Tunnelling Journal

AI in action

How is AI improving the way we deliver and operate tunnels? Here are some of the answers TJ found to that question.

While the world worries and wonders about where AI – in the wrong hands - will take us, engineers have been busy deploying it for years, if not decades. We happily use it in our everyday life, whether we're scrolling through social media, opening our phones with face recognition or composing a job description with the help of Chat GPT.

When deployed to help solve problems, AI has the potential to make the world a better place. And to make tunnelling projects safer, more efficient and less costly. The examples below demonstrate that.

Though some people bemoan the fact that widespread use of digital tools and AI means that newer engineers won't have the basic skills of their more experienced colleagues, we probably shouldn't think about it like that. Some of us remember logarithm tables and life before calculators but that doesn't mean we want to go back there.

These stories should encourage us. AI is helping to transform the industry – and it's in good hands.

INFORMATION

The knowledge assistant

"Everybody talks about having so much data, but most people don't have data, they have a bunch of electronic files," says Philipp Dohmen, Amberg's corporate chief digital officer.

By way of example, he flashes up some figures linked to a full BIM project for the Swiss railway authority. The project information consisted of 78,000 files in 9,500 folders and 830GB of data in over 100 different software packages.

Finding specific pieces of information among all that would be like looking for a needle in several fields of haystacks. So Amberg has been training AI to turn all information from files into a graphs and using LLM to enable easy access to it and to do the searching. It can look through multiple types of files, from a BIM model to Excel or PDFs, and find all connected information.

Dohmen illustrates the knowledge assistant's prowess with a case study about an offshore wind project. The company operating the turbines has a sophisticated system for organising maintenance visits, designed to minimise the number of visits to the offshore facility while hitting the right maintenance intervals for all the component parts of the wind turbines.

The challenge for the offshore wind company was that, when a new project was handed over, there were 0.25 million documents in multiple different file formats, to comb through in order to find maintenance-related issues. By deploying its knowledge assistant, Amberg unearthed information that had been missed by human searches.

"We found 100 items that no one knew about and that they needed to maintain," says Dohmen.

The search is more sophisticated than just a key word search, explains Dohmen. The assistant has been trained to look for phrases, measurements or tables that would apply to maintenance interval information.

What started as an internal tool to help Amberg engineers source information from the company's vast resources of data is now set to become a commercial venture. Next year this 'knowledge assistant' will become the first service to be offered by a new Amberg spin-off company.

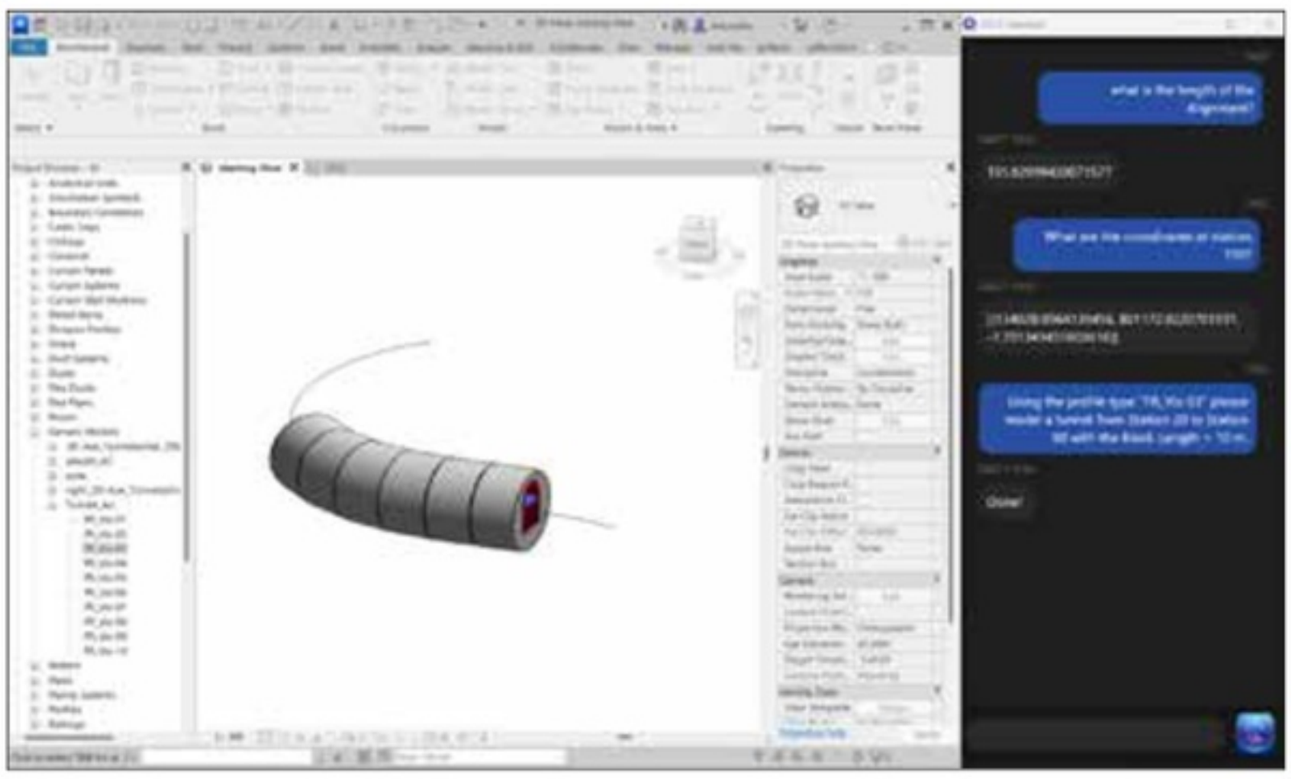
DESIGN

Pain-free BIM interfaces

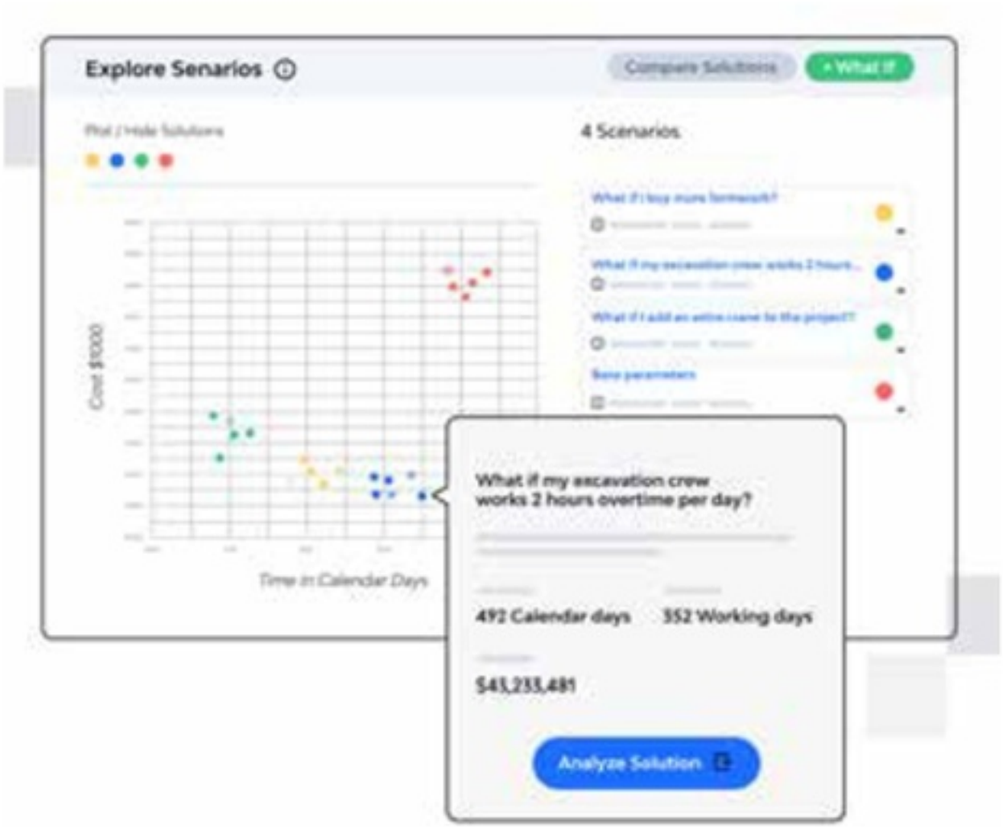
As any tunnelling engineer who has designed in BIM will know, one of the biggest pains is moving elements or details between different types of software.

The old way was to use third-party software as a sort of translator, but that wasn't by any means a straightforward task, says Dohmen. "We used to write manuals to train our people on importing a landXML alignment into Revit."

But now that is no longer necessary. Amberg design technologist Abdelali Aouada



Want to import something into a BIM model? Ask a bot to do it.



SCS JV engineers created three months of float with ALICE on HS2

has trained a large language model (LLM) to do all the hard work for its engineers. "Now we have a chatbot on top of our BIM software, and you tell him in any language to import a landXML, and all is done in the background without further notice," explains Dohmen.

The AI has been trained to call all the existing workflows, functions, codes and logic so that a user can question it at any point in the design process and the bot will find the relevant information from the database and include it in the design.

Clearly, this development is a huge time saver, allowing designers to spend more time thinking or optioneering. But it also increases accessibility to designing in BIM for people who don't have the skills needed to navigate the tricky interfaces between types of software.

"It's really hard to find people with both tunnelling and scripting or coding skills," says Aouada. "With this, it's easy to find people who know the logic of the design process and how it works. They can now communicate and get the data."

The other great thing, says Aouada, is that the AI is constantly learning. "Where there is something new, something that's not in your database, it is trained to try to come up with a solution and then ask the user if that is right. And if it is, it keeps it in the database."

And, just like the AI itself, Aouada is currently improving the tool for his colleagues. One of his current tasks is creating a new user interface that will be more friendly and intuitive than the current one, providing more and more functions and giving users access to them by chatting with the BIM model.

PROGRAMMING

Next level optioneering

An experienced tunnelling project manager will often look at a programme and see ways that time could be saved, or redistributed to give more time to tasks that need it. Sometimes it's a necessity because there have been delays, disrupted deliveries or changes that somehow need to be accommodated.

But not everyone can do this. And, clearly, the more complex the project, the more complex the programme. For less experienced site engineers, who don't have years of project experience or time spent putting programmes together, interrogating the detail of a programme is even more of a challenge.

This is where ALICE comes in. Invented by René Morkos, the company's CEO and founder, who observed the inefficiencies of construction project planning while working as a civil engineer, ALICE stands for Artificial Intelligence Construction Engineering. With the ability to go beyond even the most agile and experienced of project manager brains, ALICE can look at multiple possible project paths and present the user with a choice of top options.

"In an afternoon, ALICE can create a million different options for you," says ALICE's chief marketing officer Phil Carpenter.

Carpenter points out that a lot of planning engineers – or schedulers in US English – are set in their ways and so tend to follow similar paths for every programme or schedule. "The people who are doing these schedules have probably been doing it for 20 years, so they have certain ways of doing things. If they looked at things differently, they would probably find more efficient ways of doing them."

Although Morkos started developing ALICE in 2015, while studying for a PhD in artificial intelligence applications in construction at Stanford University, it is only in the last three years that its use has blossomed says Carpenter. ALICE is being used in a range of construction sectors, mostly industrial and infrastructure, with some real estate too.

In the UK, ALICE has been used on several HS2 tunnelling projects and hailed by HS2's innovation team as one of the project's successes. The ALICE website has case studies on projects from SCS (Skanska, Costain, Strabag)

Phil Carpenter: "ALICE can create a million different options."

JV and Align (Bouygues Travaux Publics, Sir Robert McAlpine and VolkerFitzpatrick) JV projects.

ALICE can't be used on any and every project; there has to be a BIM model, although Carpenter says that a simpler version is under development to allow it to be more widely deployed. And this isn't a 'plug and play' scenario. Currently there are a few weeks of preparation while the schedulers, possibly with input from others and from the ALICE customer success team, set it up.

Carpenter describes this set up process as "defining recipes for different elements," involving the inputting of the materials, labour and time required. "You teach it a lot about what you are doing," he says. "At present, the upfront time is usually a couple of weeks to take your BIM model and bring it into ALICE. But then the ability to do 'what if' analysis is almost instantaneous."

From a commercial perspective, ALICE saves time, money and resources. The website quotes average gains of 17% saving on time, 14% on labour cost and 12% on equipment. Clearly, if you can focus attention on some of the critical path activities, the impact can be significant.

There are other benefits too. ALICE helps to communicate different options and their impacts to stakeholders. It can find ways around supply chain disruptions or delays, such as those suffered during Covid. And some people are using it to reduce carbon emissions due to construction; for instance, by looking at ways to reduce vehicle movements.

Perhaps the most interesting part about ALICE, though, is that it allows those experienced project managers to work with their less experienced colleagues on optioneering. That means that, as well as ALICE being trained through the project managers' optioneering thoughts, less experienced colleagues are learning too.

MANUFACTURE

Automated quality control for segments

Automation in tunnel building is advancing on multiple fronts. But who checks the robots?

Who checks the robot's work? Herrenknecht is trialling an AI system.

This was the question posed by Herrenknecht to its sister company VMT when it started developing robots to work in its casting factories and on the TBM.

It all started in Switzerland, explains VMT's head of sales Florian Werres, around five years ago. Although it's challenging in many regions to find people who want to work in precast factories, Switzerland is an extreme case since wages there are high, so attracting people is difficult and expensive. As a result, Switzerland was the ideal place to trial robots.

It didn't make sense to be then employing humans to check on the quality of the robots' work. So the answer was to investigate the use of computer vision: a system that deploys a camera as eyes, with an algorithm that learns to spot specific features or items.

Well, that's the theory. "It is in the very early stages," explains Werres. "It's a pioneer project, to see if it is adding value."

Robots have long been used to create reinforcement cages for precast tunnel segments. Now Herreknecht is developing robots to carry out other tasks at various points along the segment production line: cleaning out the segment moulds and oiling them, placing the inserts and gaskets in the mould and finishing off the top of the segments after the concrete has been poured. It is this third task where computer vision is already being deployed with a feasibility study underway to decide whether it should be trialled at the mould cleaning stage too.

The idea for each task is the same: the computer vision would look at whether the robot has done the job sufficiently well and, if it hasn't, instructs it what it needs to do to correct it. Getting that loop right for the finishing robot has been tricky, explains Werres.

Currently, when smoothing off the concrete, the robot works from the outer edges of the segment to the middle. Depending on whether there is a little too much concrete or not enough, the finishing process tends to leave either a small peak or a small trough at the centre, says Werres. That means that a human is needed to come in and smooth out that last bit.

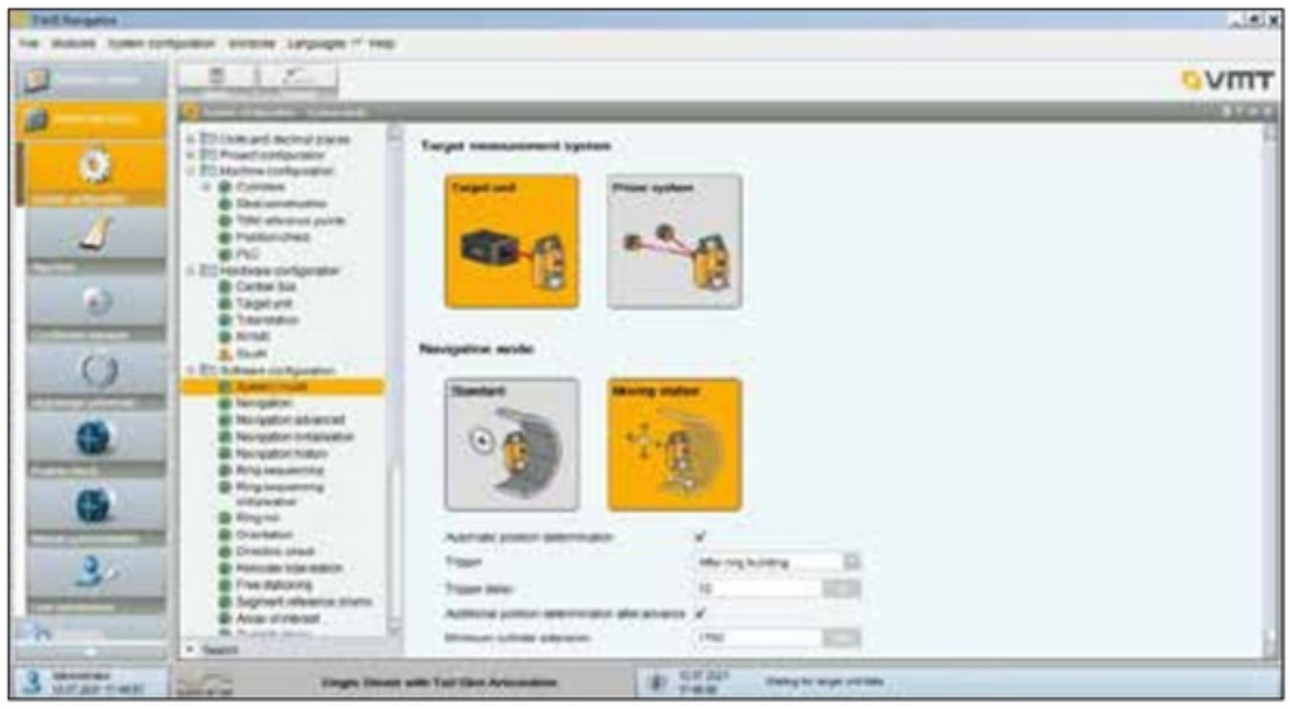
"There's still a saving because the process used to take between 5 and 7 minutes for two people. Now it takes one person around 2 minutes," he says, "It's not 100% automated but the managers of the plant like it." The finishing robot has been used on both the Gotthard Base and Brenner Base tunnels.

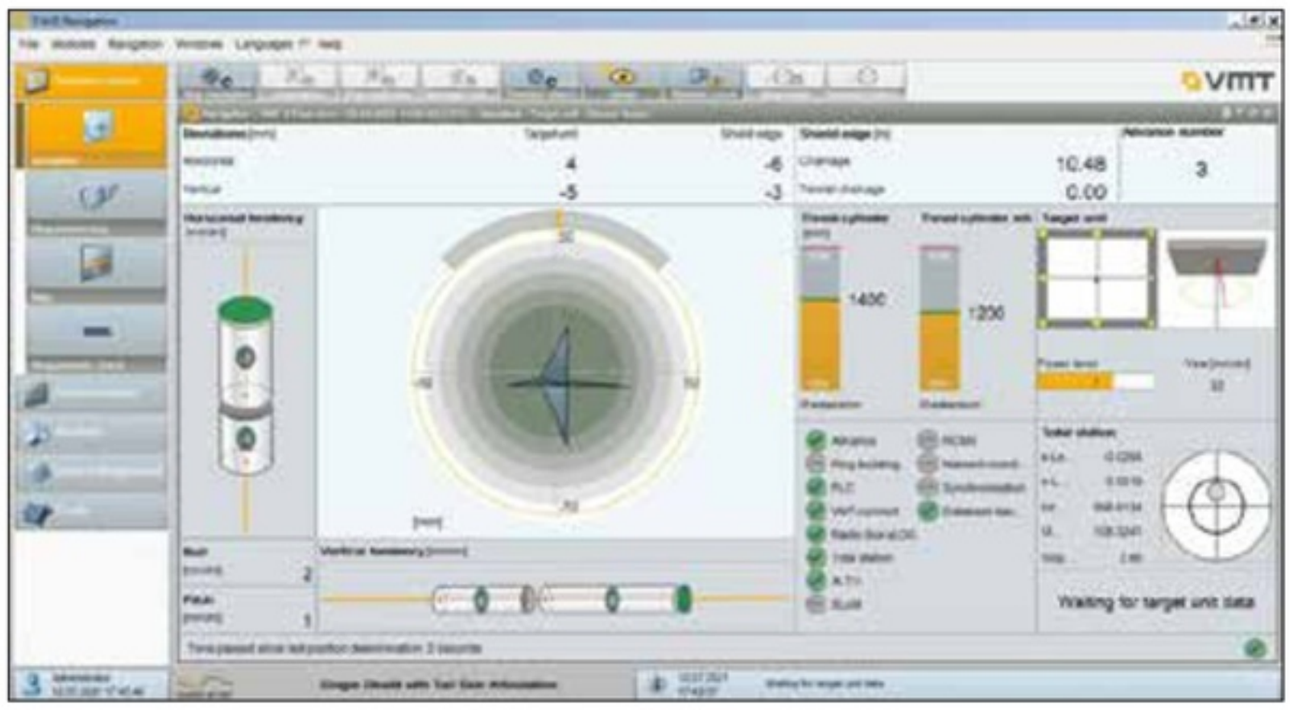
Computer vision is also being deployed on the two TBMs constructing the London Tunnels for HS2 in the UK for JV Contractor Costain Skanska Strabag. On these machines, the movement of the precast segments from the multi service vehicles at the back of the TBM

to the point at which they are erected as part of the tunnel lining is automated. The computer vision system aims to spot and record any defects such as cracks, missing dowels or wonky gaskets immediately before a segment is installed.

For this application, too, it is early days, says Werres. There is scepticism, particularly among some of the more experienced TBM operatives, but these are the first steps towards full automation of the whole tunnel construction process, he says. "Look at the automotive industry: there was a learning curve for a decade, but now car manufacturing is fully automated."

Part of the work for VMT and other companies training up AI today is to extract the know-how and experience from older generations and embed it in tomorrow's systems, says Werres: "We have to bring the knowledge to the systems to support the younger generation. We can't change them, so the industry must change. If we stick to old patterns, young people will leave the industry or won't even apply for jobs."





VMT's latest version of TUnIS for steering TBMs incorporates an AI 'tweaker'.

Florian Werres: "The industry must change...or young people will leave."

CONSTRUCTION

Next-generation TBM steering

Imagine an experienced tunnel boring machine (TBM) driver looking over the shoulder of a less experienced colleague and suggesting a little tweak to the alignment. This is what navigation system company VMT trained a machine learning algorithm to do.

Introduced last year, the algorithm is now part of TUnIS Navigation software and already at work on about a dozen machines according to VMT's head of sales Florian Werres.

"It is a prediction that helps to improve the accuracy of the system by analysing the machine type, its behaviour over the last 3 to 5 metres and where the machine will be according to the current alignment," explains Werres.

We are only talking about a few millimetres, but over the length of a tunnel, that all adds up. And the algorithm is working very well, says Werres.

VMT developed the algorithm to improve the accuracy of the latest generation TUnIS Navigation, which it introduced in 2020. Whereas the initial version of TUnIS incorporated a total station mounted on the wall of the tunnel, aligned with a target on the TBM, the latest version sees the total station on the gantry of the machine itself measuring prisms on the tunnel wall.

The new system has several advantages over the original one. The total station does not need to be frequently relocated, which requires surveyor time and sees holes drilled through the tunnel segments for supporting brackets. Instead, the stick-on prisms must be moved along the tunnel wall – which does not necessarily need a surveyor and which does not damage the tunnel lining. Consequently, there is less risk of the surveying holding up production.

However, there was one hiccup. As the machine is advancing, the total station is moving which meant that it couldn't be relied on for steering data during that part of the cycle. So, instead, the system takes readings from sensors on the TBM's extending rams and interpolates that to give its position

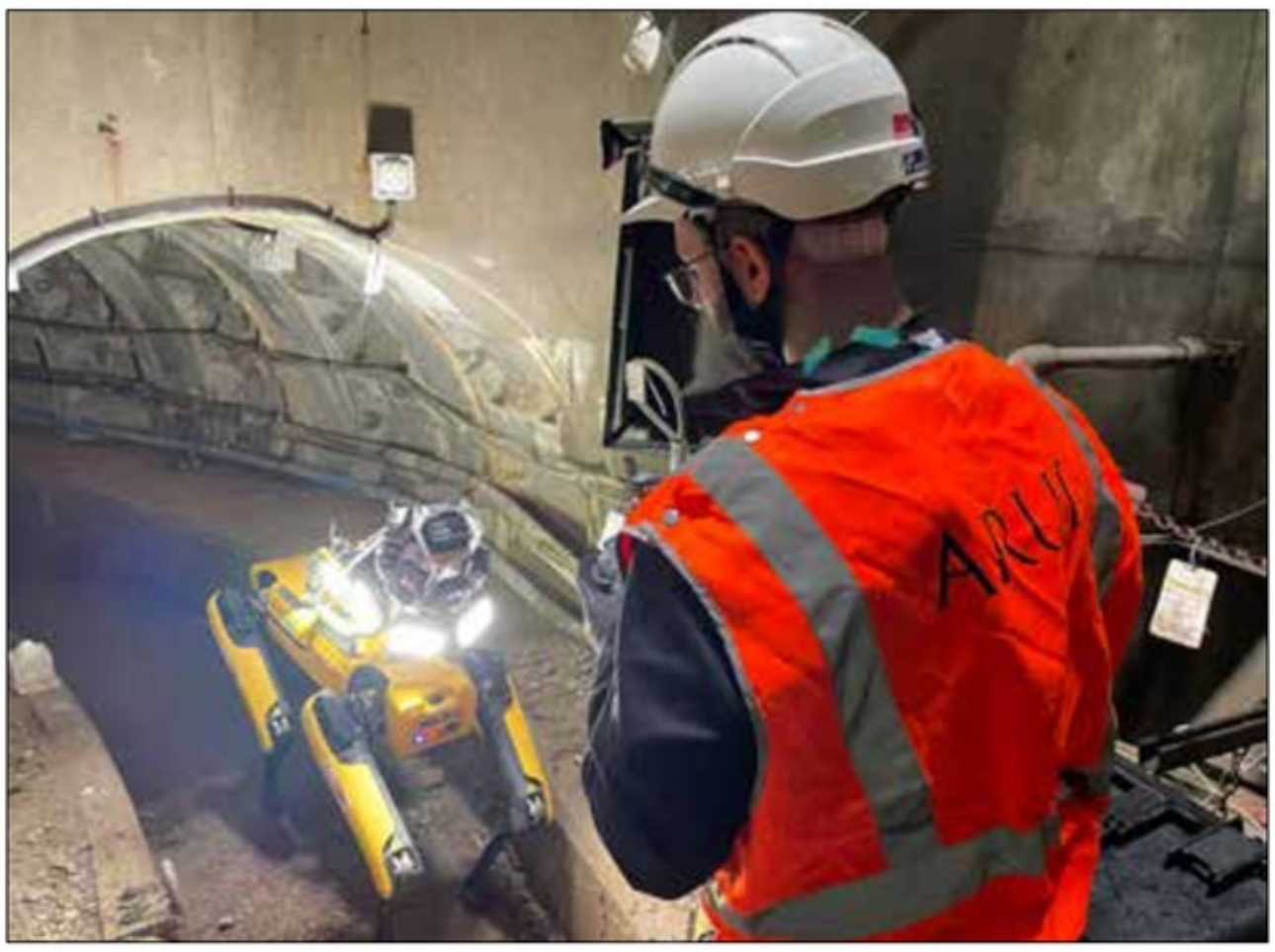
and hence its alignment. When the TBM stops again, the total station takes over, which can lead to a little 'jump' in on the TBM position screen.

"When the machine operators see this jump, it makes them feel insecure," explains Werres. "The prediction from the algorithm helps to smooth out the alignment and increase the accuracy."

VMT looked at several options when trying to tackle the issue of the jump, which is worse in hard rock than soft rock due to the way that the ram cylinders extend. Initially they looked at using more sensors or different ones. It was only when those lines of enquiry had been exhausted that a TBM specialist in the team, who had come from parent company Herrenknecht to work at VMT, suggested AI.

It has been a bit of a shock to the surveyors that AI can do better than physical measurement, says Werres: "In most cases the machine learning algorithm knows better where the machine is than the sensors because every sensor has a limited accuracy. That was really surprising for us."

There's another change in mindset required too, says Werres, for surveyors like his colleagues. "With a big number of projects and training data, we know that we can make the algorithm bulletproof but we will never understand in depth how it calculates the alignment, because the algorithm is complex," says Werres. "Surveyors like to understand exactly how everything works, so this is something we must get used to."



Spot the Dog collects tunnel condition data to be analysed by AI.

Yung Loo: "There's an appetite for predictive maintenance using learning from data."

ASSET MANAGEMENT

Safer inspections

Arup's Loupe 360 tool, which deploys machine learning to analyse survey information collected from tunnels, may not be the first of its kind, but its combination with Boston Dynamics' robot dog Spot last summer was certainly a novel deployment.

Spot has been engineered to cope with the same terrain as a human, including stairs, slopes and gravel. In a trial for UK Power Networks, the robot walked through one of its tunnels in Central London, equipped with cameras and thermal imaging. Loupe 360 then carried out the inspection work that human eyes would normally do in situ, analysing the information collected by Spot's equipment.

Loupe 360 is Arup's most advanced AI tool currently, says senior engineer Yung Loo. "It's an area that's advancing fast because there's a real appetite to move towards predictive maintenance regimes that rely on learning from data." Arup has developed the machine learning algorithms so that Loupe 360 can identify defects and tunnel features such as signage, cabling and lights.

According to UK Power Networks, using a system like this could cut the time humans spend in confined spaces by 50 percent, reducing safety risks and saving costs. Over 160 inspections a year take place in UK Power Networks' 47 tunnels, costing over £1m. Using a system like Spot and Loupe 360 could save £162,000 a year initially – 16% - rising to double that by 2028, says the power company.

Another benefit of using AI-based survey systems is that they will ultimately be more accurate and consistent than a team of human surveyors. And it will be possible to go back and reanalyse historical data, says Peter Kottke, associate geotechnics and tunnelling at Arup: "One of the benefits is that we are getting so much data. AI routines can evolve and then we can reprocess that data. When you send in a human, they might take a few photographs, but they would not have photographed a location before a defect appeared."

Information gathering and analysis by Loupe 360 could also prove useful during the construction phase, says Loo, for daily records. "It gives a more objective baseline of what was constructed so there are less areas to disagree with respect to what was built and how that fits in with defects and snags." The data collecting equipment can be fixed onto the locos or multi service vehicles used to being tunnel segments to the tunnel boring machine.

Loupe 360 isn't quite 'business as usual' for any asset owner yet, says Loo, but several organisations are carrying out trials. One of its next deployments was to be at research establishment CERN, on the Franco-Swiss border, for a survey of the newly upgraded High Luminosity Large Hadron Collider tunnels.