Healthcare delivery soaring to new heights with interactive simulation

Dr Robert DiRaddo is the Section Head of Simulation and Digital Health at the National Research Council of Canada. Based in Ottawa, the NRC celebrates its centennial this year. Dr DiRaddo's team develops mathematically-based and interactive virtual reality technology for a wide range of uses, such as training neurosurgeons, training pilots to fly drones and helping passengers control anxiety.

In its 100th year, Canada's National Research Council (NRC) is continuing to push the boundaries of technology to deliver new solutions to old problems. Its aims of realism, convenience and affordability are at the centre of the NRC's drive to advance virtual simulation technology, which has the potential to vastly improve health outcomes for patients. In keeping with this, Dr Robert DiRaddo's Simulation and Digital Health team has been developing interactive simulators to aid training and improve patient care.

Virtual reality (VR) simulators are key to this for several reasons: they can enable long-distance skill sharing and treatment; create an immersive experience to help patients combat conditions such as anxiety, phobia and ADHD; and set benchmarks to monitor progress, allowing users to improve their skills and develop new ones.

RISK-FREE SURGERY TRAINING

The NRC's headline product, developed with simulation technology giant CAE Healthcare, is called NeuroVR™ (previously NeuroTouch). The innovative system provides interactive simulation of neurosurgery procedures. Teaching modules include instrument handling, fundamental skills, endoscopic surgery and microsurgery. The technology allows training neurosurgeons to practise techniques before operating on real patients, and helps experts demonstrate or brush up on their skills. Around 11% of diseases can be treated with surgery, so this technology will clearly play a vital role in healthcare.

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practice of a challenging and vital procedure in a safe, risk-free environment – to neurosurgery. Because teaching hospitals are able to offer less and less actual training time as burdens on health services increase, VR simulation can be a key part of training and provide critical practice time. Nushi Choudhury, a Research Officer for the NRC's Health Technologies program, highlights the importance of simulation, saying, "when the stakes are high and training in real settings is not feasible, simulation methods have found their niche". The technology is now being used in 20 teaching hospitals worldwide, some able to communicate over the internet.

The simulator employs force feedback technology known as haptics, where the computer gives tactile indicators like in real-life surgery, and relies on the surgeon's touch to control the simulator. This can reveal what physical cues surgeons are responding to, and help students learn how to conduct procedures. Additionally, it can establish benchmarks to test improvement, and set standards for excellence in neurosurgery.

Q&A

What was the drive behind developing Virtual Reality (VR) technology to improve patient outcomes?
VR, or what we refer to as Interactive Simulation, allows user interaction with a mimicked real-life scene, at controlled risk and relatively low cost. It provides a mechanism for objectively quantifying performance measures of skills, for users/patients. If one is able to quantify performance, then one is able to systematically track it to an improved outcome.

How versatile is this technology? Do you see it being extended into other fields?
There are numerous applications for Interactive Simulation. For example, Interactive Simulation is used in the aerospace sector, mostly to train pilots. It also has applications in the industrial sector for training of skills such as maintenance and operational skills. Simulators to teach drivers also exist. There are also many more examples.

What kind of feedback have you received from students and experts who have used the NeuroVR™ neurosurgery simulation?
We certainly have several that indicate its value. One resident indicated her level of comfort was greatly increased prior to her first OR (operating room), largely because of training on NeuroVR™. While there is of course more work to do to increase 'suspension of disbelief', NeuroVR™ is currently being used to train residents throughout the world. One such initiative involved the University of Toronto training surgeons in Ghana via Skype, with a NeuroVR™ at each location.

How will this technology impact patient procedures?
NeuroVR™ targets training. The core technology can be expanded to handle patient-specific rehearsal, i.e. an experienced surgeon practising a complex intervention before going into the OR. Such technology would require work on facilitating the surgical workflow and assuring compliant technology.

How do you develop accurate lifelike models of internal body structures for simulation?
We rely on a comprehensive biomechanical tissue testing laboratory for obtaining constitutive mathematical models, relying on Newton's first principles. We then insert these models into the simulator to increase realism, while assuring a cost-effective simulator.

What are your team's priorities for further developing healthcare simulation technology in the future?
Our focus moving forward is to work with clinical and industrial partners: firstly, to deploy constitutive-based simulators in the clinical space; secondly, to expand the use of Interactive Simulation for other applications such as homecare and product development. We are well on our way on both objectives.

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APPLYING EXPERTISE
The technologies and expertise at the NRC include physics-based, real-time clinical simulators such as the NeuroVR™, as well as services for digital health monitoring and custom development for training, for instance using mannequins.

The simulated environment can also be used to assess stress levels in other situations outside of surgery. This could be particularly important in outpatient health care, for example allowing home-based care to be conducted remotely, perhaps demonstrating exercises or rehabilitation tasks. It can also be used to assess cognitive performance, for instance in psychotherapy or mental health assessments. This can be useful in treating anxiety or improving fine motor skills.

One practical application of the technology developed at the NRC is to combat in-flight anxiety, which approximately 40% of people reportedly suffer from. This can eventually involve immersive VR technology or non-immersive alternatives such as relaxing music, meditation tutorials and stress-relieving audio-visuals. Similar products have been tested in half of the Spanish airline Iberia's fleet of Airbus A320s, and installation in the remainder of the fleet is planned to be completed shortly.

The technology also extends beyond the flight itself. Simulations of the flying experience include being in the terminal, going through security and actually being on a plane. Anxiety about flying is generally reduced, the more an individual experiences it, but for most people it is not an everyday experience. Simulations can help walk people through the process in advance, helping to reduce the stressfulness of the real life situation.

CROSSING CONTINENTS
DiRaddo's team has also used simulations to remotely train other neurosurgeons who are located far away from their base in Canada. Dr Allan Okrainec of the University Health Network (UHN) in Toronto believes that "telesimulation is absolutely the way of the future." His team conducted the first distance learning general surgery telesimulation in 2007 with a teaching hospital in Botswana. Since then, more partnerships have been developed with hospitals in developing countries, which can improve the training offered to local neurosurgeons.

Teletraining is a good way to cut the costs of training and to share expertise. It is especially useful in developing countries because travelling abroad for training is extremely costly, and beyond the budget of many teaching hospitals. The first use of VR in telesimulation was in partnership with Korle-Bu teaching hospital in Ghana in January 2014. Surgeons at the Toronto Western Hospital UHN delivered training to neurosurgeons in Ghana on how to treat hydrocephalus – an abnormal accumulation of fluid on the brain which has a high incidence in Ghana and predominantly affects children. The procedure can be life-saving but only around a tenth of paediatric patients in Ghana receive it. The live four-week training was the first of its kind worldwide, and was called a "milestone in effectively teaching neurosurgery skills through electronic means" by Marjorie Ratel, President of the Korle-Bu Neuroscience Foundation Canada.

WHERE NEXT?
VR is a versatile tool that can be applied to many fields and areas. The next steps are to improve interconnectivity between simulators, allowing them to 'talk' to each other, and improve the real-life rendering of patient-specific scenarios. This can be achieved by incorporating more high-quality data, allowing neurosurgeons to practise scenario-specific procedures before conducting them.

The team aims to drive excellence in patient care, and wants to push simulation into common use in medicine. Rolando del Maestro, Director of the Neurosurgical Simulation Research Centre at the Montreal Neurological Institute and Hospital (MNI), and an early supporter of the NRC's simulation research, predicts, "in the next 5-10 years, I expect every major neurosurgery centre to have simulators". He adds that "transitioning this dream to an approachable reality will result in a worldwide improvement in the care of surgical patients".

Detail

RESEARCH OBJECTIVES
Robert is currently developing a strategy to expand simulation to new fields in healthcare, such as training for other surgical specialties, human factor design of surgical devices, rehabilitation, surgical rehearsal and image enhancement. In this context, his group of 24 employees, in synergy with other colleagues at NRC, are mobilising to offer industry services ranging from custom software development to hardware integration.

SOME COLLABORATORS
- CAE Healthcare
- Mount Sinai (Toronto hospital)
- Hopital Foch
- Medical University of Vienna
- University of Minnesota
- University Health Network
- McGill University Health Centre (MUHC)
- Bayer

BIO
Robert DiRaddo obtained his PhD in Engineering from McGill University and joined NRC in the early 1990s. Robert developed the SIGBLOW industrial consortium, targeting the delivery of simulation technologies for the automotive, packaging and petrochemical industries. In the mid-2000s, Robert initiated the development of simulation for the medical healthcare sector, in particular for training and device design. Robert holds the position of Section Head and Principal Research Officer at NRC. He also holds adjunct professor positions in the Faculty of Engineering at UBC and at McGill University, as well as an adjunct professor position in the Faculty of Medicine at McGill University.

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