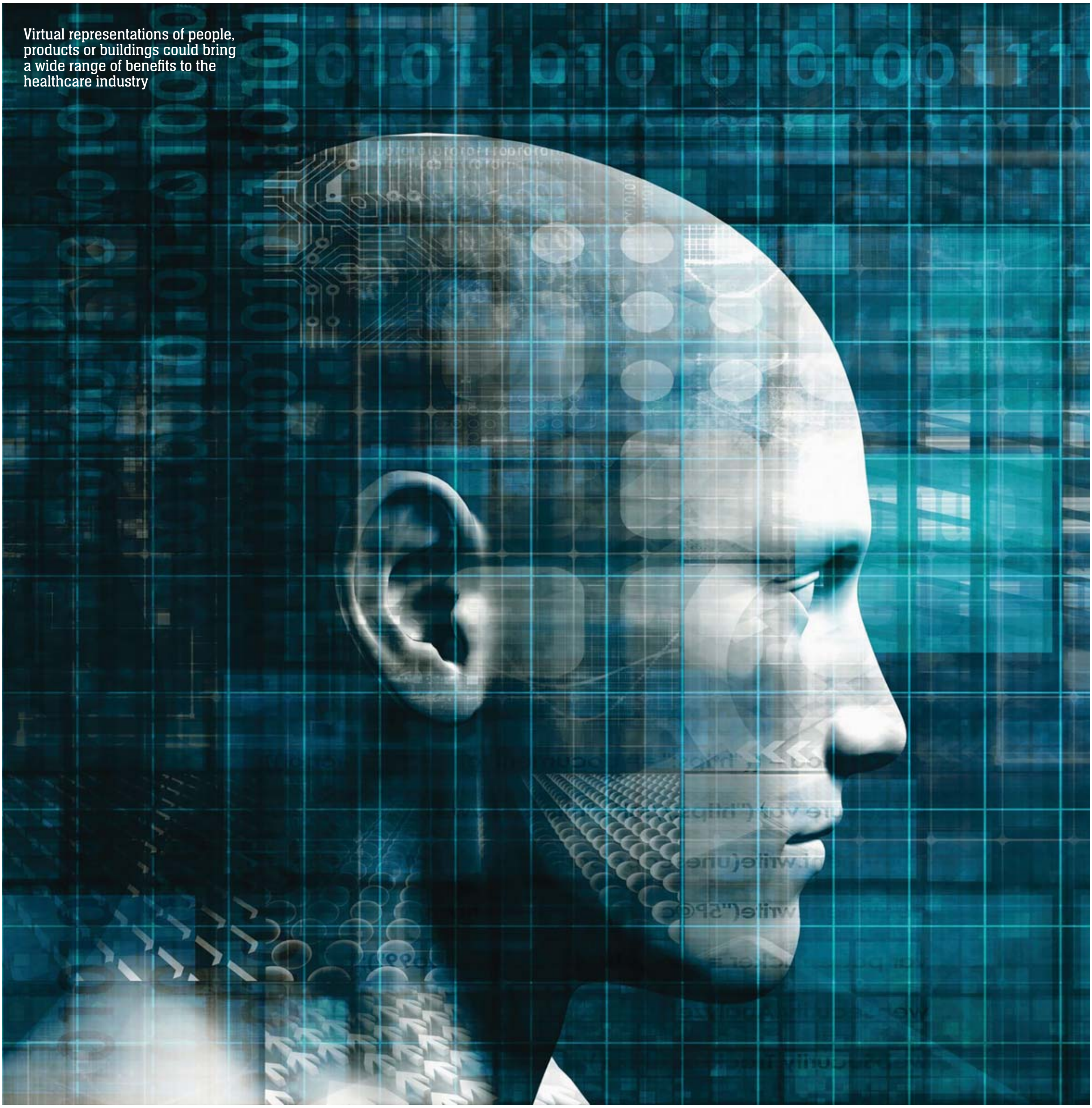
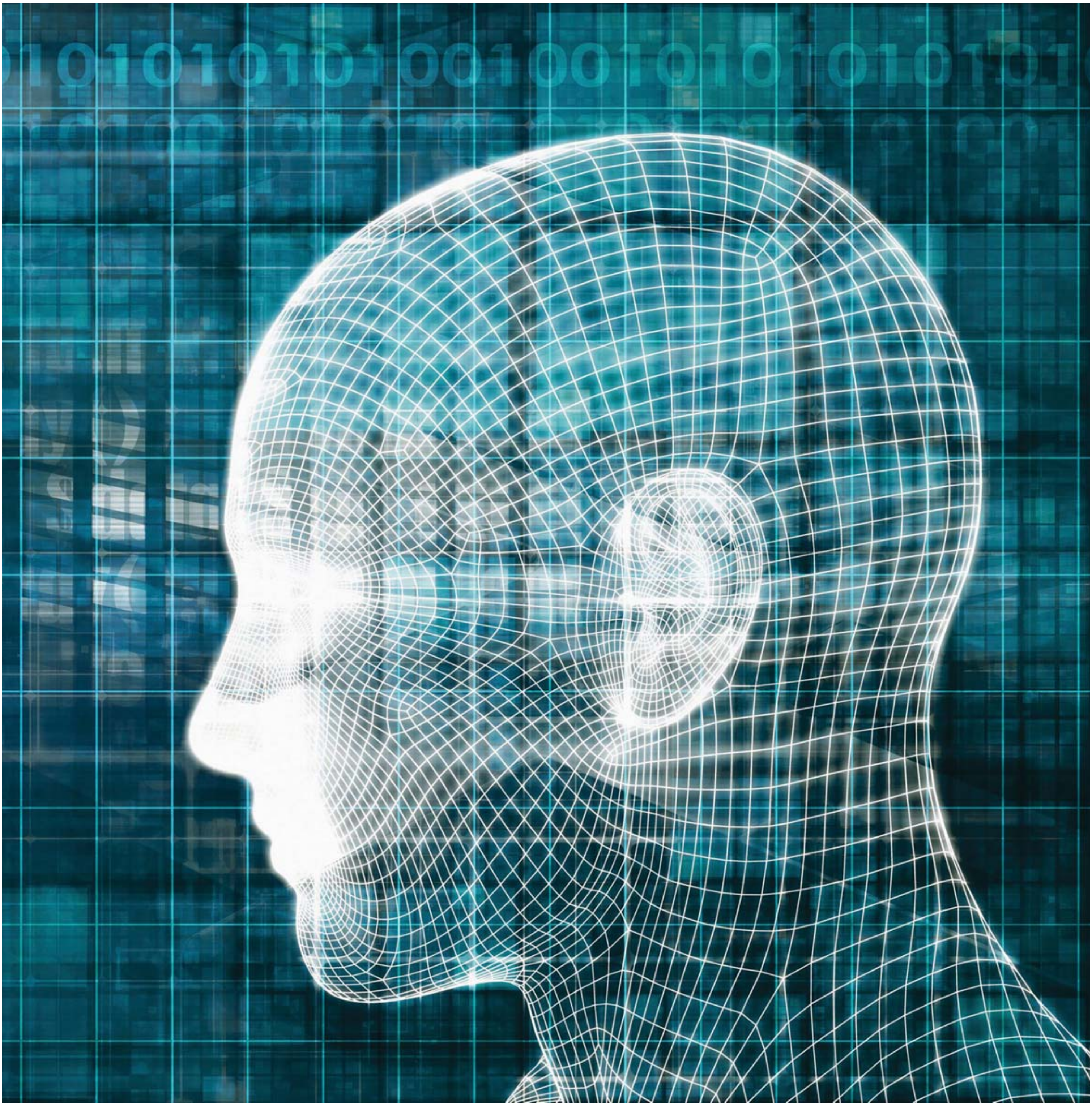


Virtual representations of people, products or buildings could bring a wide range of benefits to the healthcare industry

Digital twins will **revolutionise healthcare**



Digital twin technology has the potential to transform healthcare in a variety of ways – improving the diagnosis and treatment of patients, streamlining preventative care and facilitating new approaches for hospital planning.

By **Lindsay James**

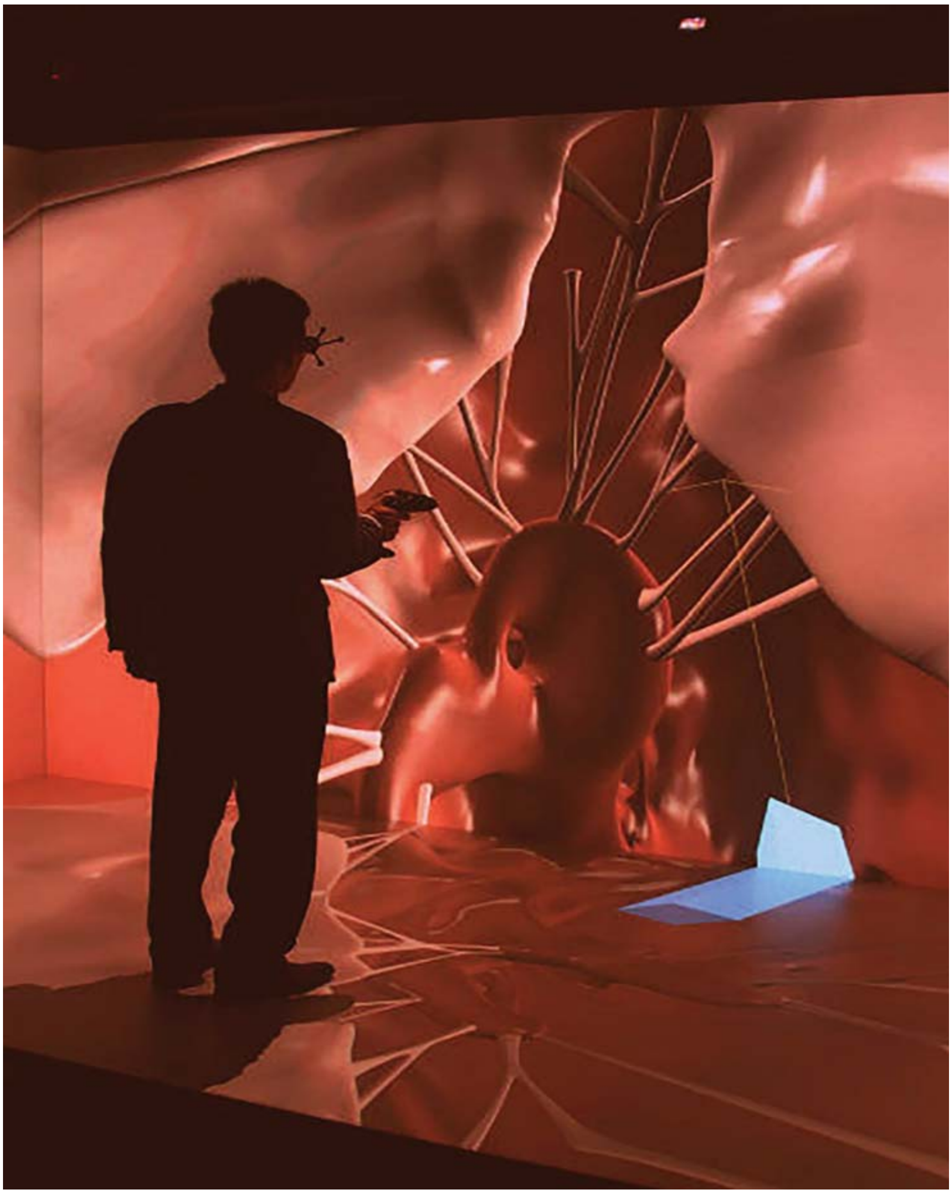
IN THE FUTURE, a digital twin of our genetic profile could be created for every one of us at birth. If we get ill, this 'virtual self' could be computationally treated with hundreds of thousands of drugs to ensure the most effective medication is chosen. It could also be used to discover which medical conditions we may or not be predisposed to, enabling us to prevent major diseases before they take effect.

This is the vision of several healthcare industry pioneers, including Mikael Benson, a professor at the Centre for Personalised Medicine at Linköping University Hospital in Sweden. Benson believes diagnostics of a much higher resolution are needed to bridge the gap between the complexity of common diseases and today's healthcare system, which he says is not only primitive, but fundamentally broken.

"There's far too much trial and error involved in diagnosing and treating people today," he says. "This costs time and money – two things our healthcare system does not have in abundance. Improving patient outcomes by just a small fraction could make a huge difference. For example, a 10 per cent reduction in the number of patients who are not responding adequately to treatments for diabetes and heart disease in the USA would save approximately $200bn annually, according to research published in *Lancet*."

Nancy West, head of enterprise services at Siemens Healthineers Great Britain and Ireland, agrees: "The biggest challenge facing healthcare is the need to improve value for patients," she says. "Most diagnoses and treatment protocols are designed for typical patients, and the delivery of care is >

> 'There's far too much trial and error involved in diagnosing and treating people today. This costs time and money – two things our healthcare system does not have in abundance.'
> **Mikael Benson**
> Linköping University Hospital



The Living Heart Project has realised the world's first realistically functioning computer model of the complete human heart

< fragmented and principally focused on volume. Healthcare is yet to leverage the full potential of data and, as a result, the positive impact it can have on patient experience."

The efficacy of treatment is not the only challenge facing the industry. Budgets are being stretched beyond their limits, while inefficient workflows and unnecessary deviations remain undetected. "Time is of the essence, and unfortunately many underlying systems and processes are not yet optimal," says West. "During our current global pandemic, these challenges are only amplified. Every minute that can be saved by optimising processes can significantly improve the patient experience and transform the delivery of care."

While the challenges are undeniably huge, experts agree that advances in digital twins – virtual representations of people, products or buildings – could offer a solution.

"We believe digital twins have potential across both clinical and operational dimensions in the healthcare industry," says Brian Kalis, managing director of digital health at Accenture. "The ability to model the physical world in a digital format could help with medical education, research and care delivery in the future. Digital twins also have the potential to improve operational efficiency of healthcare enterprises through the ability to track and trace healthcare facilities, equipment and supplies in near-real time to more efficiently match supply and demand."

"Digital twins mirror reality and can detect problems that may otherwise remain imperceptible," adds Dr Craig Buckley, head of research and scientific collaboration at Siemens Healthineers GB&I. "They represent the next step towards the goal of providing the right treatment for the right patient at the right time."

Rare defects

Significant progress is already being made. The Living Heart Project, for example, was launched to develop the world's first realistically functioning computer model of the complete human heart. This project came to life when Jesse Levine, the daughter of Dr Steven Levine, a senior director at 3DEXPERIENCE firm Dassault Systèmes, was born with a heart that is literally backwards, with right and left ventricles transposed. This rare defect led Jesse to have four pacemakers implanted by the age of 20, none of which had been tested on a patient with her condition prior to placing in her body.

After decades of dealing with the ambiguity in treatment options, Dr Levine sought a model to unite other healthcare specialists, medical device companies and regulatory bodies to collaborate around aspects of human anatomy and disease models.

"Through this initiative, a fully functioning Living Heart has been developed and is now available to anyone worldwide," he explains. "It is being used for designing new medical devices, analysing drug safety, designing personalised surgical treatments and in biomedical education."

The heart is also the focus of Siemens Healthineers, whose team has created a digital twin in order to simulate the use of cardiac resynchronisation therapy – a treatment option for patients suffering from chronic congestive heart failure. It involves an advanced pacemaker that resynchronises the beating heart using two electrodes, one implanted on the right ventricle, the other on the left.

"We have been able to virtually implant the electrodes, and virtually generate electrical pulses," says Buckley. "If the asynchronous pumping of the virtual heart was corrected, it served as an indication that resynchronisation therapy could also be successful in the real patient. This is an excellent example of using digitalisation and artificial intelligence (AI) to help physicians develop more precise prognoses. The simulation of different scenarios not only improves treatment, but also offers the potential to realise substantial time savings, improve success rates and, in turn, the overall cost position."

Benson, meanwhile, has focused his efforts on digitally mapping different diseases. Along with his colleagues at

Linköping University Hospital, he has completed a seven-year study which has successfully used high-resolution data from individual patients to create advanced computer models of 13 autoimmune, metabolic and malignant conditions including breast cancer, influenza, Crohn's disease and eczema.

"Unlimited copies of these digital twins can be created and computationally treated with thousands of drugs, or combinations thereof, to discover the most effective medication for the individual. The drug that has the best effect on the twin can then be selected for actual treatment of the patient," says Benson. In the next three to five years, he believes digital twins of individual cancer patients will be in clinical trials. Linköping University is part of an EU project that is working towards this goal.

In the longer term, Benson expects that digital twins of healthy individuals will be analysed to predict their risk of developing different diseases. "The twins will then be digitally subjected to different exposures to identify those that increase or decrease risk," he says. "For example, a patient at risk of cancer or autoimmune diseases will greatly increase that risk by smoking. The twins may be regularly updated and tested for signs of change in order to prevent disease. I envision this being population-wide and coupled with education about disease mechanisms. Thus, each willing individual will take increasing responsibility for their own health."

Detectable changes

Dr Mohamed Rehman, chair of the Department of Anaesthesia and Pain Medicine at Johns Hopkins All Children's Hospital in Florida, USA, shares a similar vision. He believes that in the years ahead, clinicians will be able to compare an individual's digital twin against future readings from their fitness tracker to look for signs of disease or recovery from illness and surgery. "Once we validate that certain detectable changes in status from a patient's digital twin are associated with health complications or adverse outcomes, we can use this knowledge to intervene in the future in order to prevent these complications," he says. "This would mean that as the patient recovers at home, a clinician could track their progress and look for early signs of worsening or complications. The data from a patient's digital twin may also enable physicians to create treatment plans specific to a patient's lifestyle (for example, a reliable indicator of their usual level of physical activity) and monitor actual compliance with certain components of the plan of care."

Using evidence from clinical trials, Rehman expects to be able to tailor automated lifestyle nudges and hooks to well people, for example by using Bluetooth-connected glucose monitors and smart refrigerators with connected insulin pumps to allow diabetics to have tighter control of their blood sugar levels.

"We could also minimise office testing of heart rate and blood pressure, avoiding white-coat syndrome," he says. "Perhaps most interestingly, we have the potential to predict disease before it presents clinically – diseases such as sepsis, respiratory exacerbations and sickle cell crises. This can lead to earlier intervention with treatment, potentially preventing critical deteriorations and hospital admissions. For example, we could make automated suggestions that asthmatics adjust their medication when local air pollution is high, and their sleep is disturbed."

Progress is also being made in using digital twins to help improve processes and systems. By running hospital-wide simulations, healthcare leaders can work out the impact of tweaking staffing – for example, understanding whether a fix in one department will create a bottleneck in another.

This is an area that Siemens Healthineers has been keen to explore. "There are many examples of digital twin and simulation models being applied to the day-to-day delivery of improved systems and processes across Siemens Healthineers customers," says West. "Workflow analysis, system redesign and process improvement methodologies benefit from digital twin technology to map and test changes to improve patient care."

In a strategic partnership with the Medical University of South Carolina, the firm is exploring a range of digital twin applications, including process optimisation using digital models of the hospital's daily routine. The goal is to offer patients the best possible care, and, at the same time, set a new standard for other hospitals. "Several scenarios can be simulated as digital twins and their effects on process efficiency can be represented without incurring major costs," says West.

Despite these huge endeavours, completely revolutionising healthcare is a very tall order – and several challenges will need to be met for digital twin technology to become the norm, especially when it comes to mapping human physiology.

Take Benson's breakthrough, for example, which involved the creation of a purpose-built scRNA-seq laboratory and the use of one of the fastest supercomputers in the world: tools which are not exactly accessible to all. There's also a current lack of user-friendly software that would enable both patients and physicians to use digital twins to discuss optimal treatment based on informed consent.

Earn and maintain trust

That's without mentioning the issue of data. "Datasets need to be deep and detailed, with the kind of size that may require national collaboration," says Rehman. "We need to move away from current electronic medical record designs – which are the product of clinical and medico-legal documentation – to a deliberate design that facilitates data mining and automated collection of clean data. Computing capacity and the learning abilities of AI will need to continue to expand. As clinical informaticists, we need to generate an urgency and excitement around digital twins, to engage our colleagues along the entire adoption curve."

It's also important to earn and maintain the trust of the public and of patients – the source and benefactors of the data required. Anonymising data, where necessary, is an important element of this. "Maybe patients should own their own data," Benson suggests. "Willing individuals could share their data and participate in research in an informed, high-level and perhaps mutually beneficial way. Other data could be anonymised. Handling this correctly requires multi-disciplinary expertise and patient input and is likely to create an entire ecosystem of new occupations in the future."

Despite these complications, experts are unanimous in their opinion that digital twins hold a huge amount of potential for the years ahead.

Benson is confident that advances in computational and network analyses will enable widespread adoption of his methods. To speed up the clinical implementation of digital twins, his data and algorithms have been made freely available in the public domain. What's more, he says, change is already happening. Large software companies already have FDA-approved diagnostics on the market, and he expects that solutions for expanding digital twins to integrate increasingly detailed molecular, routine clinical and medical imaging data will follow soon. There will also be huge commercial opportunities for solutions that address problems like how to protect integrity, solve regulatory issues or use medical data.

Levine is also excited about what's to come. "We will build on our progress to enable the full power of the virtual world to modernise healthcare," he says. "We plan to continue to deepen our understanding of cardiovascular disease, to improve the models and, more importantly, refine the method to customise it to be patient-specific. We will also apply the methodology to build the living brain, lungs, knees, shoulders and systematically develop medically relevant models of the human body."

Ultimately, the goal is to bring a renaissance to clinical care. "Modern medicine still reflects time-tested paradigms for assessing, training and delivering care," Levine concludes. "However, the modern world demands more. We are living longer, are more active and more productive, and we expect standards of care to be as reliable as air travel and as understandable as online shopping.

"To do this we need the full power of digital healthcare, and at the centre will be your virtual twin that serves not only as a medical record, but as a guide for more precise treatments. In the years to come, we will continue to connect the dots between the research communities, device and drug development companies, clinical care teams and citizens. We want to remove the mystery, which will lower costs and enable all of us to better understand, monitor and maintain our health as long as possible." •