Explainable AI for Industrial Processes in Construction

Dr Ming Lu

EXPLAINABLE AI FOR INDUSTRIAL PROCESSES IN CONSTRUCTION

Within the wider worlds of engineering, manufacturing and construction, there is a growing demand for accurate computer modelling of large-scale projects. Through the use of artificial intelligence, engineers can more accurately predict and improve various aspects of construction work, from calculating the total cost of a project, to optimising the quality of concrete. **Dr Ming Lu** and his team at the University of Alberta are developing such artificial intelligence systems, towards ultimately overhauling how we plan large-scale engineering work.

Computational Solutions to Engineering Problems

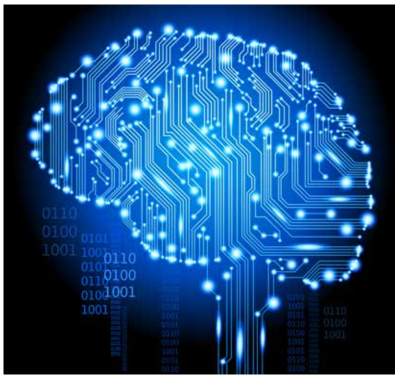
Throughout history, engineers have relied on a combination of skill and experience, passed down from generation to generation, in order to improve upon their designs and methods over time. However, there are drawbacks to this method of gathering information. It can take a long time to train competent engineers, meaning they are often in short supply. Furthermore, some engineering jobs can be time consuming and require a lot of data processing. In essence, many aspects of the profession need to be optimised, so that engineering projects can be completed as efficiently as possible.

Towards this aim, Dr Ming Lu and his colleagues have been researching how we can implement exciting new artificial intelligence (AI) systems into the various fields of engineering. By harnessing the power of AI, he hopes that many large-scale engineering projects can be completed more efficiently and with less subjective input.

Optimising Concrete

For thousands of years, humans have been using lime to create cement, leading to the material that forms a cornerstone of our society: concrete. Increasing in popularity since the Industrial Revolution, this material has been widely used and thus closely studied. This means that there is a huge bank of knowledge on the properties of the material, which modern engineers must appreciate to achieve the best results.

One such property is referred to as the 'slump' of concrete, which describes the consistency of fresh concrete before it hardens. This property is essential to understand when working with concrete, as it can affect the way that the material sets, and thus the quality of the final product. As such, it would be useful if engineers could design a system that accurately predicts the outcome when producing concrete using different methods and ingredients.



Previous studies have used artificial neural networks to model the quality of different concrete mixtures and predict the outcome of specific mixing processes. While these neural networks have proven to be effective, many researchers believe that they are too complicated to fully understand and implement effectively. Thus, researchers have been attempting to develop other systems, which are easier to implement while still achieving the same standard of results.

Dr Lu and his team propose a different method of modelling this phenomenon, using what is known as a 'model tree algorithm'. This method, which works

by classifying data and sorting it into categories to better understand it, has been previously shown to be effective for this sort of work. Thus, the team began to compile data and work towards producing a system that would achieve this goal.

Through their work, the team developed a system that can analyse existing data in order to gain better understanding of the factors affecting the slump of the concrete. They then used their system to attain estimates about theoretical mixtures based on a number of possible variables. This is a major breakthrough, as it could allow engineers to better understand how concrete can be produced in an optimal way for a specific purpose, before any resources are consumed. This approach would help to make the construction industry far less wasteful – in terms of raw materials, money and time.

Cost Estimation of Steel Fabrication

Any type of construction project is going to incur large costs due to numerous factors, including the labour required. Often these costs will be calculated by first estimating the number of 'labour-hours' that each team will require to complete their tasks, which can be used to give a rough estimate of the total labour costs involved. However, during the planning stages of a construction project, it can be almost impossible to achieve accurate estimates, which can cause cash-flow problems down the line.

Therefore, many engineers turn to computational management systems, which can more precisely predict the labour-hour requirements for construction work, leading to more accurate cost estimations.

In a recent research project, Dr Lu and his colleagues developed a model that can accurately predict the labour costs involved in large-scale construction projects. In this case, the team used a steel fabrication project as a case study. The process of making steel, which itself is widely used in construction, has many crucial steps, each of which can have their own associated costs. Thus, it was a perfect example to test the team's new model.

Utilising a similar process to that employed to solve the concrete problem, Dr Lu and his team implemented an AI that was able to provide reasonable estimates for the time, and therefore costs, involved in various steelmaking projects. This tool could be invaluable for assisting with the decision-making process when it comes to planning large-scale work in the future.

Calculating the Cost of Prefabricated Components

Dr Lu and his team then decided to extend the limits of their computational work and branch out into other fields of cost prediction. This time, the study wasn't focused on the fabrication of steel, but the prefabrication of parts for construction, such as precast concrete components or prefabricated piping spools.

With a huge number of different designs, materials and components available, engineers have more choice than ever when it comes to purchasing and using pre-made parts. This can help to significantly reduce the work required, and allows engineers to use a wider array of different components within their projects.

However, pre-made parts can sometimes be expensive, so it is important for engineers to understand whether it is more cost-effective to buy such parts or to build them from scratch. In addition, engineers need to predict the time and cost required for making various structural components.

This can once again be achieved through carefully designed models, which can use existing data to establish accurate cost

scaling and come up with optimal plans. Dr Lu's team has been using data from the manufacturing of pipe spools and wall panels, in order to produce a precise and adaptable model.

Once again, the team was successful in delving into established mathematical theories and designing a system that could produce a reasonable prediction of the uncertainties in the costs involved in these processes by analysing existing data on the subject. This tool could provide a suitable way for engineers to plan their work within budget, to the greatest efficiency and cost-effectiveness.

Creating an Explainable AI System

As Dr Lu has demonstrated, well-designed AI systems can allow engineers to greatly cut down on the time they need to spend making calculations. As such, these systems help us to achieve large-scale engineering projects more efficiently.

However, while these AI systems are incredible, their complexity can lead to issues in usability. If an engineer cannot understand how an AI system calculates its results, it is difficult to evaluate how effectively it is working.

The solution is an additional branch of computer management system design, known as 'explainable AI'. This revolves around the design and implementation of a second model, which can help to articulate the logic used by an AI system, while still allowing it to work effectively. In short, this allows the end user to understand the mechanisms that the system used to reach its results, evaluate its effectiveness and gain additional insight into the problem being solved.

Working alongside a structural steel fabricator, Dr Lu and his colleagues set out to develop a system that would not only predict the labour-hour requirement involved in steel fabrication, but would also do so in a way that can be interpreted by professionals working at the company.

'Model explainability matters as much as prediction accuracy in engineering applications,' says Dr Lu. 'We wished to turn the model tree algorithm into an explainable AI, so as to reveal which inputs play what roles in predicting outputs, along with the uncertainties associated with the predicted outputs.'

When it comes to understanding how to work with certain materials, such as steel, it is hard to do better than real on-the-job experience. The AI system designed by Dr Lu's team was not supposed to replace this know-how, but rather lend analytical decision support to complement this know-how. To ensure that these predictions were accurate, the team designed their system so that users, both inexperienced and experienced, can understand how the AI system reaches its conclusions.

Transforming the Field of Engineering

Through the inventive use of AI, Dr Lu and his colleagues have demonstrated how we can better cope with the complexities and variations in connection with construction and fabrication processes, providing construction engineers and managers with much needed decision support by making the most of the available data. The team's systems not only make accurate predictions, but also allow users to understand how they reach their conclusions. Efforts like this may ultimately change the world of engineering, providing future generations of engineers with the tools they need to build as effectively as possible.

Meet the researcher

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Dr Ming Lu earned his BEng specialising in Road & Traffic Engineering at Tongji University, Shanghai, before being awarded his PhD in Construction Engineering & Management at the University of Alberta, Edmonton. Here, he holds his current position as Professor of Construction Engineering, and continues his research into computation and automation across several engineering fields. His work has led to the growth of the Construction Automation Lab at the University of Alberta, which works towards developing automation within Civil Engineering and combining it with unique management systems. Dr Lu is also passionate about training the next generation of engineers. As well as designing and teaching numerous courses at the university, he also supervises the training of PhD students and postdoctoral researchers. Dr Lu is also an active member of many professional societies, including the American Society of Civil Engineers, and the Alberta Professional Engineers and Geoscientists Association.

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KEY COLLABORATORS

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FURTHER READING

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