

Institution: University of the West of England, Bristol		
Unit of Assessment: 11		
Title of case study: Enabling musical expression with gestural interaction		
Period when the underpinning research was undertaken: 2014 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Tom Mitchell	Role(s) (e.g. job title): Associate Professor in Creative Technologies	Period(s) employed by submitting HEI: September 2007 to present
Period when the claimed impact occurred: 2014 - 2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact		
<p>Research at UWE Bristol by Associate Professor Tom Mitchell led to the development of 'Dataglove' and wireless communications technology which enable gestures to control sound and music. Continuing research and collaboration with musician Imogen Heap, spin-out company MiMU and Bristol-based x-io Technologies have led to commercial development and extensive applications. The technology has been used to enrich and transform performance by high profile musicians including Imogen Heap and Ariana Grande, reaching audiences of many thousands through international tours, appearances in premier venues and broadcast media. Devices have also enabled performance by those with disabilities including cerebral palsy, and the development of assistive technologies to support communication by people who are hearing but non-verbal. Commercial development has attracted investment and generated significant sales, employment and continued innovation within the UK.</p>		
2. Underpinning research		
<p>Research at UWE has enabled the development and evaluation of wireless, gestural technology leading to new forms of musical instrument and artistic expression. This enables end-users to design the movements with which they can perform their music, to become the creators of their own unique and personalised gestural musical instrument. The research was initially carried out in the Creative Technologies Lab at the University of the West of England (UWE) by Dr Tom Mitchell in partnership with musician Imogen Heap, x-io Technologies Ltd and spin-out company MiMU Gloves Ltd. The research has been supported by funding from the European Commission (G1, G2), Innovate UK (G3), the Leverhulme Trust (G4), and UWE (G5, G6). The underpinning research has made two significant and novel contributions:</p>		
Wireless technologies for gestural music interaction		
<p>Intersecting computer science, engineering and wearable technology research, this interdisciplinary research has resulted in the development of a comprehensive dataglove-based system enabling musicians to play music with gestures in real-time. The research has included the development and evaluation of tools and techniques that can be rapidly combined to enable the identification of a range of musical gestures in real-time (R1, G3). The use of wireless datagloves in large-scale music performance venues with large audiences raises research questions and challenges which have been addressed in partnership with Bristol-based company x-io Technologies Ltd, and with support from the EU-funded Microelectronics iNet (G2) of which UWE was a partner. This work included the design and development of a device named x-OSC, a wireless interface designed with stack optimisations for low-latency creative and music applications (R2). Communications systems</p>		

and algorithms have also been developed and optimised for real-time performance scenarios. This has included the design, development and evaluation of a wireless antenna that suppresses unwanted interference (R3) and a novel heterogeneous device synchronisation method for sensor networks using Open Sound Control (R4). These innovations are now used extensively in MiMU and x-io Technologies' products (see Section 4).

Mapping as a creative endeavour

Taking a user-centred approach, UWE researchers have also developed and evaluated techniques and interfaces that enable non-expert users to interactively train neural networks to identify gestures and map these gestures to control music. This process enables musicians to define the unique movements with which they perform their music (R5, G6). Evaluation of the practice and compositional approach of expert users has revealed that the ability to design personalised choreographies offers musicians a unique design space within which to develop new forms of musical expression, along with a personalised performance identity and aesthetic. This approach to user-led gestural music interaction has contributed the practice of *mapping as a creative endeavour* to the music and human-computer interaction research community (R6, G3).

3. References to the research

- R1** Mitchell, T. J., Madgwick, S. and Heap, I. (2012) Musical interaction with hand posture and orientation: A toolbox of gestural control mechanisms. *The International Conference on New Interfaces for Musical Expression, Michigan, USA*. <http://eprints.uwe.ac.uk/18267>
- R2** Madgwick, S. and Mitchell, T. J. (2013) x-OSC: A versatile wireless I/O device for creative/music applications. *The International Conference on Sound and Music Computing, Stockholm, Sweden*. <http://eprints.uwe.ac.uk/20302>
- R3** Mitchell, T. J., Madgwick, S., Rankine, S., Hilton, G., Freed, A. and Nix, A. (2014) Making the most of Wi-Fi: Optimisations for robust wireless live music performance. *The International Conference on New Interfaces for Musical Expression, London, UK*. (Long Paper). <http://eprints.uwe.ac.uk/23119>
- R4** Madgwick, S. O. H., Mitchell, T. J., Barreto, C. and Freed, A. (2015) Simple synchronisation for open sound control. *The International Computer Music Conference, Texas, USA*. (Shortlisted for best paper). <http://eprints.uwe.ac.uk/26049>
- R5** Brown, D., Nash, C. and Mitchell, T. (2018) Understanding user-defined mapping design in mid-air musical performance. *The International Conference on Movement Computing (MOCO 2018), Genoa, Italy*. <https://doi.org/10.1145/3212721.3212810>
- R6** Brown, D., Nash, C. and Mitchell, T. (2018) Simple mappings, expressive movement: A qualitative investigation into the end-user mapping design of experienced mid-air musicians. *Digital Creativity*, 29 (2-3). <https://doi.org/10.1080/14626268.2018.1510841>

Evidence of the quality of the underpinning research

- G1** Mitchell, T. *MiMU Gloves project, WEARsustain*. European Commission, 2017 – 2018, £40,000.
- G2** Mitchell, T. *Southwest Microelectronics, iNets*. European Commission, 2013 – 2015, £82,000.
- G3** Mitchell, T. *Posture and Gesture Recognition for Wireless Musical Gloves*, Innovate UK, 2015 – 2016, £11,568.
- G4** Mitchell, T. *Exploring Molecular Data with Immersive Technology: Interactive Sonification in Virtual Reality*. The Royal Society, 2019 – 2021, £98,752.
- G5** Mitchell, T. *Reimaging digital musical instruments through printing*. UWE Interdisciplinary

Research Fund, 2019, £25,000.

G6 Mitchell, T. *End-User Action–Sound Mapping Design for Mid-Air Music Performance*. UWE Studentship, 2015 - 2020, £75,000.

4. Details of the impact

Since 2014, the underpinning research has produced substantial economic and cultural impacts, as well as helping to break down barriers faced by people with disabilities.

Economic impact

The underpinning research has resulted in a range of commercial products developed in collaboration with two industry partners (see Figure 1).



Figure 1 NGIMU (left), MiMU Gloves (centre) photograph Nathan Gallagher, x-OSC (right)

- [MiMU Gloves Ltd](#) is a London-based technology spin-out incorporated in 2017 to commercially exploit the research produced by UWE (R1 – R6). MiMU develop, manufacture and sell datagloves for music along with software that implements the notion of mapping as a creative endeavour (R6). This feature provides MiMU with a unique selling point - users are able to define the movements with which they perform their music. To date, MiMU has generated more than GBP1,230,000, through a combination of research and development grants (GBP400,000), private investment (GBP380,000), and product sales (GBP450,000) (S1). This income has created employment for 5 UK residents (2.2 FTE) and 20 freelance sub-contractors, and increased turnover for UK manufacturers (S1). In 2018 the [MINI•MU](#), a simplified version of the technology, was made available to children in partnership with [Pimoroni](#), priced at GBP40, with 4680 kits sold to date. In 2019, the MiMU gloves were launched with 170 pairs sold to date.
- [x-io Technologies Ltd](#) is a Bristol-based embedded sensing company who co-developed aspects of the underpinning research in partnership with Dr Mitchell (R3, R4, R5). x-io now develop a range of commercially available devices that exploit the techniques and algorithms contributed by this research. For example, the [x-OSC](#) device is an outcome of this collaboration (R2), which was designed initially for the musical datagloves but can be used within the creative technologies sector more generally. To date, a total of 650 x-OSC devices have been sold, generating over GBP100,000 which have been used for creative installations, performances and teaching (S2). Furthermore, the underpinning wireless communications research (R3, R4) has been critical to the development of the [NGIMU](#), a device that has sold over 4000 units to date (S2) generating over GBP1,300,000 (S2). This work has also contributed to the visibility and growth of x-io Technologies, enabling them to enter new markets in the creative industries, creating employment for long-term subcontractors and sustaining UK design and manufacturing (S2).

Cultural impact

The MiMU gloves are used by a growing number of musicians - becoming a central and highly visible feature of their music performances (see figures 2 and 3). The technology enables unique modes of creative expression and has significantly enriched the creative practice and careers of these musicians, as well as enriching the experiences of their audiences. Selected musicians include Ariane Grande, Imogen Heap and Chagall.



Figure 2 Imogen Heap (left) at 2020 Grammy Awards, Chagall (right) photograph Ben Houdij, both performing with the MiMU gloves technology

- [Ariana Grande](#) is a multi-platinum, Grammy Award-winning recording artist who reached number one in the US album charts with the album *My Everything*. The musical gloves were incorporated into the associated *Honeymoon Tour* in 2015, visiting 81 international cities and attended by a combined audience of 808,667, generating a total of USD42,000,000 (S3).
- [Imogen Heap](#) is a Grammy Award-winning musician, technologist, performer and long-term research collaborator of Tom Mitchell. Having used the glove technology within hundreds of high-profile performances, Heap has become internationally renowned as '*the musician with the gloves*', and has stated that it would now be '*impossible*' for her to perform without them (S4). In 2018/19 Heap brought the *Mycelia Tour* of 20 European and North American cities to a combined audience of 20,000 (S4, S5). Heap notes that '*the technology [...] attracts new audiences to my music which has helped to sustain me as a professional musician*' (S4).
- [Chagall van den Berg](#), a professional musician who has made the gloves technology her '*primary instrument*', has developed a performance called '*Calibration*' which is based entirely on the glove systems (S6). Chagall's career has been transformed by this technology. In 2014, when the technology was first adopted, she had three international performances booked. In 2018, this number had increased to 45 – a combined audience of 70,000 (S6). Chagall notes that the gloves are responsible for '*everything [she has] accomplished as a musician*' (S6).

Accessibility

The underpinning research has also been developed so as to help to erode barriers for people with disabilities, improving access to music performance and enabling people without speech to communicate (see Figure 3).

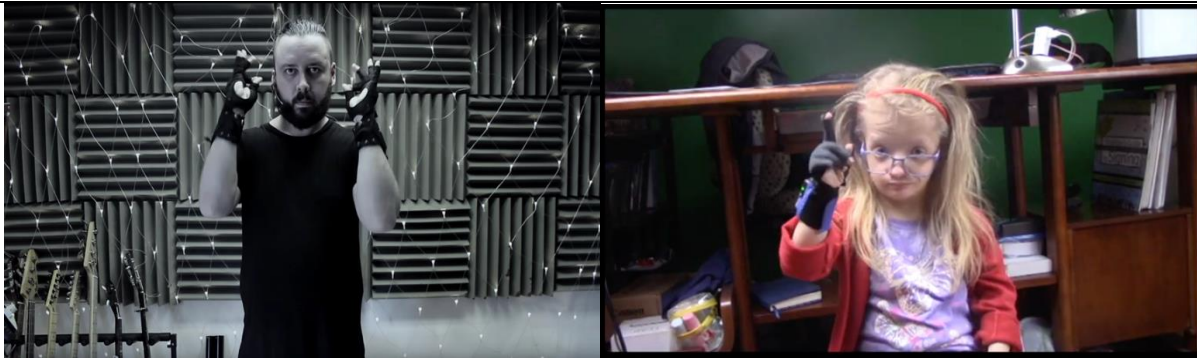


Figure 3 (left) Kris Halpin – ‘That You’ll Never Know (Live MiMU Gloves Performance)’ <http://youtu.be/WNU7JGUwB98>, and (right) Alexis Watson – ‘Alexis’ Thank You to the MiMU Team’ <http://youtu.be/bf5cdHVx53s>

- [Kris Halpin](#) is a musician with cerebral palsy, which affects movement, posture and co-ordination. Facing significant barriers to music and performance, this research and technology has been instrumental in enabling Halpin to work full-time as a professional musician (S7). The interactive machine learning and mapping techniques (R1, R5, R6) enable the glove technology to learn the nuances of a wearer’s movements, enabling musicians with physical disabilities to perform music with a high degree of expression (S7, S8). The removal of these barriers has had a profound and positive influence on Halpin’s wellbeing, who considers the gloves to be ‘*the most important breakthrough in accessible music technology to date*’ (S7). For his work with the glove technology, Halpin has won multiple awards and received funding from Arts Council England, PRS foundation and the National Lottery Heritage Fund to produce his touring show ‘*The Gloves are On*’ (S7).
- The underpinning research is also helping to provide a voice for hearing, non-verbal people. Alexis Wilson (Figure 3, right) is non-verbal and critically ill, having a rare genetic abnormality that results in a number of profound health complications. Alexis communicates using a unique sign language system called VoiceSign, which has been developed specifically for people who are hearing and non-verbal. Because the MiMU gloves enable end-users to train the system to recognise their own gestures, the [VoiceSign](#) organisation, with support from Make-A-Wish Foundation, have been able to work independently to translate their hand-signs to control a speech synthesiser. This has provided a means for Alexis to speak, and has helped to enhance her communication more generally (S9), see <http://youtu.be/bf5cdHVx53s>.

5. Sources to corroborate the impact

- S1 Testimonial from the Managing Director of MiMU Gloves Ltd, London
- S2 Testimonial from the Director of x-io Technologies Ltd., Bristol
- S3 Ariana Grande MiMU Gloves tour and media coverage - collected media
- S4 Testimonial from Imogen Heap, London
- S5 Imogen Heap MiMU Gloves media coverage - collected media
- S6 Testimonial from Chagall van den Berg, Amsterdam
- S7 Testimonial from Kris Halpin, Dordon
- S8 Testimonial from Programme Leader for Research and Development, Drake Music, London
- S9 Impact statement from VoiceSign