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Turing Institute explores AI's maritime potential

A workshop for the Institute's recently formed Marine & Maritime Group discussed the challenges and opportunities in developing AI and ML applications

Mention Artificial Intelligence (AI) in the context of maritime and there's perhaps a temptation to think about autonomous ships. Yet it's really just one facet of the ways in which AI and machine learning (ML) is poised to transform marine design, technology and operations in the coming years. However, bridging the gap between the latest advances in computer science and their practical application as meaningful tools is a challenge that requires expertise from outside maritime.

It's a problem shared by many other sectors of industry, particularly SMEs which may have an innovative product or service they feel unable to develop. Providing research support and collaboration in the development of solutions is part of the remit of the Alan Turing Institute, which was founded with government backing as the UK's focal point for data science in 2015.

Following a further recommendation in 2017, and spurred by developments in deep learning and neural networks, the Institute's scope was extended to include AI. Among the academic institutions that became formally affiliated around this time was the University of Southampton (UoS), which earlier this year spearheaded the launch of the Turing Institute's Marine & Maritime Group.

In July, *TNA* was among those invited to e-attend the group's inaugural workshop, an event originally intended to take place at the British Library prior to the Covid-19 pandemic. The workshop's aim was to develop a roadmap for AI in maritime and identify the areas where it can make a difference to the industry, and where the potential challenges may be, as well presenting some case studies from maritime companies that are already taking their first steps in utilising ML.

Machine Learning theories that Alan Turing developed 70 years ago are only now being put into practice

Alan Turing, the pioneering mathematician, is far from just a totemic figure for the Institute. "Almost all of the work on deep neural networks you can find in papers attributed to Turing written in 1949 and 1950, so some of this work can take a long time before it really becomes useful," says Adam Sobey, lecturer in Engineering and Physical Sciences at UoS and co-lead of the Maritime Group. "Some of these things we need to be working for 20 or 30 years time, while some of them could be making a difference now."

Data centric engineering

The new group falls under the umbrella of the Turing Institute's Data-Centric Engineering program, an initiative that began when Lloyd's Register (LR) was commissioned to undertake a foresight review on the influence Big Data would have on commercial enterprise, specifically in engineering. A wide range of projects have emerged across various sectors of engineering, industry and manufacturing, focused around key strategic areas, or 'challenges'.

Resilient and robust infrastructure: The increased availability of sensor technology data from critical infrastructure such as power stations, oil refineries and road networks in recent years has raised the question of how to leverage that instrumentation to provide insight. By analysing this data with AI and ML methods the aim is to enhance predictive monitoring and create infrastructure that's more resilient to so-called 'Black Sky' events.

Monitoring of complex systems: Closely related is the challenge of understanding and anticipating rare but high-consequence events. Given that sensor data comes from different sources, at different rates and varying levels of reliability, how can it be exploited for predictive health monitoring purposes? Current projects include the monitoring of cyber and water networks.

Data driven engineering design under uncertainty: One of the program's major research goals is to facilitate engineering that is designed for, and informed by, data. This encompasses issues such as the human-machine interface, but a significant area of focus is the development of Digital Twins and how best to calibrate them to the sensitivity of the instrumentation and extract meaningful insight. The wealth of available data means that classical methods of calculation are beginning to reach their limits of what can be realistically accomplished, meaning that AI-based surrogates are playing an increasingly important role.

Mathematical foundations: In addition to the above, the program seeks to build stronger links between theoretical

Naval architects Olesinski has been using algorithms to explore the interior design space, but ultimately hope to use physics-based ML to speed up CFD. Credit: Olesinski

research and ensure the robustness of the data science solutions developed within these engineering applications.

The program is already working closely working on a number of projects with the aerospace industry, for example a Digital Twin of a Rolls-Royce aero engine that can be used with test rigs. Given that most aero engines are only sparsely fitted with sensors it becomes difficult to form more than pressure and temperature for some cross sections of the engine, and unfeasible to simulate the physics within a reasonable timeframe. Therefore, factors such as subcomponent efficiency and identifying cold spots are important in providing insight that forms the basis for code capable of predicting behaviour. Another project is using AI to verify the safety threshold for engine components made using Additive Manufacturing based on CFD simulations.

Construction is a further area where sensor data is providing insight for modelling behaviour. In one project, a railway bridge has been instrumented with around 160 sensors and software developed in collaboration with Microsoft that provides critical health monitoring and makes it possible to adapt service cycles.

Bringing AI into the design toolset

AI is already influencing ship design and it's by no means reserved for larger companies. Isle of Wight-based architects Olesinski, which specialises in luxury motor yachts, has been working with Adam Sobey's UoS team for a number of years, providing support for student projects and developing areas of mutual interest in AI-related techniques.

"Our current strategy revolves around building a toolset with the ability to rapidly explore the possibilities of a particular hull envelope – in terms of what we can fit into it – while considering structural aspects and exploring the hydrodynamic behaviour of different hullforms," says Bill Edwards, Olesinski's head of R&D.

Unlike merchant ships, in yacht design the emphasis is less upon optimisation and more on the subjective, so search algorithms serve as a kind of screening process to illuminate options of how the space, particularly internally, can be configured before human designers assess which particular options warrant further consideration.

Edwards explains: "We deliberately explore areas of the design space where we know would be considered suboptimal in many respects. So we're able to have quantitative discussions for and against before moving in various directions. This is why developments in genetic algorithms have been interesting to us, as techniques which promote a diversity of searches over convergence are particularly useful in solving these sorts of problems."

Genetic algorithms, a concept which can be traced back to Alan Turing's concept of a 'learning machine', first rose to prominence with the work of the computer scientist John Holland during the 1970's. However, in the last few years the UoS team, with funding from the Lloyd's Register Foundation, has developed the Multi-level Selection Genetic Algorithm (MLSGA). This is based on the evolutionary theory that an individual's fitness for survival depends not only on its own abilities but also the group it belongs to, for example a wolf and its pack.

Applying the MLSGA serves as a method for dividing the design space into smaller constituent parts and then exploring different iterations of those parts more rapidly. In other words it becomes possible to create a greater number of complex architectural models rather than spending time on research and feasibility. This makes it particularly useful for investigating the diverse possibilities for the yacht's interior space and then cherry picking the best options to show to the client. After inputting the hullform, the calibration of Olesinki's software with any explicit parameters is a simple matter and a series of different possibilities can be generated within minutes.

More ambitiously, the company is also working with UoS on developing physics-based ML as a means of 'hacking' the time spent running CFD. Given the limited insight it provides as to why a given set of parameters is performing, it might be as effective to use the flow field data from a handful of simulations rather than the grander DOE technique to inform a numerical surrogate.

Edwards says: "Those flow fields are informed by the initial simulations that have been run for checking things such as mass conservation, which is where the physics-based part of the name arises. We're constantly checking the validity of the estimates that arise from this model, and working towards flow fields that may be more valid by using the normal physical quantities that we would be checking in the course of a CFD simulation. The upshot of this is it should allow us to predict flow fields around a hull that hasn't actually been simulated.

"The other really exciting thing about using these techniques is that multiphase simulations are so time consuming because we start from a very general initial condition… you've got to wait a significant amount of time for some flow features to develop organically. By using a flow that's been estimated using these predictions and feeding that into the solver to act as the initial condition we can arrive at a result very similar to that if we'd run it from the very beginning."

While it potentially offers a tenfold speedup time it remains a work in progress and Edwards admits there is a lot of development to be done to reach the point where full parametric optimisations can be performed using these techniques. Moreover, the types of CFD simulations are continuously becoming less expensive both in time and cost in their own right due to the rapid advances with solvers. But he remains convinced that in the future physics-based ML will have a place in the naval architect's toolset for optimisation/exploration studies.

"For us the aims are clear; to be able to perform broader and deeper explorations into the potential of a design so that options can be explored at an appropriate point in the design process, in time for key decisions to be made with as much information available as possible."

Olesinski has already presented at a number of events and seminars about the work, to considerable interest and the intention is that these enhanced tools and techniques will be marketed under the brand OlesinskiAI.

Performance optimisation

Another player exploring the possibilities of AI and ML, but for ship operations and fleet management, is oil major Shell. As a company with a large maritime footprint and a stake in anything up to 2,000 different vessels on the water on any given day, the incentive to be at the forefront of efforts towards safer and more efficient shipping are self-evident and in 2016 Shell started upon a strategy of digitalisation.

"Some of the more complex data we receive from our assets we wouldn't have been able to understand or make any insight into without the help of ML or AI technology," explains James Heliwell, fleet technical excellence analyst for Shell Shipping and Maritime, in a follow-up conversation with *TNA*.

Shell's wider digitalisation strategy includes the development of solutions using technologies such as 3D printing and VR, and like many companies it is exploring the possibilities for remote surveying. But it's with the capability to start processing the data from onboard sensors that AI is proving particularly advantageous.

Until very recently, the reporting of onboard data had scarcely changed in more than a century; it was principally the noon report. Onshore analysis of vessel performance was reliant on crew going around the engine room and physically reading the gauges and sensors, writing the data down on a clipboard and then radioing or phoning it back. While the advent of email did help with some speedier exchange of information it was clearly way short of the Big Data required for meaningful analysis. Only in the last five years, with the advent of the Internet of Things and the constant streaming of data from ship to shore has such a tool been possible.

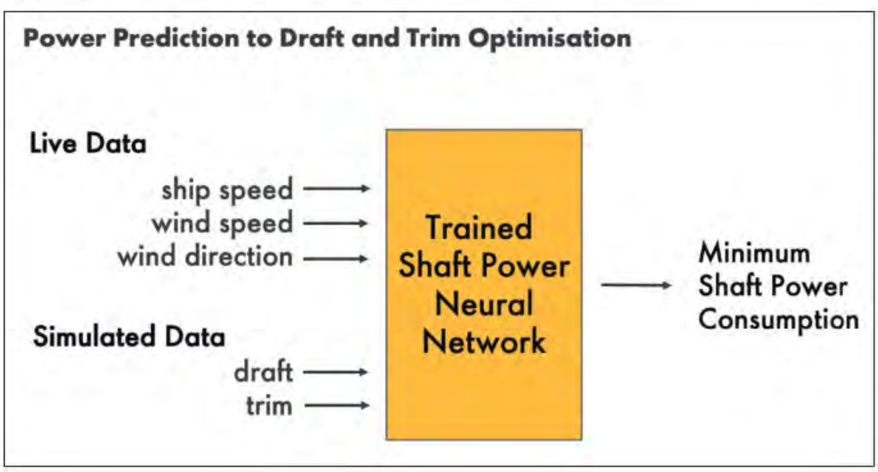
Shell Shipping & Maritime has developed a draft trim and optimisation program that is currently being deployed across 50 oil product carriers and 12 LNG carriers in its fleet. The program uses a software tool known as JAWS (Just Add Water) which initially worked off a statistical model using noon report data, before high frequency data sensor data became available.

"The thing that surprised us is that a data driven approach hadn't been developed before," says Helliwell. "Historically, CFD hull models were used to try and determine the optimum hydrodynamic condition. By using real data from the vessel in service, we can also capture the changes in vessel performance over time, such as the changes in hull fouling, to get more accurate results."

Over the past year or so, as part of an ongoing collaboration with UoS, Shell has been moving beyond the statistical model towards an AI-based tool which takes some of this data and feeds it through a neural network to make predictions. In other words, using ML to model the powering of a vessel through the interaction of the different variables.

With the aid of specialist human analysis of the raw data to help 'train' the neural network, it has been able to estimate within 2% error of the actual measured shaft power. Inevitably, there are certain problems that can arise with the reliability and accuracy of some sensors, particularly on older vessels, and these still require intervention until the neural network has

Combining simulated and actual data to calculate shaft power consumption. Credit: Shell International BV



a better understanding of such anomalies.

Nonetheless the model is currently undergoing final validation with the aim of deploying the AI-enhanced JAWS across the Shell fleet later this year. For the present JAWS is intended as a decision support tool for crew, but unsurprisingly the eventual aim is to remove the human element altogether and fully automate draft and trim using the neural network.

Helliwell admits that an optimised ship may count for little, or even be suboptimal, if similar initiatives aren't implemented across the wider supply chain, something that will require increased standardisation and sharing across data platforms. It's something Shell is keen to promote as part of its wider commitment to decarbonisation, including the recent publication of its 'Decarbonising Shipping: All Hands on Deck' report (jointly published with Deloitte and available at: www.shell.com/DecarbonisingShipping), which sets out a path for emissions reduction.

"One of the key solutions identified by the industry in the report was improvements in operational efficiency. Our work on developing JAWS is an example of the work that Shell are doing on this," he concludes.

Plenary sessions

In addition to presentations the workshop also gave ample opportunity for delegates to discuss their own thoughts about the role of AI. The consensus was that most maritime companies using ML tools are doing so reactively, fitting it into their existing processes rather than embracing radical change. In some cases still there appears to be a chicken and egg quandary about whether the tools (i.e. algorithms) are needed first, or the raw data.

When that data is being derived from sensors there are also concerns about whether it can ever be entirely trusted, or completely consistent. While it's not uncommon for a fleet to include vessels of 35-40 years old alongside newbuilds, sensor technology is advancing so rapidly that they typically have a lifespan of less than five years and it's impractical to re-instrument equipment so rapidly.

Another misgiving expressed was the provenance and security of that data. Given that many companies, whether naval architects or ship operators, don't have the in-house expertise to develop their own data analytics and are often reliant on third party specialists. But if that data is being sourced from elsewhere how can its authenticity be verified? And if that data is the intellectual property of the maritime firm then can the third party be trusted?

"Do you bring in computer scientists who don't have the maritime knowledge, or try and teach these tools to naval architects?" asks Sobey. "Hopefully that's something that universities can start to change. Much like when coding came in originally you had coders and engineers, whereas now you just have engineers who know how to code."

The Turing Maritime Group aims to publish and circulate a report based on the workshop in the near future. Sobey says: "The idea is that we want to use it to start conversations and help academics get grants from funding bodies, and start to work out whether there are fundamental joint industry projects where people might gain, as well as things like education. There are lots of things that can come out of this." *NA*