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Algorithms that work – how higher mathematics generates innovation in LSH

Kim van Amersfoort

Mathematical algorithmic modelling may seem a rarefied academic pursuit, but scientists at CWI pursuing life sciences and health research are committed to designing models with direct applications to challenges in healthcare. From optimising treatment plans for cancer patients and reducing waiting times for ambulances to improving geriatric care and suicide prevention, their work, says senior researcher Peter Bosman, "is not window dressing. Our algorithms are actually being used. We go from foundation to application."

The Centrum Wiskunde & Informatica (CWI, the Dutch national research institute for mathematics and computer science) is keen to ensure that the real-life value of its work is more widely understood. That's why, says Professor Leen Stougie of CWI, the partnership with Smart Health Amsterdam is so important for the institute. "We do a lot of applied scientific research in the broad LSH area, so it was quite natural to support the Smart Health Amsterdam initiative. One of the things that we are interested in is making new contacts for and with whom we can further develop and apply our methodologies. With CWI's broad expertise in mathematical algorithmic modelling and so on we can really enrich the LSH area within Amsterdam Smart Health."

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Posted by
Kim van Amersfoort
Community manager at Smart Health Amsterdam

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The researchers' focus is on methodologies, based on modelling and problem formulation in a quantitative way. Stougie explains that the algorithms developed have a wide range of applications across the LSH field, including medical imaging, genome research related to COVID-19, radiotherapy and geriatric care.

Prof.dr. L. Stougie, CWI

Practical applications

CWI's models are highly advanced, and, says Stougie, it's not always clear to those working in the LSH sector how they can be applied in practice. "There are people who know some mathematics and know what we are proposing, but usually people don't have a clue," he says. "I was at one of the very first Smart Health Amsterdam meetings on a boat near the Maritime Museum and I talked to people there, and they thought our work was very interesting but that they couldn't do anything with it." Practical, real-life examples, he says, are key to promoting a greater understanding of how mathematical modelling can drive advances in healthcare.

Advanced optimisation

Peter Bosman leads a research group at CWI working on, among other things, medical informatics. A field which is, he says, about "using advanced forms of optimisation and machine learning to help medical experts make better decisions." Medical experts will always have the final call, but by ensuring there are better ways of processing the available data, they can be given greater insight before making a final decision. CWI's work with medical imaging, for example, is focused on helping doctors analyse the images more efficiently. "How you contour the prostate, for instance," explains Bosman, "so that you can actually see where it is and how big it is, and then plan treatment based on that." His group is also working with Amsterdam UMC to help doctors create more effective plans for administering radiotherapy to treat cancer – another example of using optimisation to support medical decisions.

Prof.dr. P.A.N. Bosman, CWI

When working in this field, says Bosman, it's important that the data you are working with represents 'the best possible thing'. "If you don't yet know the best possible thing, you should optimise first, then create data and then learn from data to make it faster. In the radiotherapy domain, lots of innovations recently are still around optimisation. You need to help doctors optimise planning so that you maximise the probability of a tumour being destroyed and minimise the probability of damaging nearby organs. Doctors already make plans with existing software, but we can make better plans with the optimisation that we've created. You must optimise to know what's best, otherwise you'll just repeat what you did in the past."

Reducing waiting lists in healthcare

One of those practical examples that is scoring real-life success is the Dolce Vita project, a partnership between CWI, Amsterdam UMC, the Vrije Universiteit (VU), the Amsterdam health & technology institute (ahti), and SIGRA, a regional partnership of health and welfare organisations. Dolce Vita stands for 'Data-driven Optimisation for a Vital Elderly Care System' and CWI's Rob van der Mei is the project leader. The aim, he says, is to reduce waiting times in the acute elderly care system. "It's one of the huge problems," he says. "It often happens that a patient enters the acute care system and needs to be placed in a nursing home, but there is no place available. There are waiting lists at many nursing homes and many issues related to bottlenecks in the system. The idea of the project is to identify the bottlenecks and resolve them, if at all possible. The acute demand in healthcare for the elderly will keep growing, and that's why it's really urgent that we look at this issue."

Prof.dr. R.D. van der Mei, CWI

The project team has developed an allocation algorithm that explicitly considers patient preferences when deciding how care beds can best be allocated. “We have a list of patients that need to be placed and their individual preferences, we have a list of beds that have become available, and we allocate them in the mathematically optimal manner, which often results in a dramatic reduction of waiting times.” Not only are shorter waiting times better for patients, but they also reduce the overall burden on the health system. Having been launched in 2019, the project is already delivering promising results: “The algorithms we have developed have led to a reduction in waiting times by a factor of two to four in realistic use cases.”

Create, refine, reuse

Van der Mei is now seeing interest in the model from other care sectors that have similar problems with bottlenecks and waiting times. “The fun thing about the mathematical modelling that we develop is that these models to some extent abstract from the specifics of elderly care, or youth care, or mental-health care. So that means we can pretty much reuse models from one area for another. That’s the power of mathematics.” He adds that he appreciates, “that we can do things with our background in AI and mathematics that are societally relevant.”

A cross-sector approach and the collaboration between the various parties involved in Dolce Vita is crucial to the success of the project, according to Van der Mei. “We bring in the knowledge of working with data, modelling and optimisation, and healthcare professionals, who work with patients, bring the practical knowledge. And on top of that, SIGRA brings a large network of care providers and insurance companies. That aspect is also very important as a link between us academics and the policymakers and decisionmakers in the system. I’m convinced you need all three parties to get anything done.”

The power of maths

Stougie, Van der Mei and Bosman are all evangelists when it comes to spreading the word about the power of mathematics and computer science to create solutions to real-world problems. "We are the ones that can help you do what the generic software cannot," says Bosman. "We can tell you how to take state-of-the-art AI techniques, particularly machine learning and optimisation, and do something a little bit beyond what you can do today. If your problem is large and complex, that's when we can help." Van der Mei is also eager to stress the potential of their work for making a broad impact. "AI and mathematical modelling are generic and can be reused to a large extent. That's the power of the type of research we are doing. It can be of use everywhere."

That versatility is something people don't always understand, says Stougie, which can lead to them undervaluing CWI's work. "To make our work clear, we can describe a project such as Dolce Vita, but the downside is that people may think: 'Oh, that's just one specific example.'" Van der Mei agrees. "Yes, in the case of Dolce Vita, we created a use case for Amsterdam, and some people then think it's a model for Amsterdam only. When you tell them you can also use it for Rotterdam because it's only a different parameter set, then it's a miracle, right? Whereas for us this is a completely trivial change to make to a model."

Fully-fledged solutions

All three researchers want to make clear that CWI is not an ivory-tower establishment. "Yes, we do state-of-the-art science," says Bosman. "But we know how to put our science into practice. It's not just window dressing. I often say 'from foundation to application' – and by application I mean something being used. For instance, our radiotherapy algorithms are being used at Amsterdam UMC to treat patients. We don't just stop at saying 'oh, look, it sort of works on paper.' No, we build the software as well and create a fully-fledged solution that works in practice."

CWI is one of Smart Health Amsterdam's partners – see the partner page for CWI. The centre works with other Smart Health Amsterdam partners: Amsterdam UMC, ahti and the Vrije Universiteit (VU). CWI research has generated a number of high-tech spin-off companies working in fields such as data management, operational analytics, optical tracking systems, financial mathematics and biotech.

This article is part six of a series: Pioneering projects.
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Smart Health Amsterdam is the network for data- and AI-driven innovation in Amsterdam's life sciences and health sector. We invite you to join the community and sign up for our monthly newsletter.