MOTION CAPTURE AS MEETING POINT:
Seeding collaboration from the bottom-up

A Report on the Cross-Centre Motion Capture Lab. Dates: 27-30 November 2023. Location: Performance Studio. Institute for Creative Cultures (ICC), Parkside, Coventry CV1 2NE.

Contents:

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Introduction:

This Lab was set up to explore connections across a spectrum of art-science-engineering research focussed on movement and gesture. During the four days of the Lab, a small number of research teams from various Centres experimented with the motion capture systems available at the ICC. The aim of the Lab was to exchange and discuss different research aims and methodologies across disciplines to make bridges for possible future collaboration. The research centres providing teams include the Centres for Dance Research (C-DaRE), Future Transport and Cities (FTC), Computational Science and Mathematical Modelling (CSMM), and Physical Activity, Sport and Exercise Sciences (PASES).

Sharing Motion Capture Systems:

In late 2022, the ICC received UKRI funding to invest in digital technology including motion capture. The ICC has now acquired 2 camera-based Kinect Azure systems and eight IMU motion capture suits including 3 Rokoko, 2 Perception Neuron, 2 Tesla and (borrowed from FTC) an Xsens Movella.[1] What makes motion capture technology unique is that it is used in **both** artistic and scientific movement research. This requires a basic level of technical knowledge of how to set up, calibrate and run the

[1] IMU means **inertial measurement units** that measure anatomical joint angles, orientation angles, and linear acceleration in both natural and lab-based environments.

systems, and the ICC has a few researchers[2] who are using motion capture in their work, some quite extensively. The Lab was conceived as an exchange with Coventry researchers from other fields who are also using motion capture. The original invitation (sent in June) said "the purpose is to bring together researchers from different centres/ disciplines who use motion capture in their research. We would like to spend a few days together conducting various recording and analysis sessions as designed and conducted by the separate fields involved. The goal is to enable exchange and discussion of different research approaches and methodologies with the aim of making bridges for possible future cross-centre collaboration." Within a short time, researchers from the above centres (FTC, CSMM, PASES) had agreed to attend. The Lab was scheduled from 26-30 November 2023 and comprised eight half-day motion capture sessions with each session dedicated to a participating research team or researcher. Time was allocated at the beginning of each session to introduce their research interest; this was followed by conducting motion capture recordings and a final discussion to reflect and identify possible follow-ups.

Having many different motion capture systems in one place and time is very unusual, and most of the participating teams were interested in testing and evaluating these different systems for possible use in their research. They either had no access to these systems before, or they were missing the technical know-how to use them. A comparative report of how the different systems performed is included below. The Lab was deliberately organised to be informal with an open-door policy encouraging drop-in observation, although this was not widely publicised. A MS TEAMS was set up where the description, team members and schedule was posted. Folders were created for reference papers, presentations, documentation and motion capture data.

Participants, Topics & Follow up plans:

27 November
<u>Session 1</u>: Sara Sardari and Julio Escudero. Teams: CSMM and C-DaRE. "Questions to foster cross-disciplinary understanding" 40 min video recording sharing different approaches to human movement capture from scientific (physical rehabilitation) and artistic perspectives (translating motion into digital forms). Kinect & Teslasuit.
<u>Session 2</u>: William Payre, Sachita Shahi and Saif Alatrash. Team: FTC. "Pedestrians' body movement" Interested in pedestrian's gait, pace and speed when they are walking from one point to another (e.g., crossing a road). Rokoko and Xsens Suit. **Follow up plans:** Xsens data is being tested in VR and follow up study using the Xsens is in development.

28 November
<u>Session 1</u>: Ruchita Mehta. Team: CSMM. "Identification of Distressed Conditions in Elderly People" Developing non-intrusive robust Human Activity Recognition (HAR) systems. The system aims to identify signs of distress in daily lives of the elderly population. Kinect. **Follow up plans**: assess the suitability of Kinect Azure for fall detection.
<u>Session 2</u>: Pengpeng Hu. Team: CSMM. "Human body volume estimation and 4D hand measurement" Human body volume estimation for human identification and monitoring body

[2] Ruth Gibson and Daniel Bisig (C-DaRE) Alex Masters (CPC) all involved in organising and supporting the Lab.

health using vision-based method. 4D hand measurement for rehabilitation captured by single depth camera. Kinect. **Follow up plans:** Joint CSMM/ C-DaRE funding proposal in consideration.

29 November
Session 1: Jason Tallis and Steven Eustace. Team: PASES. "Downhill walking and other challenges" Explore downhill walking and stair ascent and descent for fitness and rehabilitation in elderly populations. Discuss/ Test different systems. XSens, Rokoko, Perception Neuron. **Follow up plans:** C-DaRE researchers to visit PASES to discuss possible collaboration. Xsens data is being evaluated for the possibility of developing a PASES study using the Xsens.
Session 2: Daniel Bisig and Aoi Nakamura, Esteban Lecoq. Artists: AΦE. Team: C-DaRE. "Choreography project capture" Motion capture choreography for training of Machine learning model to generate choreography in real time for an XR installation. Perception Neuron.

Working 27-29 November at various times: Ruth Gibson, Bruno Martelli. Artists: Gibson/Martelli. Team: C-DaRE 'Performers of the Future" Using image prompts and principles from the Skinner Releasing Dance Technique pedagogy in combination with AI prompts. Exploring live, real-time data streaming versus recording. Xsens and Rokoko.

30 November
Session 1: Daniel Bisig and Aoi Nakamura, Esteban Lecoq. Artists: AΦE. Team: C-DaRE. continuing "Choreography project capture".
Session 2: Guilherme Conrad. Team: C-DaRE (Visiting PhD student from Brazil). Acrobatics Motion Captured. Xsens.

Bottom-up versus top-down: a seedbed for ideas and connections:

Can such a lab help to foster cross-centre research collaborations at Coventry University? Can it contribute to the transdisciplinary goals of Coventry University research? The motion capture technology functions as a valuable meeting point when there is the requisite knowledge to run the systems and the willingness to share both kit and expertise. PGRs and research staff across the four centres participated as well as outside guests from the creative arts industries. Various insights were achieved, for example through the discovery of new technological solutions and understanding that skilled movers/ performers could contribute to better training data. One computing science researcher has found early research related to their study coming from the dance and technology field. There are two follow-up plans that might involve using the IMU motion capture systems again, with support from the ICC, and two discussions about future research collaboration.

Thus, the lab was a seedbed for ideas on an individual level with researchers taking away insights they might apply within their own discipline, as well as **a starting point** for possible future transdisciplinary research. The use of seeding as a metaphor deliberately points toward the idea of bottom up versus top down. What happens when researchers from different fields can share time together in a common space, without the express goal that they must develop a project together to respond to a specific call? Those are the bottom-up conditions this Lab was designed to facilitate, and this report gives evidence of the results. However, the new cross-centre connections made here will grow into something that goes beyond interdisciplinarity only if there is further collaborative investment of time and energy.

This brings us to two questions: firstly, how valuable are such initiatives focussed on firstly spending some time together to simply share research interests, and secondly, what does it take to nurture and support the new relationships that are sparked through this sharing? On the evidence from this Lab, the answer to the first is that if a unique meeting point like motion capture technology (used in **both** artistic and scientific movement research) can be found and sharing time together can be facilitated then the answer is **yes**, it is valuable. To answer the second, we will have to wait to see where the follow up efforts go. But in the meantime, another question might be what are other possible unique "meeting points" in the Coventry University research environment and how to use them to start new collaborations growing?

Motion Capture Systems Comparison:

In the Motion Capture Lab, we employed a diverse array of motion and performance capture technologies, spanning from full suits with integrated sensors to individually fixed sensors, offering greater flexibility and eliminating size variations inherent in suit-based options. For sensor-based motion and performance capture, our primary hardware solutions included the Perception Neuron Studio, Xsens Link, and Rokoko Smart Suit.

The extensive use of the Perception Neuron Studio kit by Aoi and Esteban was notable. This choice was influenced by the kit's capacity to apply individual sensors directly to the body, eliminating the need for a full suit. This feature was crucial, especially since the performance required additional hardware fixed to the body for specific motions, such as anchoring one leg to the ground. Aoi and Esteban's prior experience with the Perception Neuron kit from a previous performance capture event facilitated a seamless transition, allowing them to continue their performance without the need to adapt to a different technology.

When well-calibrated, the Perception Neuron demonstrated excellent motion capture results at high resolution. However, its construction, featuring individual straps for sensor attachment, made the setup time-consuming. Furthermore, each sensor required individual power, necessitating disassembly for recharging in the provided case. While the batteries had a satisfactory usage duration, the Xsens and Rokoko suits, powered by easily swappable Lithium-Ion battery packs, proved more practical for efficient power management.

The Xsens suit was also used extensively throughout the lab, specifically for its precise accuracy and high-resolution motion capture data. The plethora of data feeds provided by the suit, which can be integrated with a wide variety of plugins for augmentation with other data capture equipment, such as heart rate monitors from third-party providers, made the Xsens suit the preferred option for health-based applications where minute changes in body position and vital signs can be synchronised for deeper analysis and comparison. In addition, the Xsens was tested with live streaming into Unreal via a plugin (Livelink) which makes it possible to see the performer animating a character in real-time.

When properly configured, the Xsens hardware delivered a stable motion capture experience, maintaining accuracy over extended periods, good for longer walk cycles and running, etc. provided the sensors were securely affixed in their designated positions throughout the suit. It is also possible to record when in contact with other bodies, props, studio floor (rolling) and walls. However, any slight looseness in the sensors could swiftly impact the suit's sensitivity, leading to compromised posture and articulation of the avatar, thereby diminishing anatomical accuracy.

A notable application involved Guilherme Conrad, a visiting researcher from Brazil, who harnessed the capabilities of the Xsens suit to document a comprehensive library of acrobatic movements for his research. Given the dynamic nature of the movements, encompassing rolls, flips, jumps, and cartwheels, the motion capture system needed to reliably capture precise movements with rapid rotation and elevation. The Xsens suit excelled under these demanding circumstances, proving to be the most reliable option for such intense movement, requiring minimal recalibration over several hours of activity.

In addition to the Perception Neuron and Xsens hardware, we also had three Rokoko Smart Suits, complete with gloves for hand and finger motion capture. The Rokoko suits performed excellently with very high-resolution capture, very fast and simple calibration, and reliable retention of posture throughout use. Of all the equipment at our disposal, the Rokoko suits were the most accessible from an introductory perspective. With three sizes available (small, medium, and large) and a calibration procedure that simply involves standing still for a few seconds, the Rokoko suits made it easy for participants to experience the hardware and start experimenting in a matter of a few minutes. Were it not for the specific medical integrations, and custom performance rigging needed by the projects undertaken at the lab, the Rokoko hardware would have been utilised to a greater extent.

With three Rokoko suits available, more than one ‘performance’ can be captured at the same time, which would be a useful feature for future projects. In addition to the suit and glove combination, the Rokoko also supports facial expression capture, which can add an extra dimension to performance capture. What’s more there are new enhancements coming to the system through an additional hardware device (Coil Pro) that captures more accurate positioning through EMF tracking to “remove drift and occlusion in real-time providing global positioning for body and fingers”, allowing for extremely precise position tracking with multiple subjects at once. It also copes well with foot sliding, with a built-in feature for foot contact. The Coil Pro has been added to the list of equipment the institute is seeking to purchase should we secure additional specialist hardware funding.

The available equipment also included a Teslasuit, a full-body haptic feedback suit designed for delivering immersive haptic sensations using electrical muscle stimulation, most widely used to augment VR simulations for training purposes and immersive gaming experiences. Whilst offering motion capture capabilities, the Teslasuit is less capable than the other hardware within our inventory therefore, it was considered a supplementary feature on top of the haptic capabilities of the suit, rather than as a primary choice for motion and performance capture in this situation.

Although Teslasuit's motion capture system may not be as reliable or accurate as other mocap devices, it does offer stable haptic feedback. When the avatar mirrors human motion, it triggers a haptic response in the body while it is in contact with digital objects. In the first stage of this exploration, a digital garment created from previously recorded mocap data from Teslasuit was placed in the 3D digital space. During the lab, a participant wearing the suit interacted with the digital object, walking around, reaching out to, or passing through it. While the user was in contact with the digital garment, Teslasuit triggered a haptic response. This unique capability allows for exploration between the analogue and digital realms. It provides an additional non-visual layer of interactivity between the user/wearer and the space during movement captures.

In addition to sensor-based technologies, we integrated camera-based tracking using the Microsoft Kinect platform and Zed 2 stereo image capture technology. The Kinect primarily recorded depth information, while the Zed 2 tracked multiple subjects in space without the need for dedicated motion capture hardware on each subject. Examples of this use in potential projects included audience interaction, where participants would be free to move around a performance or installation, whilst not constrained by hardware, enabling interaction with a performance regardless of physical limitations and the friction of requiring cumbersome equipment to take part.

The Kinect Azure cameras employ the Time-of-Flight principle to capture high quality point cloud data. Kinect Azure cameras can for example be used as low-cost alternatives to Photogrammetry or Lidar for volumetric body capture and 3D surface reconstruction. Other than that, Kinect Azure cameras are also equipped with an IMU and a microphone array, the latter of which can be used for sound source localisation. Among the drawbacks of Kinect Azure are its sensitivity to infrared light and an SDK which is insufficiently documented and provides examples for only two use cases (Point Cloud Fusion and Pose Estimation). Furthermore, the production of the Kinect Azure has been discontinued which puts its long-term usability into question.

The Kinect Azure cameras have been used in three use cases in the Lab. Sara Sardari employed Kinect cameras in the context of physical rehabilitation for capturing the motion of subjects and providing real-time feedback about the correct execution of said motions. Ruchita Mehta used a Kinect camera to record point-clouds of a lab participant who was imitating an elderly person falling to the ground. She plans to evaluate whether these recordings can be used to detect fall events while granting the recorded person anonymity. Pengpeng Hu has demonstrated the use of a Kinect camera as a low-cost volumetric capture device. For this purpose, he recorded point clouds of his hands.

The ZED 2i is a stereo vision camera with integrated IMU, barometer and magnetometer. ZED cameras estimate a depth map from a stereo image to eventually generate a point cloud. The quality of the point cloud is clearly inferior to that obtained with a Kinect Azure camera. On the other hand, the ZED 2i offers several advantages over the Kinect Azure: its maximum perceived distance is much longer, it is insensitive to infrared, and it provides an excellent SDK that integrates a range of machine-learning based computer vision algorithms for example for detecting bounding boxes or body poses of multiple people in real-time. Because of this, the ZED 2i camera can be employed as a low-cost and non-intrusive motion capture system for tracking a large number of people.

The ZED camera has been used in a single use case. Aoi Nakamura and Esteban Lecoq tested the capability of the ZED to track the 3D body poses of multiple people. They conducted these tests under low light conditions to mimic the light situation in a video installation setup. These tests served to assess the ZED's suitability to track the positions and poses of audiences to drive the behaviour of an interactive installation.

Photographic Documentation (larger copies available on request)


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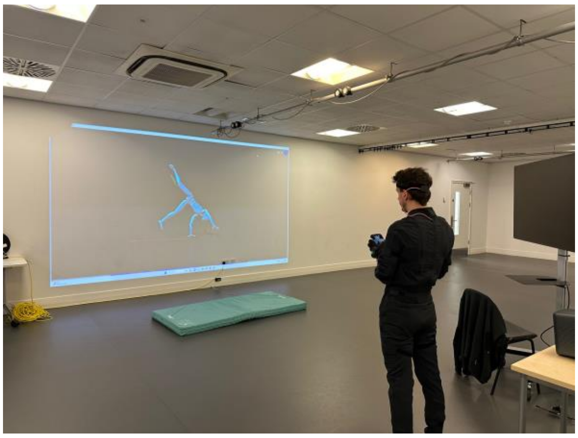
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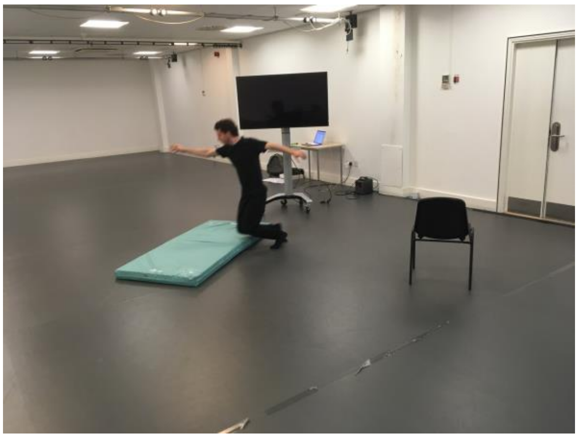
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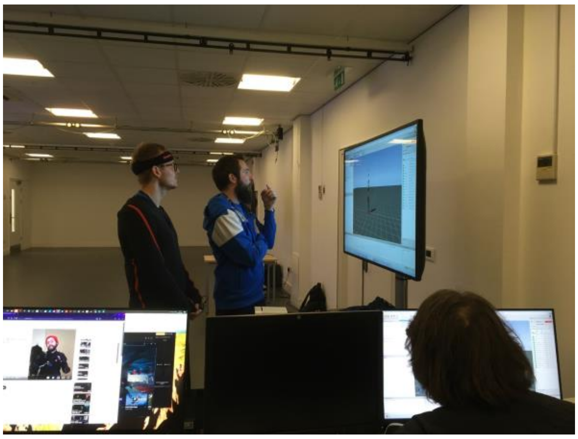
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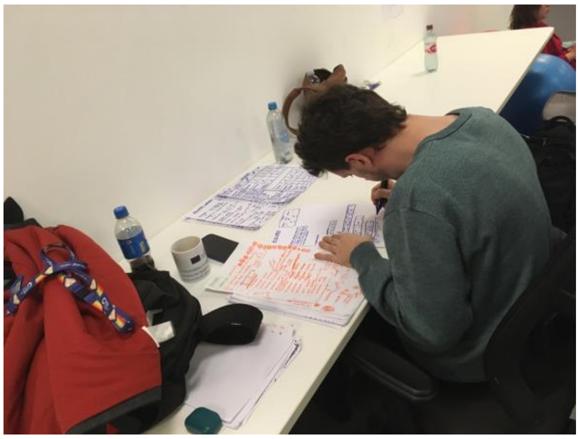

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