some 'show and tell' events to introduce the technology to the wider industry.

How long it will be before we see fleets of robots on the streets is not something Machan can predict; even with the system trialled and proven, the project will hinge upon a decision by SGN's board on further investment. "We've left it quite open as to how we commercialise the system," Machan says. "We need to go through the pilot first for the robot to gather data about our assets, for us to gain confidence in it and for our health and safety guys to see that it works safely and we can use it in and around the assets.

"One of the things that we are going to be doing – and that our independent assessor will also be doing – is to work out what we can expect RRES to achieve. However a lot of the iterative work we have already done with the development and prototyping has been to focus on any way in which we can introduce a higher level of reliability and repeatability into the operations."



An array of sensors allow the robot to map the underground landscape, locate the services and plan the excavation

And while it may be possible to directly compare efficiencies, cost savings and so on with standard excavation procedures, such comparisons will also need to consider the wider implications. "Will we still plan in the same way?" asks Machan. "For example if we want to do a service transfer we may be able to do that in an hour and we won't need to close that street for a day or more, we can just go in and do it. Could we have a system where the robot is summoned when it is needed, a bit like an Uber?"

Ofgem's NIC funding comes with the requirement that the technology be made available for others to use, to enable benefits to be exploited to the full. "The robotic arm system is very adaptable so it could be used in any application where you want to take people out of hazardous situations," Machan continues. "We are keen for other utilities to adopt the system too and even create their own tooling for it."

Ironically Asmari considers that the biggest hurdle they still face is not a technical one, it's dealing with the general public's perception of job-stealing robots. "We want to educate people that it's more about taking operatives out of dangerous situations, keeping disruption to a minimum, and getting the job done faster, better and more efficiently," he says.

The robot is currently being trialled at ULC's facility in upstate New York