TheStandard

2023 Edition

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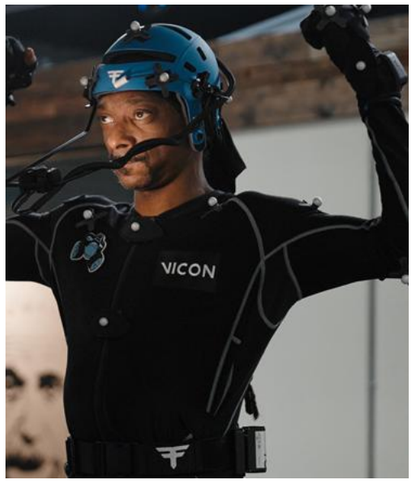

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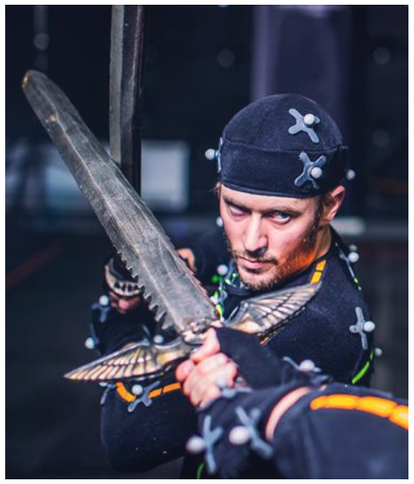

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Motion Capture - A Key Playmaker in an AI-Powered Rehab Landscape

IMOGEN MOORHOUSE
VICON CEO

I'm delighted to welcome you to the 2023 edition of The Standard.

For well over a year now Vicon has been driving towards one thing: our next-generation flagship camera, Valkyrie. As our CTO Mark Finch notes in his editorial, many tech companies release iterative new versions of their hardware annually, but when it comes to our hero cameras we don't do 'iterative'. Valkyrie is a powerhouse of optical capture technology built from the ground up to be the best motion capture camera in the world. That's not possible by simply tweaking the previous generation's design.

Unfortunately, in a world still beset by economic uncertainties resulting in supply chain issues, it has taken longer to get Valkyrie to market than we would have liked and nothing about it is 'off-the-shelf'. But we know that it's worth waiting for, and we want to thank you for being patient while we have made sure Valkyrie is the transformative piece of technology we know it is.

Moving to this edition of The Standard, once again the work our community is doing with Vicon technology continues to be inspiring.

I'm struck, once again, by the proliferation of motion capture applications in fields we could never have guessed at just a few years ago.

Take our article on Matt Workman's use of his Vicon system to educate YouTube creators on the power of motion capture for VTubers. It's a fascinating window into a fast-growing entertainment sector. It's notable, too, that despite the fact that Vicon is the premium motion capture solutions provider, our technology still offers value to users with lower budgets simply by virtue of being so effective.

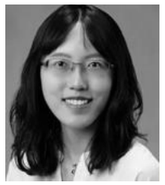
Similarly, our articles on projects such as IIT SoftBots' soft robotic prostheses, Pixomondo's latest leap in virtual production, and Tonal's smart gym all demonstrate how our customers are pushing the envelope using motion capture, often in ways that drive the technology's capabilities in new directions or to wider user bases.

While the last year was an exciting one for Vicon, it also came with some hardship. We lost one of our co-founders, Dr. Tom Shannon, and his enthusiasm, curiosity and roving mind are sorely missed. We've done our best to capture what made him special to us in our tribute at the end of this issue.

Thank you, once again, for being part of our community and I look forward to how you use our technology to achieve your goals in 2023.

EXPLORING THE HUMAN FACTOR IN PROSTHETIC ADAPTATION

MOTION CAPTURE COULD HELP IMPROVE STABILITY IN AMPUTEE MOVEMENT



Hui-Ting Shih, PT, PhD
University of Nevada, Las Vegas (UNLV)

Amazing work is being done using Vicon systems to understand how to build better prosthetics and wearable robots, but Dr. Hui-Ting Shih is working on the less explored side of the equation: the human wearing the limb.

Shih, a Doctor of Interdisciplinary Health Sciences and Rehabilitation Sciences at the University of Nevada, Las Vegas (UNLV) has recently completed the first phase of her research into how prosthetic users recover from trips. Exploring how people move with prosthetics is very much part of her department's DNA.

"When it comes to rehabilitation, most people think about the prosthetic leg and the need to make it better so people can walk more easily," explains Dr. Szu-Ping Lee, an associate professor in Shih's department and her PhD. adviser. "Our approach is slightly different. We believe that the prosthesis is only part of the equation. The other part is the human factor.

"If I give a patient with an amputation the best leg that's available on the market, does it really guarantee that they will be able to utilize the leg and function properly with that device? We think that it deserves more study. That's why the focus of the research in our lab is on rehabilitation or the human factor."

Shih's primary research tool is a system of 12 Vicon Bonita cameras running with Nexus. In addition to its Vicon cameras, the lab is set up with a Bertec instrumented treadmill. "We put them all together to try to develop a protocol that would simulate tripping scenarios during a walk," Shih explains.

The ultimate goal is to develop balance-training regimes that can help subjects to improve their responses to trips, with the aim of reducing falls. To do the work, Shih first had to develop a protocol with which to observe subjects stumbling and understand how they recover.

"We decided to take ground reaction force as the reference, and then we used MATLAB as the interface," says Shih. "So once the person is walking on the treadmill and one side of the force plate detects that the ground reaction force meets that criteria that we set, it will automatically deliver the perturbation. We pre-programed a change of the treadmill velocity to simulate the perturbation."

"Our approach is slightly different. We believe that the prosthesis is only part of the equation. The other part is the human factor."

LO-FI SOLUTIONS

Syncing the different technologies proved a challenge. Specifically, it was difficult to know when the perturbation had been initiated in relation to the Vicon data. Shih tried attaching markers to the treadmill belt, but the belt's vibrations were a problem. The solution Shih ultimately landed on was a DIY approach.

"Eventually, we got some reflective tape and attached that to the treadmill belt. We put two pieces on each belt, so we could easily tell the direction of movement and also the change of velocity, so that we could establish the initial reliability and validity of our protocol," says Shih.

With that technical problem solved, Shih initially worked with young adults and elderly subjects with no mobility impairments to test her protocols. Once it had been established that the protocol would provoke different responses in each population, Shih was able to move on to testing individuals with a below-the-knee amputation on one of their lower limbs.

"We put them on the treadmill for two main purposes," Shih says. "The first one is we wanted to see if they responded differently to a tripping perturbation delivered to their prosthetic side versus their non-prosthetic side. Then we're trying to see what intervention we can make to change their recovery responses."

SURPRISING RESULTS

The results were a little unexpected. "The first surprise we found was among the healthy participants, comparing tripping with slipping. We assumed, based on the literature, that the trip recovery responses would be mostly across the sagittal plane. But if we deliver it unilaterally, that's actually not necessarily true, because we also have some rotation from their responses."

There were surprises in the lower limb amputee population, too. "Originally we thought that there would be two components that would influence their responses," explains Shih. "One is the perception of the perturbation. We thought that when the prosthesis got perturbed, they might perceive and respond to the perturbation much more slowly than on the other side because of the lack of sensory organs.

"Then there's another component, and that's the motor one. After they detected the perturbation, how fast could they respond? How quickly can they complete and clear their responses?

"Surprisingly, we found that the detection component is not that different from side to side. Perhaps that's related to the protocol, and we might have put a pretty brutal protocol in place so that the perturbation is quite big, making it easy for them to detect.

"But from what we can see, that side-to-side difference in their responses is mainly down to the motor component."

The finding could have implications for any training programs that come out of the research. "This is just our initial thought, but perhaps for the intervention the key component to determine whether their trip recovery is successful or not is whether they have to use their prosthetic to make the movement or not."

In the future, Shih would like to extend the research by looking at different populations, studying different pathologies to discover what different mechanisms might be at play in their responses. She would also like to change the triggering criteria, as some research has already suggested that perturbing a subject's walk at a different phase of movement might yield different results.

Looking further ahead, Shih hopes that one day she might be able to combine the accuracy of an optical Vicon system with real-time analytics for patients. "I do see some potential if the processing could be fast enough for us to deliver some real-time feedback to the person who's doing the movement," she says, "so that it could be not only an assessment tool, but also an intervention, or it could be used directly in a basic training paradigm."

TONAL'S VICON SYSTEM UNDERPINS THE SMART GYM REVOLUTION

MOTION CAPTURE PROVIDES THE GROUND TRUTH FOR STRENGTH TRAINING ANALYSIS AT HOME

"You use wearables to look at how people run in the real world, but we use Tonal to look at how people strength train in the real world," explains Lauren Benson, Senior Manager, Research, at Tonal.

Lauren Benson, Senior Manager, Research, at Tonal

Tonal has created a smart home workout system that combines comprehensive analytics with virtual coaching and a compact form factor to provide resistance across a wide range of strength-based exercises.

The system, which replaces traditional weight training equipment with two arms, two handles and some sophisticated motors and cables, has gained attention (and investment) from the likes of Serena Williams and LeBron James.

Increasingly, everything Tonal does is underpinned by sports science that's informed by motion analysis performed using Tonal's Vicon system.

INTELLIGENT PERFORMANCE IMPROVEMENT

Prior to her time at Tonal, Benson earned her doctorate from the University of Wisconsin-Milwaukee and studied running and wearables as a Postdoctoral Fellow at the University of Calgary before a stint monitoring athletes for the United States Olympic & Paralympic Committee. She was interested in performance-monitoring wearables, but remained skeptical.

"I was always curious about companies that produce wearables designed to help human performance for the public," she says. "But I was so cautious, because I didn't know whether the companies actually invested in the intelligence that is needed for their products.

"I never felt comfortable moving into the commercial space until Tonal came along and I saw their commitment to a full performance innovation department. And as soon as I started, I was talking to Vicon about how to buy a full system."

Benson is part of the Tonal Strength Institute, which is essentially the sports science support unit for the company. It boasts personal trainers, Olympic coaches and even the former head of the US's national ski and snowboard team on its staff. Benson brings a background in biomechanics to the team, and her role with Tonal is focused on understanding how people move while using the system; testing the equipment itself and bridging the gap between the small, high-fidelity data samples that her team collects in the lab and the mass of data gathered from home users.

It was the breadth of the Vicon ecosystem that made it the right choice for Tonal. "I like the Vicon interface: that's great," Benson says. "But what I think really helped with us choosing Vicon was the ability to have the marker-based cameras, the markerless functionality and multiple ways of capturing with the IMUs, all in one integration."

The system is also integrated with Delsys EMG technology and AMTI force plates, as well as Futek load cells on the lab's Tonal units' cables.

An additional perk for Benson is the buy-in that the system enables her to get from her subjects.

"We have a group here that we call Employees as Athletes, and that's who we tap into to run tests. Honestly, the way that I get a lot of people in is I'll post a video of someone with the markers on and the bones overlaid on their video, and they see that and say, 'Oh, that's so cool! Can you make a video of me doing that?'"

Tonal's system comprises 12 Vantage cameras, eight Vue cameras, 14 IMUs and markerless integration. The system provides the ground truth against which Tonal's data is measured.

AN EXTERNAL VIEW

"We wanted motion capture because we want to know what users are doing," says Benson. The company can capture a range of user data out in the wild, but needs its Vicon system to validate its interpretation of that data.

Tonal's form feedback is based on sensors on the cables that track the symmetry, balance, smoothness, the pace of a user's movement and, most recently, Tonal's new phone-based Smart View feature.

"We know how the arms are positioned and so on, and we are able to give some level of form feedback with just that information," says Benson. With Smart View, users can also set up their phones to record themselves performing exercises and receive automated feedback from Tonal's algorithms, adding another layer of depth to Tonal's form feedback. It's a feature that's made possible thanks to the company's Vicon system.

"Without having some kind of a ground truth to know what a body position looks like when someone's doing a particular movement on Tonal, it's really difficult to fully understand what's happening. Being able to use the gold standard to look at joint angles is really helpful for that.

"And we're looking at the velocity of movements, incorporating those velocity-based measures into our understanding of how people are doing different movements."

So the motion capture and other lab data are used in conjunction with the much larger dataset from Tonal units out in the wild to build a picture of how people are using the device.

"People at Tonal have already known that they wanted to create certain new products or features, but they couldn't do it until we had the Vicon system."

The system is also used to provide external validation of Tonal's resistance profile and the speed and acceleration of the handles, confirming the data from the machine's own motors and cable tension.

"Because I've modeled the Tonal arms and the Tonal handles, and Tonal itself tracks the trajectory of the cable, I can sync those signals together," explains Benson. "And then when Tonal counts the reps, we know exactly what it looks like in the Vicon model. That's really giving us a lot of information back to Tonal. So we can say, at this exact point in the repetition, on Tonal we know in three dimensions, with all the positions and forces, what's happening with the user."

UNLOCKING POTENTIAL

This deeper understanding of the interaction between machine and user is translating into new advances for Tonal.

"This lab is going to help us do the things that we've always wanted to do," says Benson. "People at Tonal have already known that they wanted to create certain new products or features, but they couldn't do it until we had the Vicon system and someone who could use it to gain this understanding. I've had so many people come to me and say, 'I'm so glad you're building this, we can finally look at this particular thing, we can finally create this feature.'"

The system isn't just offering a framework for realizing pre-existing ideas. Benson's team is also laying the groundwork for applications that no-one has thought of yet.

"Every time we have someone coming through the lab, we switch on the load cells and the force plates, and we marker up if we need to, or we put the markerless cameras on, so we're getting joint angles all the time," she says. "So we have that information so that if we're ever interested in, say, what the forces are in the shoulder during bench press, we've got a full recording of 50 sets of bench press, and so we can start to piece that together."

KNOWLEDGE SHARING

Benson praises Vicon customer support for helping her to make her plans a reality. "They're awesome," she says. "They came out and did our setup and I've been on multiple calls with them since then asking questions. Or they'll say: 'Here, try this script. It's not official, but just give it a try and let me know what you think.' I think that's awesome. I can tell that Vicon is always trying to improve and come up with new things. And the willingness that they have to work with their users is great. So I've been super excited to work with them, and every time I'm on a call with them it's really exciting and fun."

That future-facing approach is a fit with the Tonal Strength Institute's culture.

"We don't want to just be something that hangs on the wall that you pull on every now and then," says Benson. "We want it to actually have a strong human performance value. And to do that, we have to do it right. So we're just going to keep collecting, growing our database of movements on Tonal with full motion capture data, and using that for future questions."

SNOOP DOGG, LARRY DAVID, NFTs, AND AN UNLIKELY METAVERSE PROJECT

ASTRO PROJECT IS AN INDIE START-UP TAKING BIG SWINGS

James DeFina, Futurist Director and Filmmaker, at Astro Project

The Crip Ya Enthusiasm music video sounds improbable: a gamified, Web3 metaverse project built in a video games engine, starring Snoop Dogg blended with Larry David, featuring appearances from long-dead rappers Tupac Shakur and The Notorious B.I.G., all wrapped around an NFT component and powered by motion capture.

While the video is high profile and very complex, it's not the product of a large studio or well established VFX house. It's the work of Astro Project, a small start-up formed less than a year ago by a pair of founders who had never used motion capture before.

The studio is the brainchild of director James DeFina and YouTuber Jesse Wellens. The pair began collaborating several years ago, but it was when they became interested in Web3, the metaverse and digital production, that their partnership coalesced into a company.

Wellens wanted to do a metaverse project using animation. He showed DeFina the videos Matt Workman made for his Cinematography Database channel documenting his journey learning to use a Vicon system, and DeFina quickly saw the possibilities.

"I thought, that's amazing. It's the future. And basically, we were like, OK, let's start a company doing all this," says DeFina.

From there, investing in a Vicon system was the obvious choice. "I saw Matt's work with Vicon and I did a lot of research, and I liked how the stuff looked. I wanted to recreate that."

James' and Jesse's learning curve got a lot steeper when one of the most famous rappers in the world got in touch.

"Snoop Dogg hit up Jesse, and said 'Hey, I want you guys to do this music video for my next song.' And he wanted us to combine him with Larry David to create a 'Larry Dogg' character."

We didn't really even know the full scope of what we were getting into. We just said, let's go for it," says DeFina. "In a month it really just happened. And suddenly we were asking, okay, how much is a Vicon system? Where do we get it?"

At the time, however, supply chain issues meant there was a six month wait for the system they wanted to buy, and they needed to begin work almost immediately. Jeffrey Ovadya, Director of Sales & Marketing for Vicon, stepped in. "He was really helpful. He was even saying, you can borrow a system until yours is ready," says DeFina.

James got set up with 16 Vero 2.2 cameras, a Lock Studio and a video camera, all running through Vicon's Shōgun VFX software into Unreal Engine. Procuring a system was only half the battle, though. James had to learn motion capture very quickly. "The training was great, which was awesome. Everybody at Vicon has been very helpful. Because I probably hit them up like a million times about everything, because I was just learning everything so fast."

KNOWLEDGE SHARING

An unusual aspect of the project was how DeFina and Wellens found a way to pay that learning forward using NFTs. The first wave of NFTs were predominantly digital collectibles, but those being offered to Astro Project's backers also have a much more practical function.

"We created digital keys that would give people access to download some of the environments, and then some of the characters and some of the mocap data," says DeFina. "We're letting people download the data and teaching them how we're doing everything, so they can learn and practice on an actual project. They might not have a motion capture system, but they can use some of our mocap data from the Vicon system and then see how it's done in Unreal Engine.

"Nobody else is really doing that."

The form that the keys take is a tongue-in-cheek nod to digital culture – a virtual donut. "We decided to do these digital donuts because in 3D design, one of the first things people ever learn is how to make donuts in Blender," says DeFina.

ONE DAY TO SHOOT

While Astro Projects is inviting fans to learn from its work, DeFina is well aware that he's still a relative beginner himself. Capturing Snoop Dogg, in particular, was a learning experience. "The day of the shoot, I was on a zoom call with people from Vicon and a couple of our other technology partners, and we're all trying to figure out how they can work together simultaneously. It was one of our first shoots ever, and we had Snoop coming in for one day, and we had to just go for it," he says.

Fortunately, the creative direction only required a light touch. "We kind of let him do his thing. Obviously the character's half Snoop, half Larry David. Since he was looking like Larry David a lot, we kind of just wanted him to move like Snoop Dogg, right? Like his mannerisms, his dancing and all that, so that people know it's him."

And for all the venture's challenges, it was a success. "When we showed him the final project, he hugged us. He loved it. He definitely wants to do more."

A MORE DECENTRALIZED METAVERSE

Now that DeFina and Jesse have their system set up and understand how to use it, they want to experiment with further boundary-pushing content.

"One thing we really want to do is make hyper-realistic animated content with custom Epic metahumans and Unreal Engine," says DeFina. "But then, we also want to do minigame experiences that can go along with a piece of content, like AAA minigames."

James is also interested in using his Vicon system and Unreal Engine not for filming things he couldn't shoot in real life, but simply for the sake of convenience. "It's almost a one-to-one comparison, right? For example, with a virtual set I can light something just how I light it in real life without needing this whole crew."

James and Jesse have also been experimenting with VTubing and creating a virtual podcast, streaming motion-captured characters in real time. "We've been testing some new tech that could allow us to do live streaming in two different locations at the same time with two characters. So, we can have somebody in our studio, and then somebody who's physically in Canada, at the same time in the same virtual environment," says DeFina.

Looking ahead, DeFina sees a future for all this metaverse content that isn't only about the big operators such as Epic, Meta and Roblox.

"It's always been a thing with these big gaming companies: they were the only ones doing it," he says. "And I think that now, more and more creators are going to get into it. There's going to be a lot of smaller studios and startups using motion capture animation for the metaverse. It also leads to a lot more collaboration between people. And as technology gets better and better, things are going to become easier for people. There are a lot of people building solutions inside of Unreal Engine to make everything simpler. I think it's just going to get easier and easier."

For more on independent creators using motion capture to push the boundaries of digital culture, see our feature on Matt Workman and VTubing on page 34.

BUILDING A BETTER PROSTHETIC FOOT

SOFT ROBOTICS OFFERS NEW POSSIBILITIES TO AMPUTEES

The design of prosthetic limbs has made incredible progress in the last few decades but, according to IIT SoftBots lab, two crucial elements have significant scope for improvement: the hand and the foot.

Anna Pace, Biomedical Engineer and Postdoctoral Researcher, Soft Robotics for Human Cooperation and Rehabilitation laboratory (Istituto Italiano di Tecnologia, Genoa, Italy).

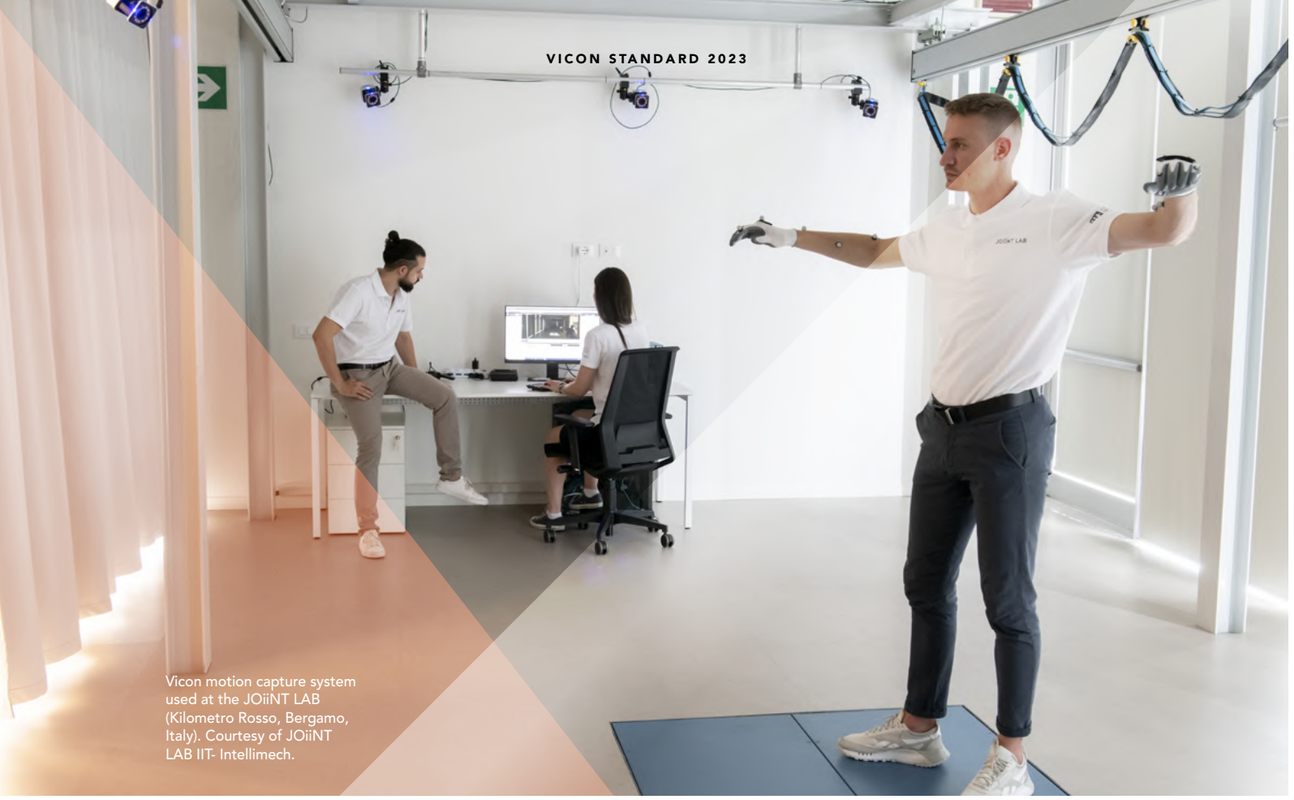
"The human foot is a complex system in which bones, muscles, ligaments and tendons work together, adapting the whole structure to all kinds of terrains and tasks, ensuring bodyweight support, impact absorption and user's stability during daily activities. Despite all the efforts made in the last decades to improve the design of prosthetic feet and, thus, the quality of life of people with a lower-limb amputation, commercial prostheses can withstand the body weight while still lacking the flexibility and elasticity required for a stable ground adaptation," explains Anna Pace, a Biomedical Engineer and Postdoctoral Researcher at the Soft Robotics for Human Cooperation and Rehabilitation laboratory (Istituto Italiano di Tecnologia, Genoa, Italy), led by Professor Antonio Bicchi.

"The existing benchmark for prosthetic feet is represented by feet with a stiff and flat sole, which obviously hinders ground adaptation," she says. "Therefore, the prosthetic user's stability is jeopardized when there are uneven terrains or obstacles, leading to possible falls that could be lethal for the user."

While some manufacturers of prosthetic feet have incorporated features such as a split toe or actuators in the ankle into their designs in a bid to combat the problem, they're still paired with a flat, rigid sole and come up short compared to the subtle reactive adjustments a human foot is able to make.

A BIOINSPIRED DESIGN

The SoftBots lab, with the help of funding from the 'Natural BionicS' ERC Synergy project, is working on another approach – soft robotic prostheses for an enhanced interaction with the environment. The lab already has a working soft prosthetic hand that can adapt its motion to task requirements and object shapes, and now Pace and the SoftBots team are working on a foot that is capable of adapting to different terrains in a manner that mirrors human lower limbs.



Vicon motion capture system used at the JOiiNT LAB (Kilometro Rosso, Bergamo, Italy). Courtesy of JOiiNT LAB IIT- Intellimech.

"The prosthetic user will be able to fully control the prosthesis as well as to receive sensory feedback from it as a real part of the body."

"Our robotic SoftFoot shows an anthropomorphic and intrinsically adaptive design with a longitudinal arch made of two rigid components (one anterior and one posterior) connected to each other at the ankle joint; a heel component; and a foot sole made of five elastic and flexible structures," says Pace.

"This peculiar design allows the foot to vary its shape and stiffness depending on the load acting on it and the ground profile, leading to an overall improvement of the user's stability on uneven grounds," she goes on.

A version of the SoftFoot has already been tested on HRP-4, a humanoid robot, and the results showed an improved ability to navigate obstacles when compared to a rigid foot. Now, the team is working on a prosthetic version of the foot for people with a lower-limb amputation.

The ambitious aim of the ongoing Natural BionicS project – in collaboration with Professor Oskar Aszmann (Medical University of Vienna, Austria), Professor Dario Farina (Imperial College London, UK), and their research groups – is the development of upper- and lower-limb prostheses directly interfaced with the central nervous system.

"The prosthetic user will be able to fully control the prosthesis as well as receive sensory feedback from it as a real part of the body. That's possible thanks to bio-hubs that are surgically created at the residual limb, allowing a bidirectional flow of information between the prosthesis and the central nervous system," explains Pace.

MOTION ANALYSIS IS FUNDAMENTAL TO THE DESIGN

Pace and the SoftBots team are using a Vicon system equipped with 12 Vero cameras and two Vue cameras at the Bergamo JOiiNT LAB, a technology transfer facility established by IIT and the Intellimech industry consortium, to test the foot.

The system is used for teleoperation of robots and for testing the ergonomics of human/robot interaction, and it has been crucial for performing gait analysis. "The system has been fundamental in running a preliminary experimental session whose results will drive the design of the new prosthetic soft foot," explains Pace.

"Specifically, we recruited an able-bodied subject and a prosthetic user with a lower-limb amputation, and asked them to perform some daily-life tasks in our lab, including walking on ground with obstacles, while using different commercial prosthetic feet," she says, adding that, "The able-bodied subject could walk with the prostheses thanks to some boots and ad hoc adapters."

"The motion capture system was used to record the gait and analyze the biomechanics of the two subjects," Pace says. "We got the subjects' kinematics by recording the 3D motion of the reflective markers placed on their skin, as well as the dynamics, thanks to the two force plates embedded in the ground and an additional sensor synchronized with the rest of the Vicon data."

The team is currently processing the data and plans to incorporate it into the design process for the foot soon.

"Our experience with the Vicon mocap system has been great so far!" Pace says. A number of features made it a strong fit for the SoftFoot project: "The possibility of synchronizing 3D marker trajectories with other data sources through the Vicon Lock Lab; the option to use a MATLAB package for post-processing in the Vicon Nexus software; the ability to record trials in which the sensor is considered as a second subject, so that its 3D motion can be captured and its orientation in each frame obtained by streaming the trial data in MATLAB; the option to display an overlay of the video from the Vue cameras with the 3D skeleton from the Vero cameras.

"Moreover, the creation of a custom skeleton template in Nexus was straightforward, the Nexus auto-labeling function worked well with the custom protocol, and the gap-filling function was very useful."

There's still plenty more motion analysis in the pipeline, too. "Motion capture systems represent the gold standard for an accurate gait assessment, so we'll use our Vicon system for evaluating and comparing the performance of the new prosthetic SoftFoot with that of commercial prosthetic feet, and for analyzing the overall prosthetic user's biomechanics while performing activities of daily living with different prosthetic feet," says Pace.

"Quantifying the prosthesis and user's performance through motion capture will help us to further optimize the design if necessary. We will also plan to assess the prosthetic SoftFoot performance with a larger number of prosthetic users," Pace concludes.

While it may be a while before the SoftFoot is ready for use by amputees, Pace sees the SoftBots line of research into soft robotics as extremely promising: "It can truly exceed the performance of prosthetic feet currently on the market," she says.

"The creation of a custom skeleton template in Nexus was straightforward, the Nexus auto-labeling function worked well with the custom protocol, and the gap-filling function was very useful."

MOTION CAPTURE

A KEY PLAYMAKER IN AN AI-POWERED REHAB LANDSCAPE

Investing in superior data collection is key to unlocking the full potential of analytics. Vicon's signature is precisely to provide rich and reliable kinematic data to enable accurate insights which will, in turn, drive informed decisions and improved outcomes.

Pablo Callejo, Strategic Business Development Director at Vicon

Jenna had been a skillful soccer player since she was little, a one-of-a-kind midfielder with outstanding stamina, work rate, and versatility. That's why nobody was surprised to learn that she had been recruited to play for her dream team. The shock came when she suffered a devastating stress fracture in her knee during pre-season training. There's never a good time for injuries, but why did that happen to her, when she had always been so fit? And why then, when she had not yet played a single official game? Was her professional sports career over? With these gloomy thoughts she started her treatment and rehabilitation process: an arguably long journey with an uncertain outcome.

Luckily for her, recent advances in rehabilitation programs had successfully implemented AI-powered solutions that delivered extremely encouraging results: studies demonstrated a 31% shorter time in return-to-play and a 100% recovery of knee joint function in young patients like her. This AI-enabled application would tailor physiotherapy exercises for her and ramp up training programs as the knee improved. And what she thought was magic did work on her! Jenna was back in the field in only a few months' time, feeling her knee as strong as ever.

Our friend Jenna is a fictional character, but her injury is one of many real risks lurking for elite athletes of all ages and disciplines, and just a tiny sample of the various musculoskeletal conditions that in one way or another, sooner or later, will likely affect many of us. According to the World Health Organization (WHO), musculoskeletal disorders (MSD) are the leading cause of pain and disability worldwide, affecting over 1.7 billion people. For this reason, an initiative called 'Rehabilitation 2030' was launched in 2017 "to draw attention to the profound unmet need for rehabilitation worldwide, and to highlight the importance of strengthening rehabilitation in health systems." Vicon, IMeasureU and Contemplas are proud to contribute to this initiative through a myriad of users of our Life Sciences solutions. For instance, athletes can benefit from using our wearable technology by having their lower limbs load-monitored with IMU Step.

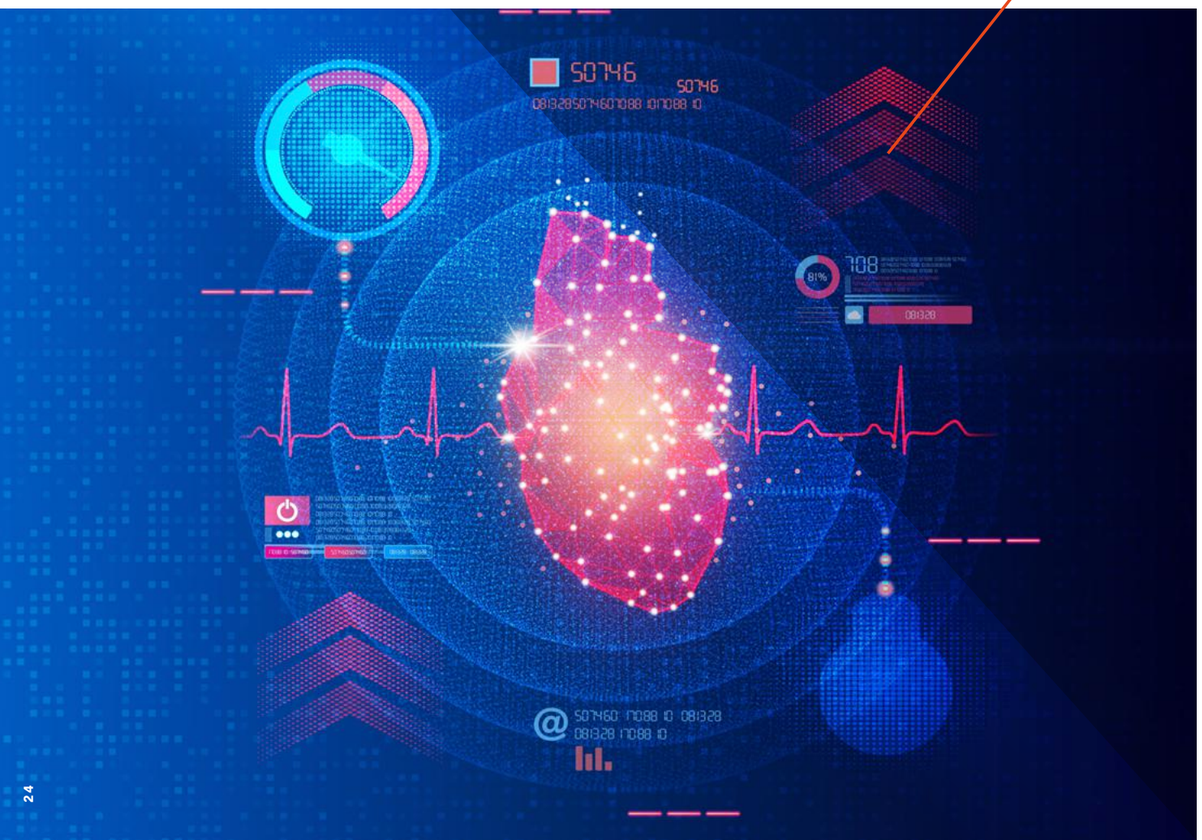
The use of Machine Learning (ML) methods in rehabilitation programs is also real, and indeed a powerful application of mathematical-statistical machine learning techniques. And is there a more noble and humane use for these revolutionary solutions than empowering healthcare and wellbeing?

The integration of advanced analytics, machine learning, and other artificial intelligence techniques presents numerous opportunities to generate actionable insights to drive better decisions, improve patient outcomes, respond to real-time situations, and ultimately save lives.

Artificial Intelligence has sometimes been compared to a GPS. Just as a navigation system helps guide a driver to their destination by providing real-time information on traffic, road closures and the best route to take, an AI-enabled rehabilitation programme helps guide an injured athlete through the rehabilitation process by providing real-time feedback on their movements and techniques. The GPS system will adjust the route if there is a traffic jam and will always look for the most efficient way to reach the destination. An AI-enabled rehabilitation programme will also adjust the rehabilitation plan if the athlete is not progressing as expected and will always look for the most efficient way to get the athlete back to their sport. Just as the GPS helps the driver reach the destination in the shortest time possible, the rehabilitation programme helps the athlete recover in the shortest time possible and achieve their goals. Furthermore, the GPS system is constantly updating and learning from new data, and similarly, the rehabilitation programme will also be constantly learning from the data it collects, to improve the outcomes for the next person who uses the programme.

This is no longer science fiction – it is happening, and it is not the result of 'magic', as Jenna thought. These solutions are built on several key components. Firstly, 'sensors' (IMUs, cameras and other devices) are used to collect data on a 'patient's' movements, strength, and more physical variables. This data is then analyzed, using advanced algorithms and machine learning techniques, to identify patterns, trends, and insights that inform rehabilitation planning and progress for new subjects. Predictive modeling is also used to estimate future outcomes and make predictions about patient rehabilitation progress, and this is precisely the edge of ML over traditional statistical methods. ML methods can provide decision support to rehabilitation specialists

"Just as the GPS helps the driver reach the destination in the shortest time possible, the AI-enabled rehabilitation programme helps the athlete recover in the shortest time possible and achieve their goals."



by recommending interventions, exercises, or treatments based on the analyzed data. Additionally, it can track and monitor a 'patient's' progress over time and provide feedback to both the patient and the rehabilitation specialist...Finally, there can be a customization to each patient's individual needs and goals. These building blocks work together to improve rehabilitation outcomes, increase efficiency, and provide a more patient-centered experience.

At Vicon, we are very aware of the great responsibility, and opportunity, as we observe the advancement of analytics based on motion capture data – whether these analytics are descriptive ('characterize the past'), predictive ('project future trends') or prescriptive ('suggest a course of action'). The better the input data is, the more accurate and meaningful the results of the analytics will be. Richness and quality of data are essential. Healthcare, research, sports performance and other fields are more reliant than ever on data to drive decision-making. Whether it is lab-based motion tracking, in-the-wild tracking, or a combination of both, our ultimate mission remains the same: providing the best tools, which will always be the result of careful development, thorough quality testing and consistent validation. And, wherever possible, we work hand in hand with complementary technologies and partners to 'capture the world' as accurately and comprehensively as possible. That's Vicon's signature.

"At Vicon we are very aware of the great responsibility, and opportunity, as we observe the advancement of analytics based on motion capture data"

TURNING THE LINK BETWEEN MOTION AND PERCEPTION ON ITS HEAD

UW Photo Service

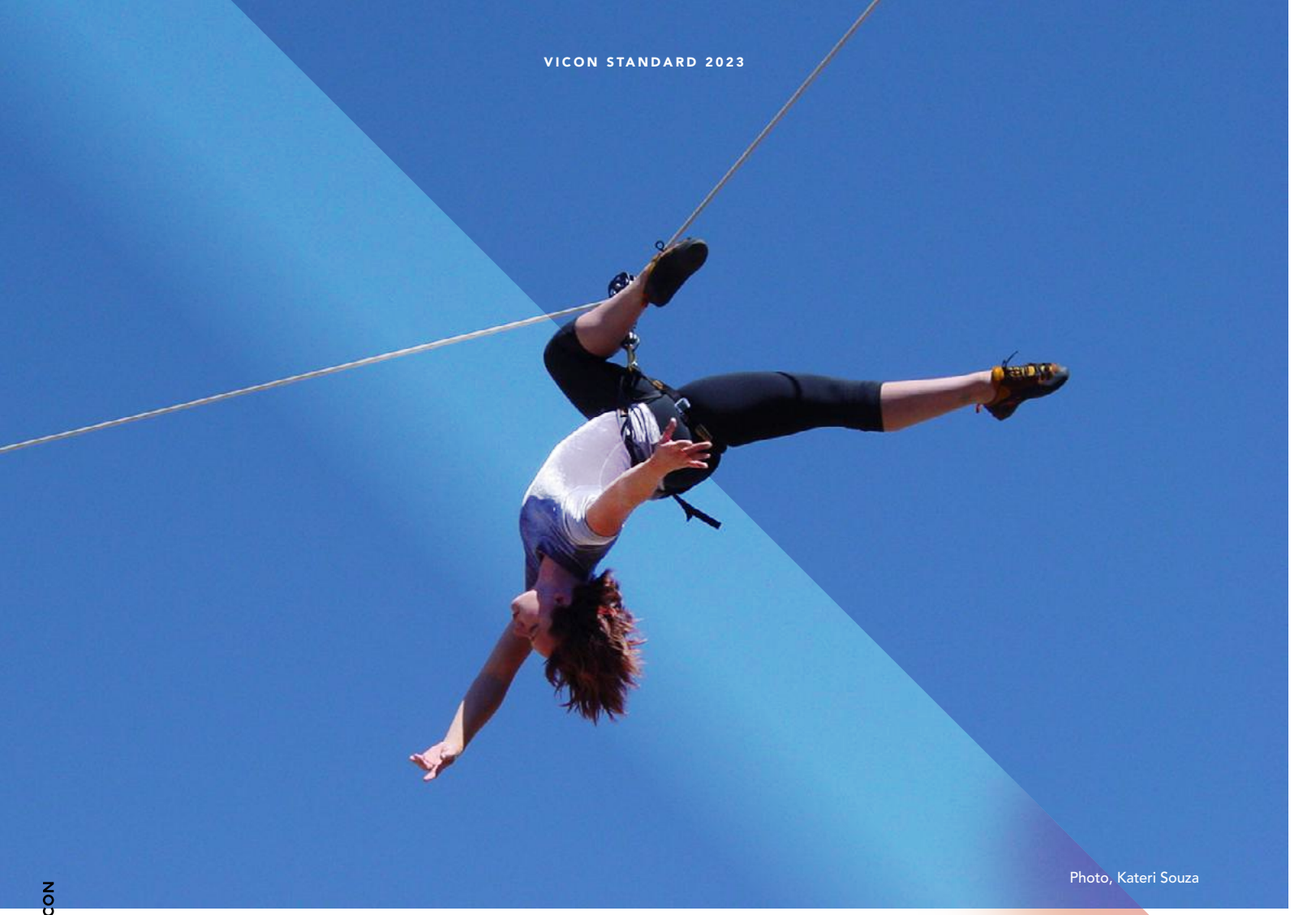
VERTICAL DANCE STUDY SHOWS LINK BETWEEN PERCEPTION AND ACTION EXPERIENCE

Dr. Xiaoye Michael Wang, vision scientist, VR researcher and postdoctoral fellow from the University of Toronto's Faculty of Kinesiology

Dr. Margaret Wilson Department Chair, Professor, 20th Century Dance History - Modern Dance - Kinesiology for Dance - Vertical Dance -Pilates

In the videos produced for The Vertical Dance Project a series of dots shift hypnotically, conjuring something very recognizable from incredibly little visual information: human movement. The project, a collaboration between researchers at the universities of Toronto, Wyoming and Shanghai, has used a Vicon system to yield powerful insights into human perception that could have widespread impact on the creation of digital humans.

"To talk about the significance of this project we need to first talk about the work by Gunnar Johansson in the 1970s," explains Dr. Xiaoye Michael Wang, a postdoctoral fellow from the University of Toronto's Faculty of Kinesiology. "He attached highly reflective markers onto people's major joints, and then used high intensity spotlights so that he only captured the markers, and then he used the data to show that people can actually see meaning in movements, just based on the motion of a few dots. If they were static, people wouldn't be able to see anything. Once they start moving, people can see it."



Photo, Kateri Souza

Since Johansson's work in the 70s, other researchers have discovered that inverting biological motion is very disruptive to people's ability to understand these movements. With The Vertical Dance Project, Wang and his colleagues have probed the phenomenon deeper, seeking to better understand the mechanism behind it.

The specific format of the study was the result of serendipity. Dr. Qin "Arthur" Zhu, Division of Kinesiology and Health, University of Wyoming, attended a performance staged by his university's Department of Theater and Dance. The production involved dancers tethered to a cliff face performing movements upside down and horizontally, using the vertical cliff face as if it were a floor.

"When I talked to the dancers," says Zhu, "I asked if they had a hard time interpreting the inverted motion of their dancing partners, and they said no, we can read and anticipate their movements well. That sparked the idea. Maybe because they have the experience of inverted movement through vertical dance, their perception is unique and allows them to overcome the inversion effect."

Zhu and Wang collaborated with Dr. Margaret Wilson, a professor from the university's Department of Theater and Dance, to capture 10 pairs of dance movements that are spatially congruent or incongruent as point-light displays using eight Vicon Bonita cameras and Nexus software. Each movement was performed both on the ground and in the air, with the display of half the movements inverted to test the perception of typical dancers, vertical dancers and non-dancers on whether the movements had been inverted.

A POWERFUL LEGACY

The team were pleased with the execution of the study. "What's great about the Vicon system is that the accuracy of the data and the sampling frequency is really good, even with the legacy camera," says Wang.

"Another way to see how accurate the Vicon system is, is that using the data we are able to replicate all the movements smoothly and accurately enough that dancers all understand that this is a human movement," adds Zhu.

Indeed, the only notable challenge in the data collection came from just how well the cameras performed.

"What was challenging in the original data collection was the fact that the body hanging on the rope has a vibration or an oscillation," says Wilson. "We finally came up with a tether to try to hold them still. But in spite of that, as you look at the data, it's sensitive enough that you can see that gentle vibration in the movement if you understand that that's a possibility.

"It's so subtle that if you don't think it's a possibility, it's not there. But I often wonder if that was a cue for the vertical dancers because they know there's no way to stop your body. So what's interesting about the motion recorded by the Vicon system is that you can see the oscillation in spite of our best efforts to try to limit it."

The study found that vertical dancers were much better at recognizing the inverted movements than the other subjects, suggesting that their unique experience with observing and performing inverted movements does, indeed, enable observers to use dynamic information to identify artificial inversion of motion.

"What is consistent is the direction of gravity," Wang explains. "We take gravity for granted, but if you perform a movement upright versus upside down, the direction of gravity can actually specify how we are supposed to move. That is the key, because vertical dancers have more experience in seeing and performing these movements, and therefore they're probably more familiar with the interaction between the ance movements and the direction of gravity."

The team has plans for a further study that would use a more comprehensive marker set to derive a subject's center of mass. They would then perturb it to see at which point vertical dance perception is broken.

"We could use this to further elucidate the mechanism behind biological motion perception. We also plan to integrate those with eye-tracking, to see where people are looking and what kind of information they use," Wang says.

BREAKING OUT OF ACADEMIA

Wilson is excited by the implications of the study for her practice as a dance teacher. "What's so intriguing is understanding what information we use to make sense of our world, or of movement. When we see a vertical dance performance, we see the whole body and it's an unfamiliar experience to people who've never hung from a rope. When people have vertical dance experience, they have experienced the pressure in their heads and the pressure on their hips, so they can appreciate the movement.

"But I think more than that, as a teacher I'm considering, 'what information am I using to make a judgment on aesthetics? What information am I using to look at injury risk? What information am I using to try to help this person master the skill in a more efficient way?"

Zhu sees applications for this research both in situations in which people have to work upside down, such as on construction sites, and in the tech world. While the life sciences and the world of video games, virtual reality and the metaverse might appear to be poles apart, he sees this research as something that could help developers bridge the uncanny valley. "When you see someone operating an avatar you can actually really tell whether this is animated by a person or animated by a computer in terms of the movement dynamics," he says.

"And therefore I think what we're doing here is we're actually setting up the foundations in terms of what makes it authentic purely based on the movement. We're not talking about how the avatar looks, because it can be a lion or an elf, but in terms of how it moves, and how, based on this piece of information, we can say this is a person, or this is not a person. I think what we're doing here can offer a bit of insight into this area, and that can hopefully help people who are doing advanced technological R&D to incorporate that into their design of avatars."

Qin "Arthur" Zhu, Ph.D. Professor, Motor Learning and Control / Human Perception and Action

While the Vertical Dance Project has a very focused field of study, its applications are potentially broad. As Wilson puts it: "We need to be able to look across the room and see the human coming at us, but then also the tiger. We use very little information to read that. Even with the light point display, there are things that we as humans pick out, in terms of shoulder width or hip width or our physical stance, and so I think these experiments are giving us an understanding of how we filter a lot of information."

For more on The Vertical Dance Project, see the team's Nature article.

UW Photo Service

IS MOTION ANALYSIS BEING UNDER-UTILIZED IN UPPER LIMB ANALYSIS?

STUDY UNCOVERS IMBALANCE IN BIOMECHANICS RESEARCH

The core work of Fraser Philp, a clinical academic based at the University of Liverpool, is on upper limb dislocations in children and a rare neuromuscular disease known as FSHD. While his use of motion analysis for these studies is quite focused, it has led him to a much wider inquiry into the state of motion capture in upper-limb assessment, and it could have a broad impact on the world of biomechanics.

Fraser Philp, Clinical Physiotherapist and Lecturer in Physiotherapy and Rehabilitation Science. University of Liverpool

"I started a process of looking at whether we could identify models that are appropriate for the upper limb for my work," says Fraser. "I found that motion analysis of the lower limb is frequently used for clinical and surgical decision making, and there was a clear link between the type of movement that they were assessing and any therapy or surgical outcomes, and then specifically what biomechanical data they needed to get out of it.

"But as I started to get into more upper-limb studies, I was quite surprised. The upper limb is more complex in some ways, but we aren't using equivalent technology to help us to answer questions about it in the same way."

ASSESSING THE STATE OF THE ART

In a bid to shed some light on the issue Fraser undertook a survey of labs using motion analysis for biomechanical research. Beginning with labs contacted through the Clinical Movement Analysis Society of UK and Ireland (CMAS), then incorporating a number of international facilities, Fraser gathered 55 responses.

"The main finding is that practice is quite variable," says Fraser. 75 percent of the respondents performed some sort of upper-limb assessment, with 44 percent doing so for clinical purposes. However, only 33 percent used 3D movement analysis. Furthermore, even among the labs performing motion capture, there were differences in practice between facilities accredited by the Clinical Movement Analysis Society of the UK and Ireland and other international societies and affiliate laboratories. Namely, in the UK and Ireland there was a more clinical focus compared to a research-focused approach overseas.

Barriers to upper-limb analysis identified by the study include funding, clinical need, and the availability of standard reference tasks and protocols. Beneath these factors, however, there may be other issues contributing to how 3D motion analysis is used by clinicians and researchers, largely stemming from how complex the upper limb is and the multiple ways we can perform movements and tasks with our arms.

Chief among these issues is the fact that walking enables people to meet most of the functional requirements of daily life, says Fraser. "If you need to do anything in life, you pretty much need to walk and there are only so many ways you can do that," says Fraser. Upper-limb issues, while debilitating, are less likely to affect a patient's ability to function in everyday life in quite such a profound way. Again, this is because we can complete upper-limb tasks in multiple ways whereas the options for the lower limb are more limited.

"Where upper-limb assessment was used in a clinical practice, it was often the case that these labs had a group of patients and they had motion capture technology, and they were saying, well, we've got these resources, what else can we do with them?" In other words, the upper-limb assessments that the labs were performing were an extension to the care they were already providing for patients on the lower limb. And many labs are set up primarily for gait. "Then when you start doing more arm- and finger-analysis, you're moving to a different setup," Fraser adds.

"And the more research-based labs were exploring more musculoskeletal, orthopedic conditions. It was more about understanding mechanisms, and trying to find something that can be translated into clinical practice later," Fraser adds.

STICKING WITH WHAT YOU KNOW

Adding to the challenges is the fact that upper-limb movement is simply more complex than that of the lower limb, something that was reflected in the early practice of biomechanical motion analysis. The impact of that can still be seen today.

"I think some of it is a case of researchers doing what we've always done," says Fraser. "When motion analysis started, walking was the activity we studied because it was a nice, repeatable reference task. It was comparable between people and it was less complex. Walking, to a degree, can be explained in a two-dimensional component, then 3D expanded our understanding of the other planes of motion.

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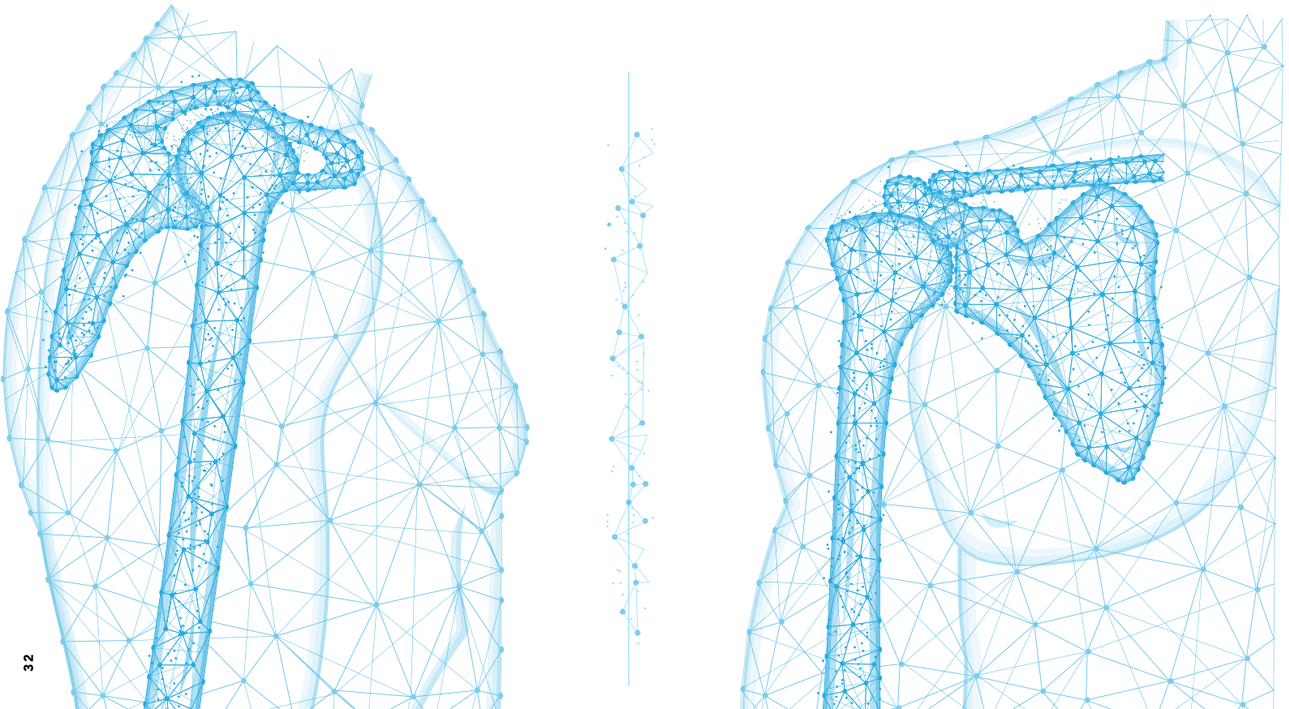
Then when you start doing more arm- and finger-analysis, you're moving to a different setup"



"But I think it's also because there's a canon – we know what to do, we know what marker sets to use, and the ease with which those practices can be expanded is quite helpful."

These different issues all feed into one straightforward, pragmatic concern. "I think that perceived clinical need and justification of cost, or business case, is probably the biggest factor," says Fraser. "If you're a surgeon wanting to do a procedure in the upper limb, you can do virtual surgery, but if you don't know that 3D motion analysis exists, or how you get someone to do it or to run that process, then you're less likely to want to use it."

IMPROVING PROCESSES FOR BETTER OUTCOMES

Ultimately, Fraser's goal for the study is simple: "Better clinical decision-making on the basis of improved measurement is probably the thing I'd like to see on this," he says.

"The whole process needs to be made a bit more streamlined. At the moment, if you want to look at the upper limb you've got to start building custom marker sets and custom models and working on the issues around the interpretation of that data.

"Some really good examples of practice and some workflows that other people can emulate would probably be the thing that would help. If there's a flagship example of practice, and it's executed well and the knowledge is out there and available, people can seek to emulate that activity. But what we found is that there's no really clear, well-defined, robust example for people to copy."

Fraser says that his study is already helping with that. "This research has made the issue visible. And as a result, we have a starting point." And so there have been some discussions that have happened off the back of Fraser and his team's paper. People are starting to look at expanding the use of this tech and develop a wider community of practice.

"There does seem to be lots of really good, exploratory work among Vicon users to find these answers so that it can be translated."

Fraser gives an example from his own experience. "We've worked closely with another lab in Leuven in the planning stages. Or there's the European Society for Movement Analysis in Children (ESMAC) – people were using their marker set and their model a little bit. So, there's this element of collective behavior."

Overall, Fraser is optimistic that more widespread and systematic upper-limb study is coming down the pipeline.

"I think it's an exciting and developing area, and on the basis of the study people are starting to look at some novel applications for upper-limb analysis – spinal cord injury, FSHD, shoulder instability, all those things are quite new," he says. "And there are other avenues where impairments are common – post-stroke, or muscle repairs and reconstructions. All those subjects are exciting areas of study."

For more on the barriers to upper-limb assessment using motion analysis, see the paper Fraser Philp, Robert Freeman and Caroline Stewart wrote on the subject, published by Science Direct.

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I think it's an exciting and developing area, and on the basis of the study people are starting to look at some novel applications for upper-limb analysis

VICON

GOING LIVE WITH METAHUMANS

OPTICAL TRACKING IS THE NEXT FRONTIER OF VTUBING

In August 2022 a new streamer debuted on Twitch: Kellogg's Tony the Tiger. Tony played the game Fall Guys while interacting with prominent streamers in real time as part of a collaboration between Kellogg's and Twitch's Brand Partnership team. No costume or make-up was involved – rather, the stream was made possible thanks to a live motion capture performance that was used to animate a digital Tony avatar.

Matt Workman, Developer and Content Creator

This wasn't the first time a digital avatar streamed in real time, but it was a very clear sign that 'VTubing' has reached the mainstream.

The trend has been growing for a while. Amazon says that last year VTubing content grew 467 percent year on year on Twitch, and in 2020 some 38 percent of YouTube's 300 most profitable channels were from VTubers.

On the technological side, VTubers are still finding their feet. At the low end, content creators can spend a few hundred dollars to get a rigged 2D avatar and a good quality webcam and they'll be able to stream a crudely animated character. In Japan, however, the most popular VTubers are already being produced by studios such as Polygon Pictures using motion capture hardware, and a number of English language VTubers are now turning to more powerful motion analysis solutions too.

THE NEXT LEVEL

Matt Workman is at the forefront of this trend, demonstrating how, with minimal previous experience, an individual streamer or DIY indie studio can produce realtime 3D content using a Vicon setup.

Workman's background is in developing 3D characters and environments in Unreal Engine. His app, Cine Tracer, is a real-time cinematography simulation used by filmmakers for storyboarding, and he's currently creating clothing for Epic's metahumans - the most advanced digital humans currently in the public sphere. That work wasn't the main driver for his interest in optical capture, though.

"The original interest with the Vicon system was VTubers," says Workman. "The biggest VTubers now are mostly 2D. They're live, they're producing

"It's cool to see mocap virtual avatars really starting to happen, because I think a lot of people tried and failed in the past."

content 24/7, they're getting the highest engagement on YouTube and some of the highest on TikTok. They're massive. Some of them want to move into 3D, but it has to all be live. But there's this whole learning process and naturally they start with what is easily accessible."

Often that means using inertial capture or the tracking hardware that comes with commercial virtual reality systems. "I was talking to a bunch of VTubers, and some of the higher-end ones were using inertial suits and whatnot, but the feeling was that for live streaming, inertial is a little unreliable." Between complications with battery life, connectivity problems and accuracy issues, many creators are in need of a more robust and reliable solution.

"So my thought was, what if you gave a high quality optical system to an indie VTuber?" says Workman. "How about matching high fidelity motion with one of Epic Games's high fidelity metahumans?"

A DIY APPROACH

Workman acquired 10 Vero cameras and set them up at home. "We weren't even sure if it was going to work," he says. "I have a drop ceiling and weird columns all over the place. We thought, 'we'll just see'.

"But on the first day I got results that looked good. It pretty much worked out of the gate. It's very robust. I set it up once and haven't adjusted it since, and it still gets the results I want, so I'm pretty happy with it."

Workman began publishing videos documenting his setup and learning process, using Shōgun and Unreal Engine to link his performances with Epic's metahumans in real time. The results have attracted hundreds of thousands of views and sparked significant interest among the VTubing community.

"I tell a lot of these people who are getting into high-end live VTubing, if you're using inertial suits, they have batteries in them that die," Workman says. "And you're relying on Wi-Fi, which is horrible. It's so unreliable in a live context. Whereas, it's so lo-fi to just put optical markers on your suit and start shooting with an optical system. You can jump in and it just works and you could run it for 12 hours. It's built for Nike and NASA to record crazy things, so by the time we get to entertainment it's just so robust."

PROOF OF CONCEPT

"Since we've proved that you could set this up at your house, more and more people have been looking at optical for high-end live, and for solo or small operations," says Workman. "It's cool to see mocap virtual avatars really starting to happen, because I think a lot of people tried and failed in the past.

"They think, 'Let's buy four [inertial] suits and have someone make us an avatar and we'll just make a music video.' And it turns out, if you've never done it and you don't have the right equipment, it's extremely difficult!

"With the Vicon systems though, you're not even necessarily going to need to clean up the mocap. If you're carefully filming the angles, you don't have to do anything.

"I think that since I put up the demos, people have realized that optical's the best thing for live."

That realization is starting to turn into action. "I've been talking to a couple of VTubers, and they have the budgets. It's just the learning curve that's holding them back, because if they're going to be 3D, they're going to use optical.

I think that eventually, if not very soon, all the major 3D VTubers are going to be running a Vicon system or some sort of stable optical, because it's live and they're just producing live 24/7. And I think that's going to be a pretty big category of views. The number of creators that are doing it is still small, even the 2D ones, but I do see that evolution."

NEXT-GEN CONTENT

Workman envisions a bigger role for motion capture in social content than just avatars talking to camera. One possibility is for the creation of licensed performances from musicians.

"Let's get these really nice 3D performances that everyone can use. We're starting to see that with a character that's dancing to pre-licensed music in an animation, you can put that into your TikTok video, those are massive. Those make a lot of money for everyone involved," he says.

"But how about getting the 3D avatar of Snoop Dogg performing his latest song, and you make your own music video using it? The best one goes the most viral, and it's all licensed and monetized so that there's no piracy. Someone can build that ecosystem, because those videos are doing massive numbers.

"Fortnite and Roblox and other platforms like that, they're already kind of doing it. The next step is trying to make it user-generated content, not material produced exclusively by Epic Games or Sony.

"There are a couple of people kind of building that space, and that's an ecosystem I'd like to be part of."

For more of Matt Workman's journey with real-time motion capture, see his YouTube channel, Cinematography Database. For more on Snoop Dogg and the intersection between motion capture and music, see our feature on Astro Projects, page 14.


THE MOST ADVANCED MOTION CAPTURE CAMERA IN THE WORLD
LEGENDARY PERFORMANCE
VALKYRIE
VALKYRIE
VALKYRIE

In a world of annual, iterative technology releases, Vicon launches a new hero camera roughly every seven years. But, when we launch, it's an event. That gap exists because there's nothing iterative about Valkyrie - it's been built from the ground up to be the best motion capture camera in the world.

Mark Finch
Chief Technology Officer, Vicon

Ben Freeman, Hardware Development Manager, Vicon

Not only does it have a 26 megapixel sensor, with the fastest frame rates in the industry, it also has a single varifocal lens with ultra-powered LEDs, which is perfect for all volume setups regardless of size or shape. For the first time, the camera has been designed to be protected from water, so that they can be set up outside in all weather conditions. This project was a team effort, and in this article, I'd like to celebrate each and every one of those team members because all of their hard work has made this camera possible.

Many factors go into designing a new camera but two of the main ones are adding functionality that continually solves our customers' needs, and integrating the latest technology innovations. Two of the major features of our new Valkyrie range are the 26 MP sensor and the bespoke varifocal lens, which both contribute to the amazing quality and increased versatility of our Valkyrie cameras. We've made many changes to enable these features, specifically we had to redesign the underlying architecture and circuitry of our new camera to deal with increased data rates and to provide enough power to our high-power strobe. John Cload, Principal Hardware Engineer, comments "The design of the high-power strobe has thrown up many design challenges along the way, but is one of the features I am most proud of."

Our Hardware Manager, Ben Freeman, who's been with the company for 21 years and whose first camera was the MX, has played a critical part in the evolution of technologies over the years. Ben says "For Valkyrie we took the decision to look towards the future. We have moved to a smaller, lower power yet faster processor where we have completely rewritten the control code to be more reliable, maintainable and flexible.

In addition, the secondary image processing that has been a feature of our high end cameras since MX, is moving from linear- to parallel-based processing. These changes not only make us fit for the next twenty years, but will reap rewards when we develop other hardware."

Rob Taylor, FPGA Firmware Engineer, says "The addition of a second FPGA brings a greater degree of flexibility and processing performance, compared with previous architectures, which will enable future enhancements to sensors and performance."

Pete West, Principal Hardware Engineer, comments "Valkyrie is a project that has tested the mettle of all disciplines in HW Dev. The image sensor was quick to come up and stream quality data, though not without its own idiosyncrasies.

Ben adds "We took a hard look at how round markers are rendered by lenses and found a way to talk to lens manufacturers in terms they understand, building upon the experience of developing our first custom lens for T-Series. In addition, we wanted one lens to achieve the fields of view attainable with the lenses of Vantage, for three different sensor sizes. We successfully worked with our lens designer to turn this into reality.

Having embarked on designing our most complex and advanced camera from the ground up, along with the rest of the world we found ourselves working from home due to the pandemic. This inevitably came with its own challenges, with the team working at desks in bedrooms and sitting rooms spread from Fleet in Hampshire to the outskirts of Gloucester via Newbury, Oxford and Banbury. At the start of 2022 we finally got back to our office only to be hit with the next outcome of the pandemic: a worldwide shortage of components, which led to daily meetings to find alternatives and modify circuits to cope.

The Valkyrie design is like no other camera we've ever made. The thought and complexity that has gone into the design, making sure this camera has an intuitive user experience, can be used in different scenarios with its waterproofing, and let's be honest here, it looks amazing."

Simon Walls, Mechanical Design Engineer, comments "As the flagship Vicon camera leaps forward in capability, ensuring the mechanical design and manufacturing processes have developed in tandem to produce improved accuracy performance, enhanced heat dissipation and an IP rating never featured before has drawn on all expertise available and some beyond."

As I alluded to above, ultimately this was a team effort, and Chris King, our Senior Mechanical Design Engineer, reiterates that: "The challenges faced on this project were definitely unique – some circumstantial, some technical, but overall, a real test which pulled on everyone's experience and resilience."

On a final note, Valkyrie is a camera that we are extremely proud of, and we are all very excited to see how you, our customers, will use it to push the boundaries of motion capture for years to come.

REVOLUTIONIZING INJURY PREVENTION WITH MOTION ANALYSIS

PITCH READY'S SAAS MODEL OFFERS DEEP INSIGHTS TO A BROAD CHURCH OF ATHLETES

Pitch Ready is a consultancy turned tech company that helps sports organizations manage return-to-play and injury prevention for their athletes. The part of the offering that makes the company unique is a software platform that takes high fidelity Vicon data and turns it into actionable clinical recommendations. The company has worked with over 50 teams in 10 different leagues internationally, and that number is growing all the time.

Tim McGrath, Clinical & Research Director at Pitch Ready

Pitch Ready grew out of Clinical & Research Director Tim McGrath's 15+ years experience as a practicing clinician in professional sport and his observations of how athletes' split-second decisions can impact pre-existing injuries.

Tim gives the example of an ACL injury: "An injury scenario generally occurs within around 40 milliseconds of ground contact, which is an extraordinarily short period of time. There is no ability for an athlete to detect this at a conscious level as it is occurring, and so prevention strategies are very much about how your brain has derived this information in advance. The strategy that the body uses within this context can either be quite protective, or it can basically set up an injury. The Vicon piece really came about as a way to objectify what people do within that space under pressure, but in a really robust and repeatable way."

With the motion analysis component in place, Tim and the team at Pitch Ready began to build a battery of tests and an accompanying database. It was the next step that would shift the company away from the realm of hands-on consultancy and into the role of tech company.

The company began to automate its process, developing a software tool that would integrate the company's Vicon data with input such as clinical information, running, strength and jump data, and generate recommendations that a clinician, coach or athlete can implement in a practical way.

"The trick with these things is you can have really robust, repeatable data, but it needs to be in a format that's palatable on the back-end to the clinician. It's really about removing biases which can cloud our decision-making in regards to allowing an athlete to return to their chosen level of activity," explains Tim.

Chris Dunn, Director of Product & Customer Experience at Pitch Ready

Jon McGrath, Director of Strategic Partnerships at Pitch Ready

Chris Dunn, Director of Product & Customer Experience, explains that it's this solution that sets Pitch Ready apart from its competitors. "We plugged that process into a seamless, elegant solution that we could ship to the mass market." It means that while the company still acts as a hands-on consultancy to help organizations understand and utilize the information that is received, it also operates as a software-as-a-service (SaaS) provider. In this capacity, it enables partner organizations with their own Vicon systems to run tests themselves, feeding their data into Pitch Ready's portal to generate their own reports, containing unique analysis, recommendations and strategies.

MASS MARKET RELIABILITY

For the model to work, Pitch Ready needed a motion capture system that would reliably produce the results it needed.

"There are a few other players in the market, but Vicon has been around a long time. It's usually a good litmus test – when teams can survive long-term, they must be doing something right. So it was really the backend support behind the system, and just how robust and repeatable the whole system is. That was attractive to us," says Tim.

Once the raw data is uploaded to the platform, Pitch Ready's software generates its report. "Everything is matched to demographic data," says Tim. "So it's age, gender, the type of sport they play, and the level that they play at, because we're using that information to reference against population norms to guide relative benchmarks needed for safe participation in sport. The software then generates a report, which talks about where that individual sits in comparison to population norms, and then there are some automated outputs which are clinically derived."

For an external organization doing its own testing, the process is much the same. They run Pitch Ready's tests using their own motion capture system, then plug the data into the platform. "It's really about empowering them into the methodology from the testing battery, making sure that they're getting good, robust data and washing out learning effects," Tim says.

SCALING UP

One of Pitch Ready's goals was to streamline the entire process, from data entry to report, to a 20 or 30 minute window.

"One of the key features of dealing with professional sports organizations is that they're always time poor," explains Jon McGrath, Director of Strategic Partnerships. "Reducing the processing time means we can test lots of players rather than testing one and spending a long time processing the data before we can pull anything meaningful out of it."

That becomes particularly important when it comes to testing whole teams to generate injury prevention strategies. "Very rarely is it possible to send a whole squad of players to a lab. So the way that the platform works is that we can capture data on lots of different surfaces and in lots of different areas. So whether it be on a basketball court or a football field, it just makes it more accessible for individuals and also teams to actually use the service," says Jon.

"Indoors, outdoors, internationally, locally, we have that ability. It's a real point of differentiation to our competitors," adds Chris.

Creating an environment that allows for highly accurate motion capture and an authentic simulation of field conditions can be challenging. "You need to make the testing sterile enough that you can compare apples to apples. It can't be so chaotic that you can't make head nor tail of it. And sport is by nature a chaotic sort of environment," says Tim.

"When we first started, we were testing in a 20 meter lab environment, but we open it right up now, because the fastest athletes we test are running at eight meters per second at the point of changing direction. So it's about really trying to promote the intensity and the chaos of it, but still making it sterile enough just to be able to compare the outputs," he says.

BRIDGING THE GENDER GAP

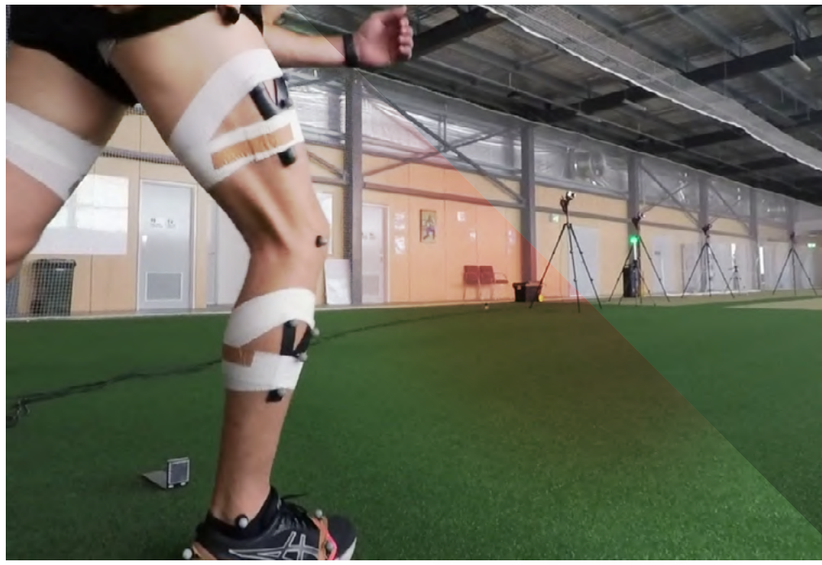
Another challenge is the lack of good data on female athletes.

"There's this rapid expansion that's kind of going on in the female codes," Tim says. Historically there have been budget constraints around women's sports that have meant that the kind of deep testing Pitch Ready does simply hasn't been carried out. As these historical gender imbalances are addressed and women's sports grow in popularity, however, demand is increasing.

Pitch Ready hopes to be part of the solution. "It's something that really excites me," says Tim. "Historically, female athletes have had such a hard road, with high injury rates and catastrophic injury. So if we can position ourselves as being quite helpful in that space, then that can change things for a lot of people."

Tim's other ambition for Pitch Ready revolves around getting even faster. "It's trying to have the ability to capture in real time with training data. This is where a lot of these markerless outputs can come into the picture. I don't think it'll ever replace optical capture, but it's really the ability to have more data coming in on a more regular basis as a way of trying to profile injury risk from a player point of view."

The two goals complement the work Pitch Ready has already done in automating and streamlining its process to reach as many organizations as possible. If Tim, Chris and Jon have their way, Pitch Ready will continue to capitalize on advances in motion capture, gathering more data to help more athletes stay safe and injury-free.



Thomas Windestam / DECA Text&Bild

BRIDGING THE PRACTICE GAP AND BUILDING CAREERS IN BIOMECHANICS

HELEN BAYNE ON THE CHALLENGES OF WORKING ACROSS DISCIPLINES

The world of motion capture contains a multitude of communities, and even within the broader category of sports science there are divergent fields. Helen Bayne has worked across a number of them in her work as an athlete, coach, student, teacher, biomechanist, clinician and scientist, and says that the key to bridging the academia-industry-practice gaps is increased understanding of others' perspectives. Her career has been testament to that approach.

Helen Bayne, Sports performance practitioner, researcher and educator

"You could say I've always had one foot in the lab and the other in the field, just that the weight distribution has varied over time," says Bayne. "I started my career almost 20 years ago as a clinical practitioner, applying exercise-based therapy to treat a wide spectrum of health conditions, but with a particular focus on sports injury rehabilitation.

"I sought to apply evidence-based practice and stay abreast of current research and experienced the challenges that all practitioners face in accessing, digesting, and applying relevant literature. I then went on to do my PhD in sports biomechanics, on the topic of low back injury mechanisms in fast bowlers, and always tried to keep in mind the practical value that my research could and should add.

"Since 2013, I've been employed in various departments at the University of Pretoria – first as a biomechanist in the sport science unit that was supporting high level University and Olympic sports programmes, and later on as a lecturer in a full-time academic position. During this time I also consulted to sports organizations such as the International Cricket Council, coordinated the establishment of a new biomechanics lab and led a project to implement an electronic athlete management system across multiple sporting codes."

Bayne says that this broad bank of experience has helped her straddle the divide between disciplines. "Dealing with people working in just about every facet of sport science across academia, practice and the broader sports industry really helped me to understand a range of perspectives from the people that sports biomechanics may have an influence on," she says.

THE PRACTICE GAP

Bayne believes that gaining this broad level of understanding can help practitioners and researchers to bring new insights to their fields.

"The ideal way to build relationships across the different spheres is to spend time in one another's environments," she explains. "For example, the researcher could attend training sessions and team meetings, and the practitioner could help out with data collection in the lab. Industry reps and technical support staff could even be encouraged to do the same, to experience first-hand what their users go through.

"In all cases, go in with a mindset of curiosity and listen to understand the new environment, without being too quick to jump in and problem-solve!

"This process not only gives us a new perspective on different demands and drivers, but can support improved communication as we learn the 'language' that varies between people and environments. So often it can just be a simple mismatch in the terminology we use – differences between a coach and scientist, for example – that is an obstacle to building good working relationships.

"Once you start working together, it's essential to formulate specific objectives that meet the needs of everyone in the team. Keep in mind that practitioners are ultimately judged by on-field performance of the team/athlete and researchers are rated by the publication and citation of scientific outputs. These are two distinct outcomes, but the process of achieving each can benefit the other.
If the collaborators understand this from the outset and go into a project with clear expectations, it will set up the foundation for an effective working relationship."

THE GENDER GAP

Some of these soft skills have been necessary for Bayne when it comes to navigating what continues to be a male-dominated field, particularly as she's progressed. "I think that there's more resistance to women taking on senior leadership roles, whereas there tends to be more gender equity at a junior level.

"Early on in your career, a good work ethic, willingness to learn, and delivery of high quality outputs are the main requirements to win the approval of your team/colleagues/employers. However, as you gain experience and skills that should be associated with progressing to higher positions or being regarded as an expert in the field, I've perceived that women tend to be overlooked and underestimated compared to male peers.

At the individual level, Bayne says, women can offset some of the difficulties by finding their voices alongside developing skills. "Become comfortable with putting yourself out there, letting people know what you're about – this could take many forms, such as speaking up during meetings, networking at conferences, or building on online presence.

"All the while, be authentic and stay true to your personal values. A supportive professional network is your greatest asset in navigating these challenges. Identify people that will not only encourage you but will give you honest constructive criticism when needed."

> "Become comfortable with putting yourself out there, letting people know what you're about – this could take many forms, such as speaking up during meetings, networking at conferences, or building on online presence."

THE CAREER GAP

Bayne says that as well as cross-pollinating insights across different fields, experiencing a range of different practices within the world of sports biomechanics can help newcomers to build their career.

"Don't be afraid to sample widely early in your career – say yes more than you say no. Each role you take on is an opportunity to build your skillset, grow your network, and learn more about yourself and the type of work you prefer.

"So, even if an opportunity that presents itself isn't your dream job at first or you don't spend long in a role before deciding to move on, the experience you gain while trying different things will never be wasted.

"But of course, at some point, you do need to start saying no to certain roles and refining the direction that you pursue. Cultivate reflective practices where you regularly evaluate whether the things that you are involved in are fulfilling, challenging you to grow, and moving you towards the person and professional that you want to be.

"Be patient. There is no straight path to 'success', so embrace the journey."

20,000'S A CROWD

HOW PIXOMONDO ADDED THOUSANDS OF PEOPLE TO THE EMPTY ENVIRONMENTS OF VIRTUAL PRODUCTION

Eric Whipp, Cinematographer, Alter Ego, Toronto

Matthew Manhire, Co-director, Manhire Media, Toronto

In the recent commercial for Caledon Football Club in Toronto, athletes play soccer at a breakneck pace on a floodlit pitch while a 20,000-strong crowd of fans cheer them on from the stands. The fact that the crowd is computer-generated isn't novel. Nor is the fact that the commercial uses in-camera special effects. The combination of the two, however, is a technical leap forward for the nascent field of virtual production.

The crowd is the work of Pixomondo ('PXO'), produced in collaboration with Alter Ego, William F. White International and PXO's Virtual Production Academy. It answers a long-running problem for advertising.

"One of the problems that we face in commercials all the time is trying to shoot large-scale crowds in a large environment," explains Eric Whipp, cinematographer on the ad. "First of all, getting into a stadium is very tricky, filling it with a crowd is very tricky."

"As any assistant director will tell you, wrangling 25 fans as extras is a pretty tall order, but wrangling 20,000 fans would be impossible and extremely costly," expands Matthew Manhire, co-director of the advert. "Pixomondo had this fantastic idea that they were testing with, and as a result we've got 20,000 unique individual fans doing various random movements to make the stadium have a sense of life and a sense of humanity."

"The crowd was developed using Vicon-powered motion capture combined with 3D scans of real people to create the animations. "

Traditionally, that kind of crowd would be done using a couple of rows of real extras in front of a green screen, with the remainder added in post-production. It's a costly, challenging and time-consuming process that Pixomondo had gone through recently for HBO's Winning Time: The Rise of the Lakers Dynasty.

In the wake of Winning Time the studio began working on a real-time solution that would achieve the same results in a way that was more cost-effective and offered more creative flexibility. In-camera effects using LED walls usually follow the lead of The Mandalorian, offering epic environments that are typically deserted. PXO set about building a system for filling those environments with people.

The crowd was developed using Vicon-powered motion capture combined with 3D scans of real people to create the animations. The system was then put together in Unreal Engine, with users able to trigger different crowd emotions that deploy over 100 different animations for any given subject. The crowd can be displayed on the LED wall of a virtual production volume, with Vicon technology used to track camera position in relation to the imagery being displayed.

The Caledon FC commercial was the perfect opportunity to test the new system out.

"Pixomondo obviously made massive developments on their shows like Star Trek, so we brought that over into the commercial world and we really wanted to highlight that."

Christopher Cox, Virtual Production Producer, Pixomondo

David Whiteson, Co-director, Alter Ego, Toronto

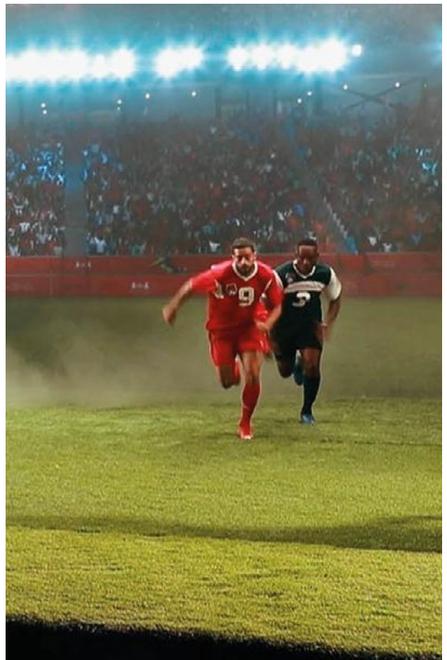
THE IMPORTANCE OF CROWDS

"Improving the capability of crowd assets is important to PXO and the virtual production industry, because it proves that we're not relegated to certain kinds of abstract assets; that we can accomplish any asset that requires a crowd," says Christopher Cox, virtual production producer for PXO.

The system also brings creative advantages to a shoot. "The creative decision maker gets to choose on the day what level of detail they want to adjust, therefore getting more out of the day," Cox says. "Sometimes, shutting down a set to change costumes or to change out patterns that are seen in the crowd can really reduce the efficiency of a shoot, whereas with virtual production those decisions are clicks of a button to swap out variables, and you can remain efficient."

"We bring the athlete in, we get what we need and then we're done, rather than putting them into an unpredictable environment, whether it be unpredictable weather or the unpredictable talent in the background," Manhire elaborates. "We have full control of everything, so it's a matter of plunking them in and them doing what we've been rehearsing in our prep."

"We have the luxury of not having to have the huge cost of renting a stadium," adds David Whiteson, the commercial's other co-director. "If we were renting a stadium, not only do we have the people problem, we have the cost of renting it for two days. Here, we can do more shots in a day because we're not fighting the sun and we can be a little bit more creative."



SHOOTING AT HIGH SPEED

Creating a real-time, reactive crowd wasn't the only technical achievement of the shoot.

"A very big thing is we're shooting at 200 frames per second," says Whiteson. "When you do that, it causes a huge amount of flicker on the LED wall because it's not in sync with the camera or the lighting. With this project we have found ways around that to achieve a high action scissor kick in slow motion that's never been done before. That just adds to our list of things that we've been able to develop and achieve to progress this medium further and further."

Another technical challenge – something doubly important for filming soccer, in which most of the action happens at ground level – was making the grass seamless. "Typically, up until now, virtual production has been about mid-shin up because we've wanted to hide the seam where the screen meets the floor. But through the discoveries that we've made with Pixomondo and Alter Ego we've found ways to properly blend the floor and the screen," says Manhire.

"Pixomondo obviously made massive developments on their shows like Star Trek, so we brought that over into the commercial world and we really wanted to highlight that. So we're seeing a full interaction of soccer ball, cleats and feet, and soccer players moving across the turf, blending seamlessly with the digital environment behind it," Manhire adds.

The meeting point between floor and screen might not seem that important to the layperson, but for Cox it's the point at which the entire project comes together. "Blending the virtual with the practical lighting can be really tough, but the most important part of the day is making sure that the floor is finding its way into a virtual blend so that the scale of the asset can actually be felt," he concludes.

ELITE SPORTS MOTION ANALYSIS

CONTEMPLAS VIDEO-BASED SYSTEMS SUPPORT COACHES AND ATHLETES IN TRAINING AND COMPETITION

For more than 17 years, we have been perfecting the movement sequences of top athletes with our video-based analysis systems according to the motto PERFORM. ANALYSIS. IMPROVE.

Yannick Huber, Product Manager CONTEMPLAS

Stijn Corten, Performance Analyst , The National Team of the Flemish Swimming Federation

Whether in the daily training process, in performance diagnostics, for competition monitoring or even in science our products are multi-talented and are used in a wide variety of sports, whether on land or on water. Coaches and athletes benefit from the unlimited flexibility of the systems - from simple video analysis to high-end 3D analysis, everything is possible!

According to Stijn Corten, performance analyst of the national team of the Flemish Swimming Federation, the motion analysis systems offer analysts, coaches and athletes "completely new possibilities for the performance assessment of high-performance athletes and their training control".

VIDEO-BASED ANALYSIS SYSTEMS SUPPORT TRAINING

In daily training, we help coaches and athletes to improve movement techniques and thus increase their performance. By integrating video-based analysis systems into existing training processes, we provide coaches with a wide range of video and movement data to analyze their athletes. From technique analysis to feedback training and supportive movement corrections, our systems allow coaches to communicate clearly - without spending additional time.

All movement data is captured with one or more cameras in real time.

"Whether in team or individual sports, CONTEMPLAS helps athletes, coaches and scientists to realize their potential and maximize their performance."

Large monitors directly next to the field or at the poolside enable the coach to give his athletes immediate feedback and visual correction assistance after the movement has been executed.

For self-directed video feedback training, athletes can start the video recordings themselves by integrating a buzzer and subsequently view their movement sequences in detail from different perspectives and at different playback speeds. Through continuous time reflection, athletes achieve a rapid improvement of the movement. This method therefore also makes it possible to do without a coach, as the athlete can see and assess him/herself.

MORE QUALITY IN PERFORMANCE DIAGNOSTICS

Performance diagnostic tests have become the methodological standard in athletic training in all sports. Established test procedures include standard jumping strength tests such as Drop Jump, Squat Jump and Counter Movement Jump.

In football, renowned top clubs such as FC Bayern München, use our video-based jumping strength measurements by using high-speed cameras and force plates to record objectively comparable performance values for the differentiated recording of high-speed strength behavior.

Coaches and therapists evaluate the quality of the executed movements by using strength curves, angles and synchronous video recordings. An analysis creates an overview, transparency and a basis for decision-making.

MAKE DECISIONS IN COMPETITION

In order to make quick and safe decisions in competition, our TEMPLO® software is used as a referee system, such as at the Taekwondo Championships in Paris, France. Based on high-resolution video images, selected competition scenes are viewed more precisely in slow motion, freeze frame and endless loop from different perspectives synchronously in order to make or revise referee decisions.

3D TECHNOLOGY FOR RESEARCH IN ELITE SPORT

Under the scientific direction of the University of Stuttgart and the Stuttgart Olympic Training Centre, the BMX starting performances and techniques of international top athletes are being studied on Germany's only BMX Supercross track using video-based 3D movement analysis. At the start, in addition to the first pedal stroke, the correct starting and acceleration position is also decisive. The athletes' jumping behavior is recorded in training with several cameras from different perspectives on a supercross ramp. Various kinetic and kinematic parameters are analyzed to optimize the position on the BMX: In the video image, the body position is additionally displayed with a superimposed 3D body model, with which the movement can be mapped in detail and independently of the plane of movement.

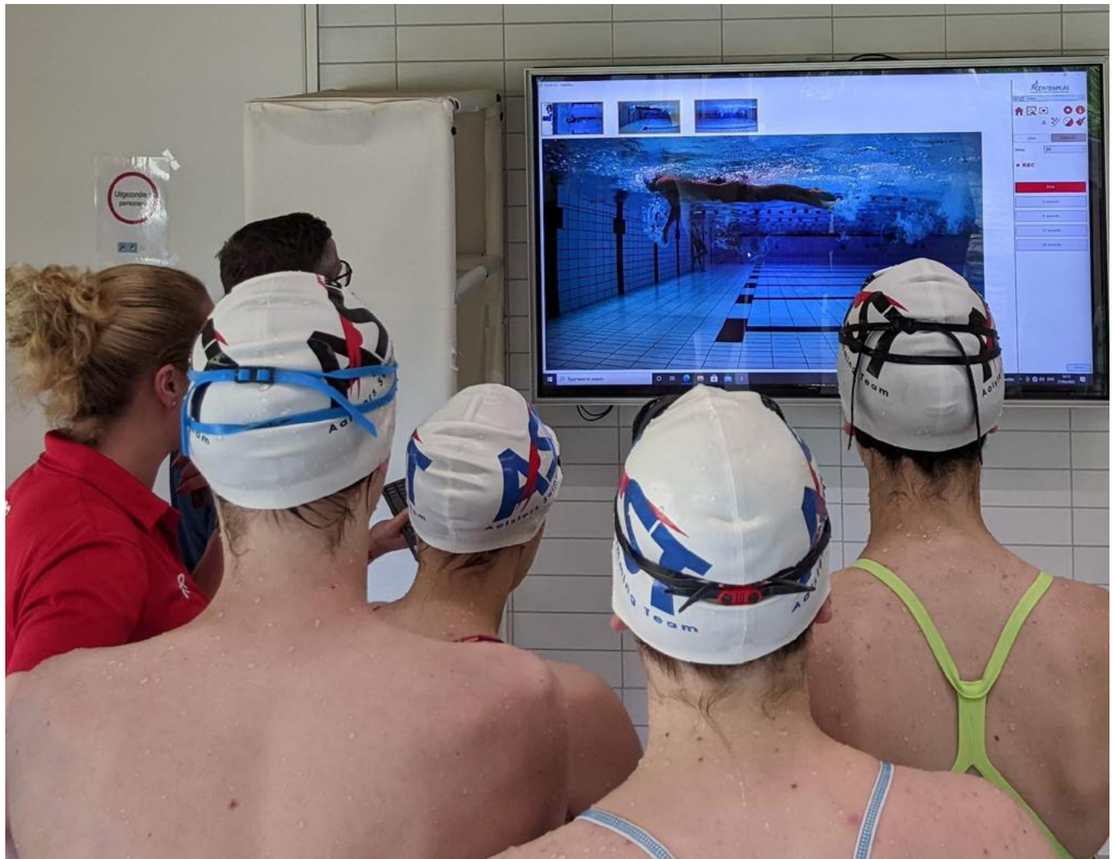
Whether in team or individual sports, CONTEMPLAS helps athletes, coaches and scientists to realize their potential and maximize their performance.

CONTEMPLAS is not only known for its system solutions, but also for its all-round service, which accompanies the customer from the initial idea through planning and implementation to the first analysis.

In this way, numerous projects with renowned customers have been successfully carried out over the past decades.

This also includes the Aquatopia project for professional swimming analyses in Aalst, Belgium.

In the three-year project, CONTEMPLAS already supported the architectural planning and the construction phase of the "analysis pools". A professional aquasport movement analysis system was installed in two swimming pools, which is used intensively by coaches and athletes in Belgium to document training progress and improve performance.



PUTTING THE SQUEEZE ON BATMAN

VICON

AT SQUEEZE MOCAP, VIDEO GAMES DRIVE EXPERIMENTATION, BUT MOVIES ARE CATCHING UP

"In our eyes, motion capture is not just a technical solution that delivers data," explains Julie Tighe, Executive Producer at Squeeze MOCAP. "It is a tool that serves our creativity. We try to integrate this artistic vision into our workflow, from preview to delivery of the final animations."

Squeeze MOCAP evolved from Moov, growing from a niche indie into a large studio serving giants such as Ubisoft and Activision across projects spanning video games, film, TV and theme parks. Squeeze has also branched out beyond its role as a service provider to become the originator of IP such as Cracké, an animated children's show that has been broadcast in upwards of 210 territories.

The studio's recent headline project was capturing the gameplay segments for Gotham Knights, an AAA game set in the world of Batman.

While Squeeze works across a range of entertainment fields, video games stand out in terms of the sheer quantity of motion capture they require.

"The video games industry has always been a huge consumer of animation, much more than all the other forms of entertainment combined," says Tighe. "In general, the volumes of animation needed for the movie or art industry are nothing compared to the ones needed by video games, and sessions look more like blitz productions.

"Squeeze went with Vicon because they are the leader of the market and were the only one to propose high resolution cameras at that time."

VICON

Julie Tighe, Executive Producer at Squeeze MOCAP

"For example, we did a two-week-long session for a big blockbuster movie recently, where we spent almost four years with an average of seven days of shoot per month for Gotham Knights, and it was just for the gameplay part of the game!"

AAA PROBLEMS DEMAND AAA SOLUTIONS

Gotham Knights presented a number of creative challenges for Squeeze, starting with the property itself. "When dealing with a very popular character, such as Batman, fans have very high expectations. They know how the character behaves, moves, talks, fights and deals with gravity, so we need to make sure our animations impersonate the character in the best way possible," says Tighe.

"As Batman has been animated many times in the past, we need to make sure fans find the same great—if not better—experience when playing the character on a video games console. It puts a certain amount of pressure on us when we work with such legendary characters, but it's a very positive pressure!

"Depending on the desire of the game's Creative or Art Director, we may want to give the character a fresh and new attitude or animation style, while remaining true to the brand's signature. In these cases, the challenge is just as stimulating, but the rule remains the same: listen to our partner in this co-creation exercise. This is what makes the project successful and unique."

Working on an AAA IP requires a world class technological foundation to work from. "Squeeze went with Vicon because they are the leader of the market and were the only one to propose high resolution cameras at that time (we've got 26 Vantage 16 cameras)," explains Tighe.

But Vicon's software is at least as important as the hardware for Squeeze. "Software like Blade, and now Shōgun, has been a game-changer," says Tighe. "Shōgun has had the perfect software evolution: a solid core, enhanced by its openness to scripting. That allows us to automate and batch process ridiculous amounts of data, obviously, but also to dig into all the possibilities in terms of pipeline design.

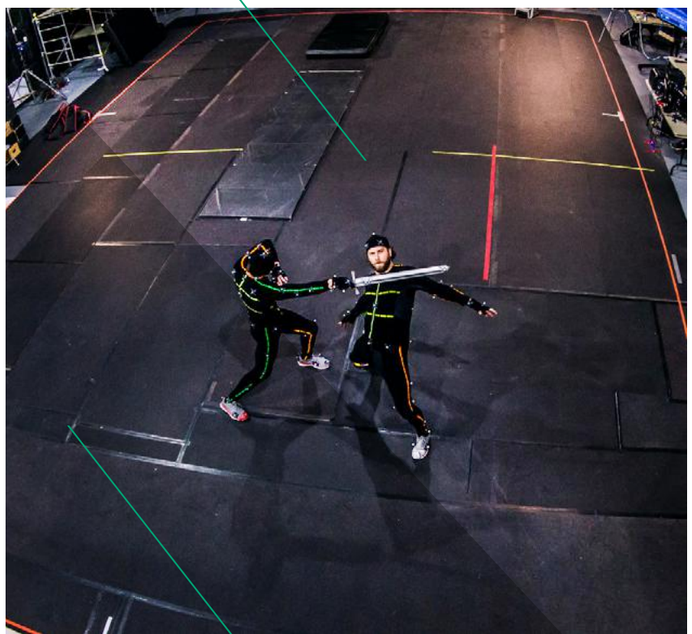
"I like the idea that more than 50 percent of the software is exclusively dedicated to my pipeline in particular, that I can play around with properties and tweaks to optimize everything to the max. Some would be happy to use the turnkey solutions offered by Vicon, which produce great quality in a few clicks, but I would say that rummaging through Vicon software became my specialty since Workstation 17 years ago! Then I logically continued on with IQ, Blade and now Shōgun."

NUNCHUCKS AND QUADRUPEDS

Shōgun enabled Squeeze to overcome a couple of interesting technical hurdles during the work on Gotham Knights.

"The first problem was knowing how to capture unusual props with 12 degrees of freedom, like the nunchucks which are a distinctive weapon of one of the main characters – something that won't be missed!" says Tighe.

"We figured out a solution with a mix of a custom hierarchy within Vicon Shōgun as well as complex relationship constraints within Motion Builder. Those two pieces of software can produce outstanding results when put together."



The second problem was capturing believable quadruped-style animations for one of the enemies in the game. "We had to use stilts for multiple performers on stage, and again a combination of a custom skeleton in Shōgun and a set of relationships within MotionBuilder. That was the only way to produce animations in real time for a character with extra long forelegs and inverted IK-style back legs," Tighe says.

While solutions such as these might currently make games the more innovative field of motion capture in entertainment, the gap is closing. "There is still much more experimentation with video games, but we all know that the industries and the pipelines are merging in some ways," says Tighe. "Virtual production is one of the best examples, with the introduction of game engines in the VFX pipeline creating a huge disruption in the way movies are made."

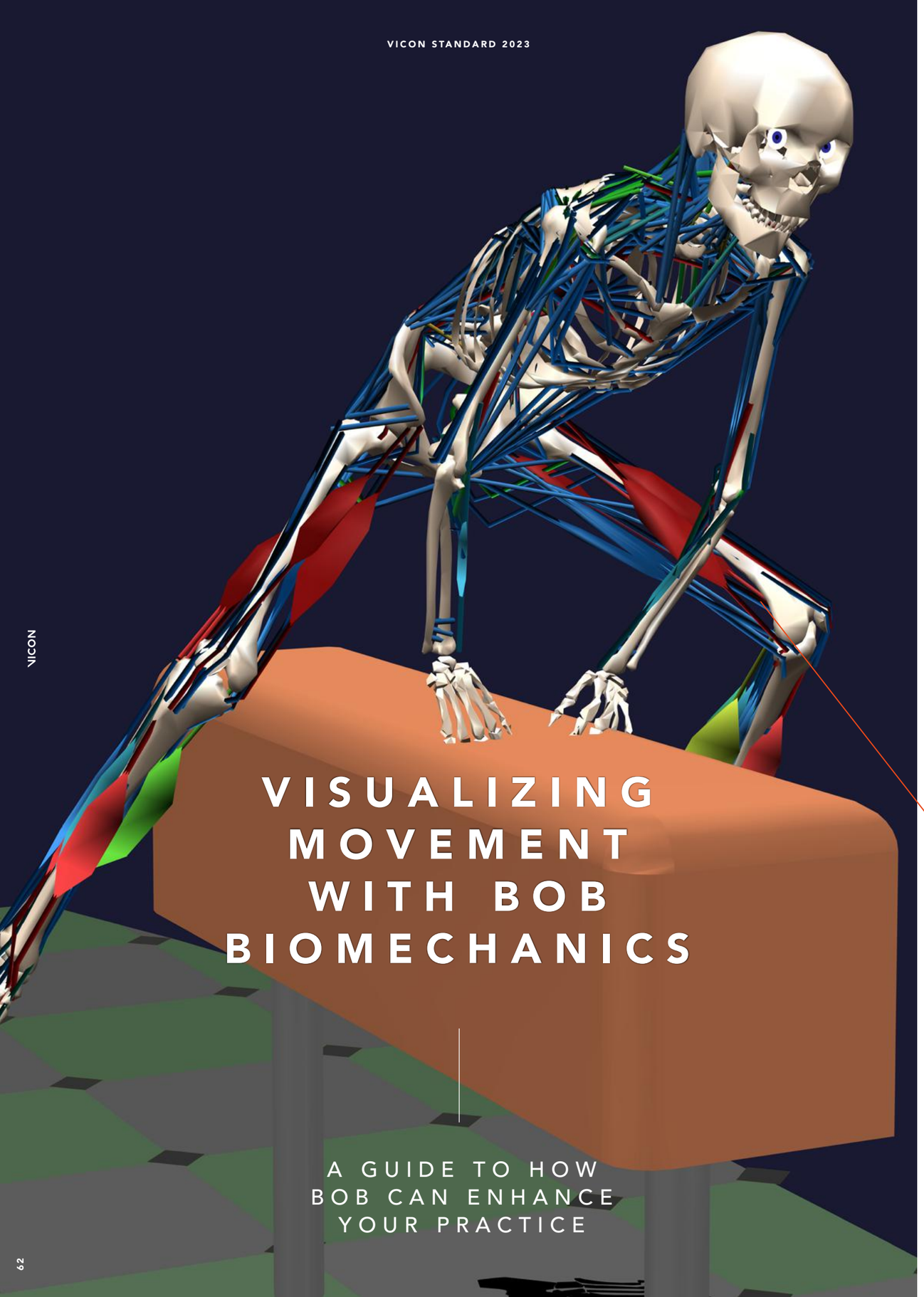
REACHING THE HOLY TRINITY OF MOTION CAPTURE

Tighe sees even more transformative developments on the horizon, though. "The main changes will come from both real-time capture and AI," Tighe explains. "If you have a close look over the last 20 years, the traditional motion capture pipeline has not evolved that much: we always have to calibrate a system, do a pass of cleaning of the data, solve it then retarget and polish.

"The major evolutions came from reducing the time spent on each task thanks to more sophisticated automatic tools, but each task has followed the same sequence. Vicon has proposed turnkey solutions, allowing big mocap providers as well as individual companies to reach a high level of quality with a minimum of effort.

"Today, we think the idea is to close the gap on some parts of the pipeline, improving the connectivity between Shōgun Live and game engines for example, making the capture software a true stakeholder in the engines' configuration.

"As for AI, we think it could help a lot in the real-time reconstruction of data. We saw a paper just last month about how optical and inertial mocap could merge and help each other in their specificity. If you add AI to that (to recognize patterns of motion when there is too much occlusion, for example), we think you'd have the Holy Trinity of real-time motion capture."



VISUALIZING MOVEMENT WITH BOB BIOMECHANICS

A GUIDE TO HOW BOB CAN ENHANCE YOUR PRACTICE

BoB Biomechanics was founded in 2016 by Dr Barbara May and Dr James Shippen to help researchers, practitioners, product designers and anyone with a need to understand the mechanism of human motion and visualize human movement. Building on our 2022 webinar with BoB, here is an introduction to how this partner integration can complement your biomechanics practice.

Dr James Shippen, Director of BoB Biomechanics

BoB (short for 'Biomechanics of Bodies') is a biomechanical modeling software solution, and the heart of the package is a human musculoskeletal model. By default, the skeleton consists of 36 rigid segments connected by 34 joints. The skeleton itself can easily be scaled based on overall height and/or overall mass, or the individual dimensions of the various segments can be individually edited, as can the inertia tensors for the segments. The segments are linked by joints that represent their anatomical counterparts.

BoB also contains a muscle model. By default there are over 600 muscle units within the model. They use Hill's three muscle elements, and wrapping is included so that the muscles fold around the underlying skeletal structure, and one muscle can wrap around another muscle deeper within the model.

The muscles are easily edited with the muscle editor that's embedded within BoB, so muscles can be added, modified and deleted. The muscles' insertions, origins and wrapping points can also be easily modified to suit the user requirements.

BoB can read motion data from multiple sources, such as from a simple look-up table of joint articulations, but the best results are generated using a motion capture system.

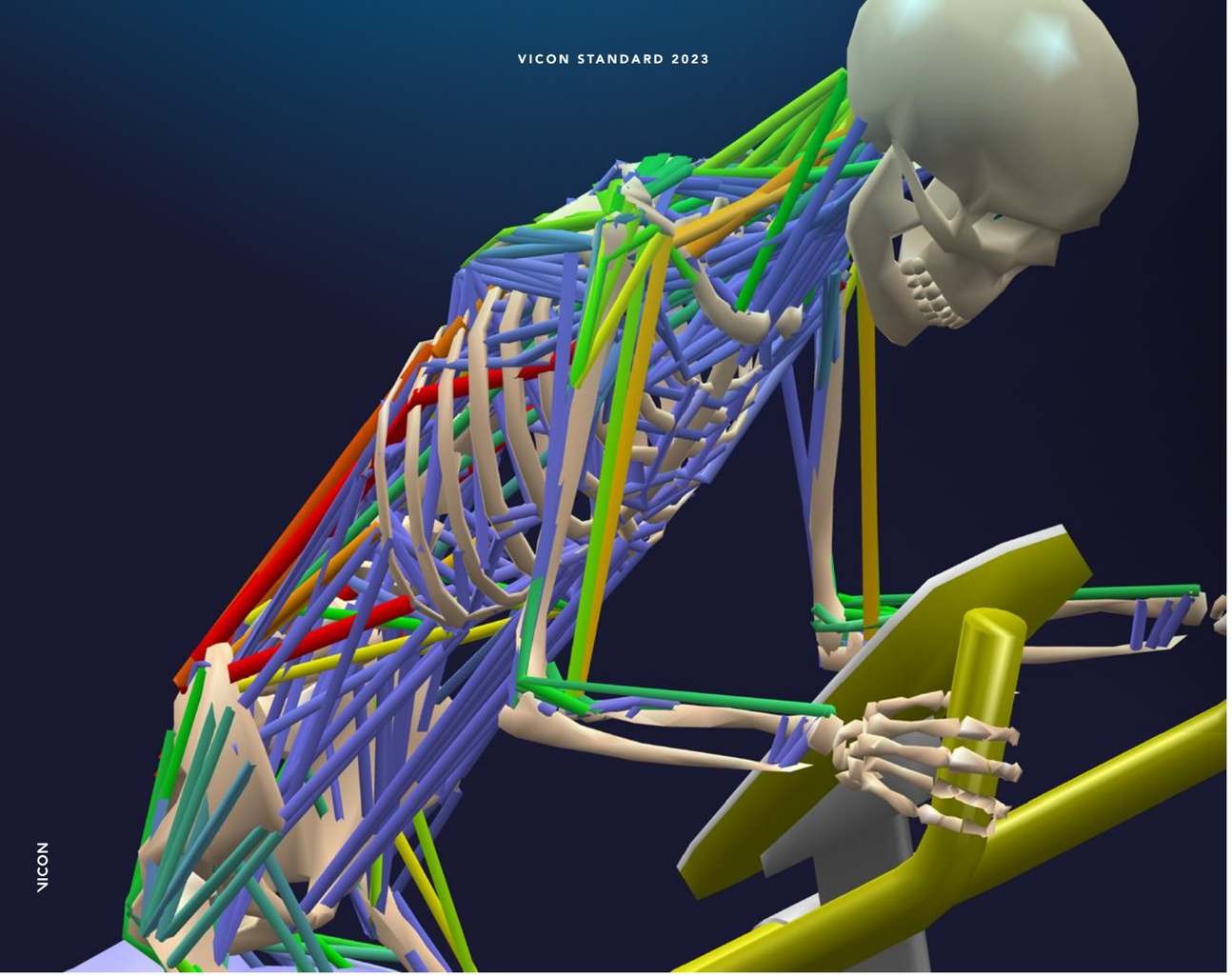
GETTING THE BEST RESULTS FROM BOB

While a look-up table is useful for very simplistic examples, it's fairly limited. What we tend to use is motion capture, and of course, the best is Vicon.

BoB can take optical tracking data and is configured by default to use the Vicon Plug-in Gait marker set. It can either be full-body or a reduced version, which means we don't need the markers on the thigh and the shin, nor on the upper arm or the lower arm. We actually use the kinematics of the joints themselves to calculate the joint axes, which means we get a marker set that's very quick and easy to apply.

BoB can also be driven by IMU data from Vicon's Blue Trident, using a very robust and easy interface. This, of course, gives users all of the obvious advantages gained by using IMUs, such as easily capturing data out in the field, tracking larger groups, or analyzing subjects moving around a large area.

Another set of inputs into BoB are the external forces that are acting on the body. So if you are working in an environment with force plates, BoB can take in the force plate data and apply that to the body. Or if you've got force transducers within the laboratory, BoB can use that data and apply those forces to the body. If forceplates are not available, BoB can calculate ground reaction forces by considering the



"BoB can take optical tracking data and is configured by default to use the Vicon Plug-in Gait marker set. It can either be full-body or a reduced version, which means we don't need the markers on the thigh and the shin, nor on the upper arm or the lower arm."

acceleration of the center of mass and appropriating the forces to the feet to be consistent with angular moment considerations.

BoB can also take video input, so you can synchronize the video to the motion capture data. This tends to be done almost as an aide-mémoire rather than an actual analysis tool, but it's very useful for checking details of the study, such as whether a subject was wearing shoes.

When all of this input has been put into the BoB model, BoB can then go into inverse dynamics mode to calculate the torques at the joints and the forces of constraint across the joints. BoB has an optimization routine built into it that's given a cost function (by default we use the sum of the squares of the muscle activations but this can be changed by the user). It can find a minimum for that cost function which will be associated with the muscle force distribution across the body. The forces within the muscles are displayed by BoB as color-coded, so the redder the muscle, the harder the muscles are working, and everything is displayed using BoB's sophisticated graphics engine.

BOB'S OUTPUTS

The most simplistic use for BoB is to aid in the visualization and the understanding of the motion that we're capturing. This can be done in a number of ways, for example, by showing the trajectories taken by any location on the body.

BoB can also show the instances of the subject at fixed intervals as it goes through the motion. We can display the range of motion of a joint, with color-coded shading that displays the movement area of the joint in both space and time. BoB can also display the velocity vector of any point on the body and the angular velocity and angular acceleration of any segment of the body.

"BoB has been used across a range of projects and sectors including vehicle design; product design; emergency service protocol development; sports optimization; dance injury reduction and even to analyze the performance of a Formula One pit crew."

While it's common to display a subject's whole body, BoB can also show a subset of the joints, the muscles and the segments within the body, as required by the user.

BoB will also calculate the torque that's occurring at the joints that correspond to the observed motion and external forces.

BoB can calculate the muscle forces across the body. As we then know what the forces in the muscles and the forces of constraints within the joint are, we can calculate the joint contact force. All of the data that we acquired from BoB can be output as tabulated data or it can be plotted against time, or any other variables, for a phase plot.

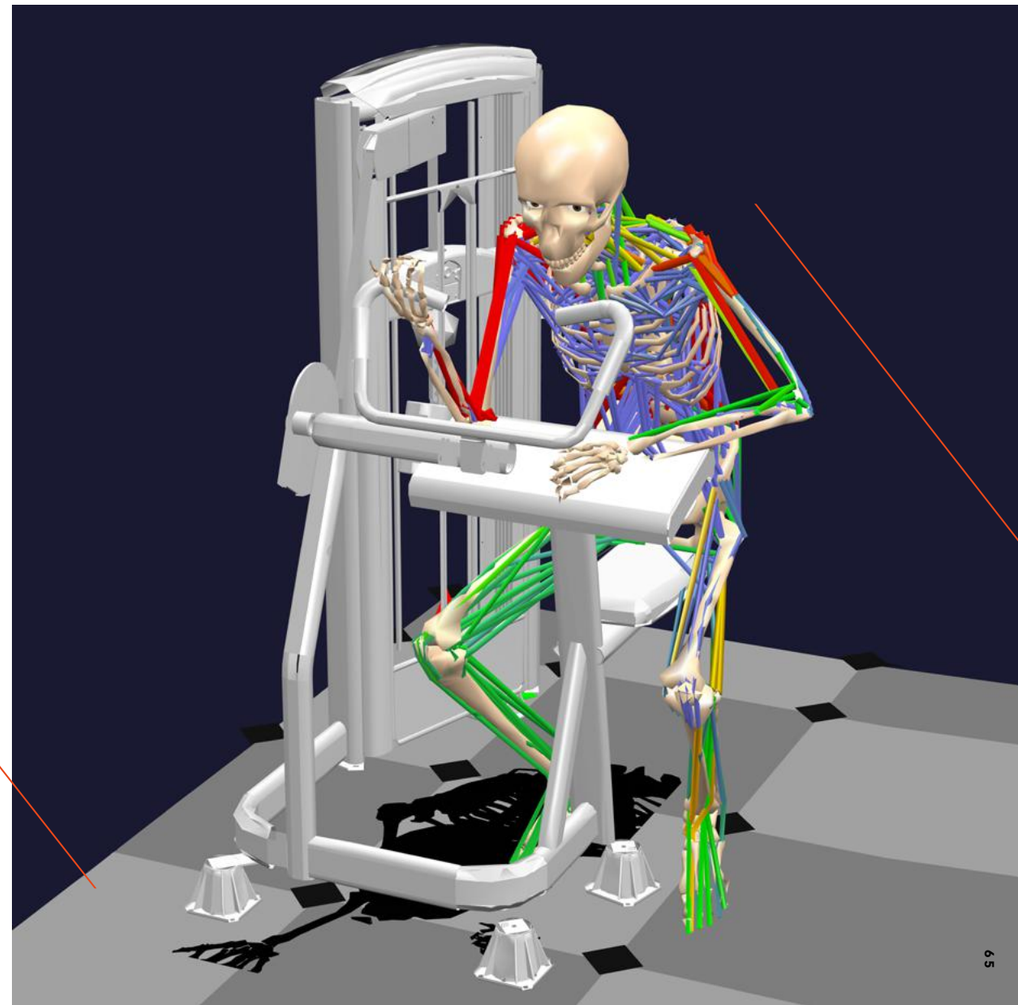
BoB can also display multiple subjects, and BoB itself doesn't have a limitation on the number of subjects.

BoB comes in four variants: BoB/Research is the core biomechanical analysis engine; BoB/EMG has all of the capability of BoB/Research plus tools for displaying and analyzing EMG signals; BoB/Ergo contains tools for the ergonomic analyst and BoB/Teaching is specifically designed for teaching biomechanics at the undergraduate and Master's levels.

BoB has been used across a range of projects and sectors including vehicle design; product design; emergency service protocol development; sports optimization; dance injury reduction and even to analyze the performance of a Formula One pit crew.

Working in conjunction with motion capture technology, BoB is a powerful tool for interpreting and understanding movement.

For more information, please visit BoB-Biomechanics.com.



A LEGACY IN MOTION

A TRIBUTE TO THE LATE DR. TOM SHANNON, VICON CO-FOUNDER

Dr. Tom Shannon
1952 - 2022

Last year Vicon lost a founder and the world of motion capture lost a pioneer, a man whose influence has been felt in every corner of our business for nearly 40 years. Dr. Tom Shannon, co-founder of Vicon, died in August 2022 aged 69. His restless intellect, roving curiosity and boundless energy will be sorely missed.

Born in Australia, on September 17th, 1952, Tom's potential wasn't immediately obvious to his teachers. "My high school guidance officer once recommended that I was much too dim to ever contemplate a tertiary education," he told an audience at his alma mater, Curtin University, Perth, Western Australia in 2020.

"I did know that I could understand how machines worked and, strangely, was reasonably good at calculus, possibly because the equations described to me motion, which I could readily imagine. But more importantly, like everyone here, I could dream, I could aspire and I could apply stubbornness, tenacity and grit to achieve my career goals even in the face of perceived wisdom to the contrary," he went on.

Those qualities earned Tom a place at Curtin University, where he studied engineering and, later, physics. Following his Master's degree, Tom won a scholarship to study industry abroad, and it was this that brought him to Oxford Instruments in 1984. His colleagues there did not share the short-sightedness of his high school guidance officer, and he was quickly put to work in a team developing technology for the nascent field of motion capture.

His spell at Oxford Instruments was short-lived, however. Not long after Tom arrived, the company decided to focus on its core business of building magnets for MRI systems. Its motion capture business, then called Oxford Dynamics, was to be sold or closed.

Tom and a team of like-minded employees, brought together by Dr. Julian Morris, determined that it would be the former. Lacking the capital to buy the business, they borrowed it from Sir Martin Wood, the founder of Oxford Instruments. Despite the new company's severe shortage of staff and resources, the founders paid Sir Martin back within a year. Vicon, under its parent company, the Oxford Metrics Group, was born.

For the best part of four decades Tom did, in the words of Dr. Morris, "everything". In the early days of the company, that meant everything from designing and testing electronics to rolling up his sleeves and manually assembling Vicon's early systems.

As the business grew, he sourced components and negotiated with sub-contractors. He would travel the world installing cutting-edge new systems and training their operators and, if need be, he would go back to fix them when things went wrong. His fingerprints were, literally, on every aspect of Vicon.

As Vicon matured, Tom wore many hats. Eventually his role became oversight of risk, information security and management systems for Vicon and its sister companies. But, as he once put it to Great British Life, "60% of my time is dedicated to looking at new worlds, new opportunities and ideas, and I get to play with cool stuff." While he was a group director, Tom was eager to discuss motion capture with anyone who came to Vicon, regardless of field, specialism or department.

This enthusiasm for and curiosity about motion capture and its myriad applications is part of what made Tom an essential and beloved part of Vicon, both for his colleagues and his peers in the wider field. His passion for the work of Vicon's customers earned him their deep respect, and he became our primary link with the world of academia and the clinicians whose work inspires many of our innovations.

Tom strongly believed in the power of collaboration across industry and academia to propel motion capture into the future, and eschewed the insular philosophies of technology businesses looking to turn a fast profit. It was the work, not profit, that mattered to Tom, and he made sure that commitment remains integral to Vicon's values.

While he was excited and delighted by the work of Vicon clients in industries such as entertainment and engineering, it was motion capture's power to help people and deepen our understanding of the world that most energized him.

That desire to help could be seen in other parts of Tom's life, too. He developed an interest in idiopathic scoliosis and, in 2010, completed a PhD in its early detection at Oxford Brookes University. He also served as a visiting lecturer at Staffordshire University, and had a keen interest in making medicine more affordable. One of his projects was an economical system for detecting changes in the spines of children with idiopathic scoliosis.

Tom's curiosity didn't start and end with science. He and his wife, Cindy, owned a farm in Somerset, and his interest in history led him to a position as a Trustee Director of the Soldiers of Oxfordshire Museum at Woodstock.

His passions ran wide and deep, making him a fascinating, charming and engaging figure for anyone lucky enough to spend time with him.

The technology world is awash with founders, but few of them will ever be able to lay claim to the kind of deep legacy Tom left behind. For nearly 40 years he was integral to Vicon. He had a hand in crafting everything from our vision to our relationships to the physical builds of our systems.

He didn't help found Vicon for status, or the thrill of an entrepreneurial project. He did it because he was deeply committed to the work we and our customers do in exploring human motion. It was that commitment, driven by his restless curiosity, that kept him deeply engaged in and essential to Vicon for four decades.

That commitment made him foundational to this company, and the wider world of motion capture, in the truest sense of the word.

"I could dream, I could aspire and I could apply stubbornness, tenacity and grit to achieve my career goals even in the face of perceived wisdom to the contrary."

Dr. Tom Shannon
1952 - 2022

2023 VICON EVENT CALENDAR

JANUARY

FEBRUARY

APTA
San Diego, CA
Feb 23-25

MARCH

GDC
San Francisco, CA
March 22-24

APRIL

FMX
Stuttgart, Germany
April 25-27

CMAS
London, UK
April 27-28

MAY

AUVSI
Denver, CO
May 8-11

ACSM
Denver, CO
May 30 - June 3

SCCB
Staffordshire, UK
May 18-20

JUNE

GCMAS
Highpoint, NC
June 26-28

JULY

ECSS
Paris, France
July 4-7

ISPGR
Brisbane, Australia
July 9-13

CMSC
Mobile, Alabama
July 10-14

ISBS
Univ, Milwaukee
Wisconsin
July 12-16

ISB
Japan
July 30 -
August 3

AUGUST

ASB
Knoxville, TN
August 8-11

Siggraph
Los Angeles, CA
August 8-10

SEPTEMBER

ESMAC
Athens, Greece
September 18-23

OCTOBER

NOVEMBER

DECEMBER

VICON CUSTOMER SUPPORT IS HERE TO HELP

SOFTWARE

Access **docs.vicon.com** from within the software to find all the user guides and product support information.

EMAIL

Wherever you are in the world, send an email to **support@vicon.com** with details of your query.

A Vicon support engineer will respond to your messaage as soon as possible.

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Open from 8am to 5pm PST (GMT -8)
Monday to Friday

Vicon Oxford:
+44.1865.261800
Open from 9am to 5pm GMT
(MST +7, PST +8) Monday to Friday

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