SMALL VOLUME HUGE CHALLENGES

CAPTURING FINE HAND-MOTION IN TIGHT SPACES WITH THE VERO

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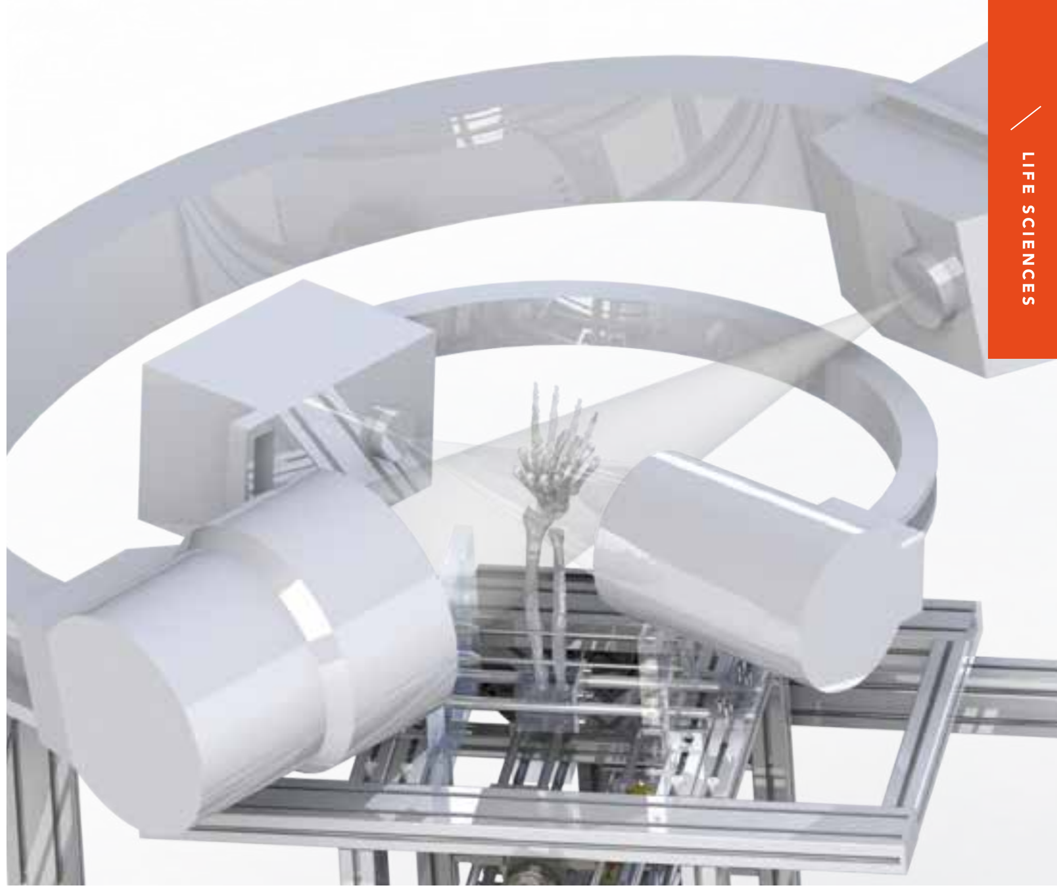


While the largest motion capture projects might pick up the biggest headlines, some of the most challenging work done using Vicon technology happens at the smallest scale.

Dr. David Ackland, PhD, Head of the Biomechanics Research group, Department of Biomedical Engineering, University of Melbourne

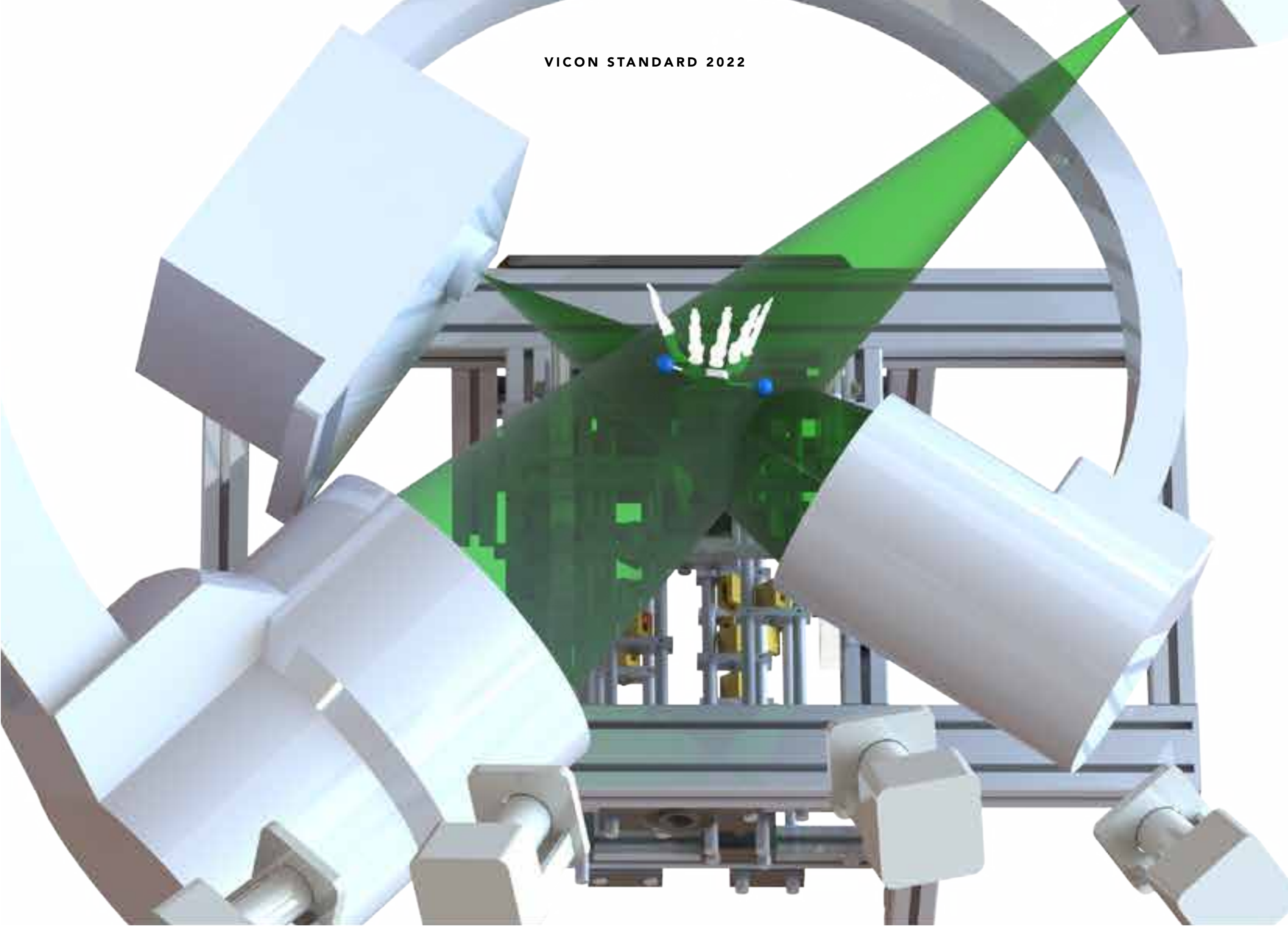
Dr. David Ackland, head of the Biomechanics Research group in the Department of Biomedical Engineering at the University of Melbourne, has been working with hand and wrist surgeons from the O'Briend Institute to better understand the inner workings of the human wrist.

Associate Professor Ackland's study has an extremely focused goal: examining the function of a specific, easily damaged ligament that controls the scaphoid and lunate bones in the wrist, and how injury and surgical interventions affect that function.

"Firstly, the aim of our study was to evaluate normal carpal bone motion," says Ackland. "Secondly, motion of the carpal bones when the ligament is torn. Then we wanted to look at the effectiveness of surgical reconstruction of the ligament, taking a look at a couple of different techniques for repairing it, as well as a novel surgical approach that has not been reported previously. And the way that we assessed this was using a custom-built wrist simulator."

The wrist simulator sits in a dedicated wet tissue lab at the university. This highly compact setup comprises a novel rig for reproducing wrist motion by way of simulated force application to the wrist muscles. Two C-arm fluoroscopes are used for X-ray imaging the carpal bones, and a set of Vicon Vero cameras surrounding the hand and arm of a cadaver are used for wrist joint motion analysis. A motion capture marker cluster is placed on the forearm and another on one of the metacarpal bones in a finger, and these are used to track the overall wrist motion in real time, which is required for controlling the muscle forces correctly. By far the largest part of the setup is the substantial mechanism below the arm that loads cables attached to the hand to simulate muscle force and wrist motion.

"What we wanted to do was to create a rig with a control method that produced highly repeatable motion of the wrist in normal, pathological and surgically-repaired states. We could then use X-rays to measure motion at the individual carpal bone level," says Ackland.



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He and his team implanted metal beads into the bones and pressure sensitive film between them, then used biplane X-ray fluoroscopy to record moving 3D images of the bones and tissues inside the hand. This information was then combined with his motion capture data so that he and his team could understand what was happening broadly with respect to the wrist joint motion, as well as internally in relation to the individual carpal bones and the way they move and contact each other.

WORKING IN A TIGHT VOLUME

The limited space between the X-ray systems created a challenging environment for motion capture, however.

"It was really, really tight," says Ackland. "It was incredibly difficult to get everything in the field of view without creating occlusions and it took quite some time to set up. It took PhD student Xin Zhang three years to design the rig, build it and to plan and develop all the algorithms for tracking the motion."

The challenges of the small volume meant that getting the right camera was essential. "The conversation with Vicon about what sort of camera would fit our needs made the Vero very appealing, because it suits a lab environment with a small capture volume while offering high accuracy. The price point was also really good for us. So it was an easy decision for us to make."

The cameras have proven equal to the task. "The Veros were able to capture the positions of markers very accurately, and we had the positions of the markers transformed into a local anatomical coordinate system," explains Ackland.

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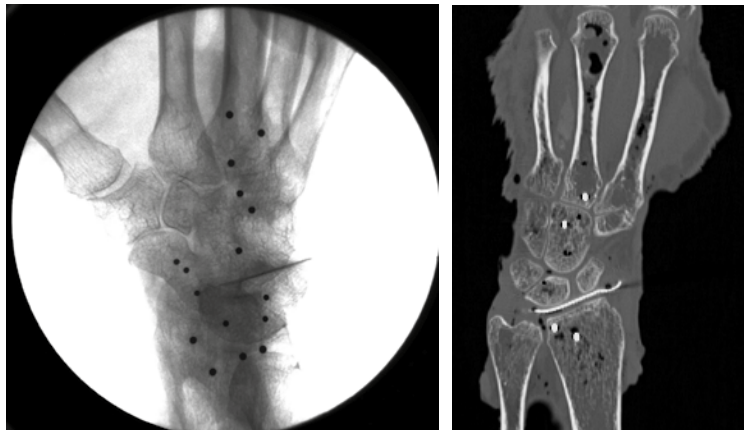

we're able to quantify the overall wrist motion with high precision and repeatability. The repeatability ultimately came from the control mechanism, which gave us the ability to control muscle forces accurately and in real time.

"The advantage of using this system was that we were able to get the data in real time and update the motors with a control pulse, and then receive new information on the updated position of the wrist instantly and change the muscle forces accordingly. W e did all this seamlessly, achieving these smooth waves of muscle forces and motion trajectories all in a closed loop and in real time in order to achieve the desired wrist motion."

GOING DEEPER

Looking ahead, Ackland wants to build predictive models. "Where we want to go from here is to take our setup and our simulations, and then take the motion of the bones that we get, and feed that into detailed finite element models of the joints so that we can then simulate the actual contact and the deformation of the hard and soft tissues. This is critical for understanding injury and joint disease such as osteoarthritis.

"We can do that by CT scanning the specimen and building anatomical models, then feeding all the data that we get from these experiments, such as force and motion, into the models to predict contact patterns in more detail. A finite element model allows us to interrogate different model elements, such as bone and cartilage, allowing us to explore contact behavior with unprecedented detail.

"Also," Ackland adds, almost as an afterthought, "we want to do the same in a live subject."