

## Impact case study (REF3)

<b>Institution:</b> Goldsmiths, University of London		
<b>Unit of Assessment:</b> 11, Computer Science and Informatics		
<b>Title of case study:</b> AI as Creative Collaborator: empowering human creativity		
<b>Period when the underpinning research was undertaken:</b> 2000-2020		
<b>Details of staff conducting the underpinning research from the submitting unit:</b>		
<b>Name(s):</b>	<b>Role(s) (e.g. job title):</b>	<b>Period(s) employed by submitting HEI:</b>
Mark d'Inverno	Professor	2006-present
Rebecca Fiebrink	Reader	2013-present
Marco Gillies	Reader	2008-present
Matthew Yee-King	Senior Lecturer	2010-present
Simon Colton	Professor	2013-2018
Maria Teresa Llano	Research Associate	2013-2019
Rose Hepworth	Research Associate	2013-present
<b>Period when the claimed impact occurred:</b> August 2013 – December 2020		
<b>Is this case-study continued from a case study submitted in 2014?</b> N		
<p><b>1. Summary of the impact</b>  Research at Goldsmiths Computing has changed how humans collaborate with machines and has opened up new modes of creative expression and performance. These creative experiences and resulting cultural outputs - including a West End Musical attended by 3,000 people, an accompanying two-part Sky Arts documentary seen by several hundred thousand viewers, and live performances for the BBC, New Scientist Festival and one of the UK's leading jazz clubs - have transformed audience and user perspectives on the creative affordance of human/machine collaboration. Our research has also informed the design and manufacture of new kinds of instruments and software for both music professionals and amateur music makers. One spin-out business has produced and sold 60,000 instruments worldwide (including strong international sales in continental Europe, Japan and the US).</p>		
<p><b>2. Underpinning research</b>  The Computing Department at Goldsmiths is unusual in that a large portion of academic staff work professionally as creative practitioners, artists and performers. This professional practice motivates and underpins their computer science research. Indeed, the combination of arts and science practices is tightly interwoven into our research practice, leading to investigations of computing systems/AI's potential to support, challenge, and provoke new forms of creative expression and content generation in the Arts.</p> <p><b>The conceptual underpinning of the role of AI in Human Creative Expression:</b>  Principles for researching the relationship between computation and creativity underpinned a workshop in Dagstuhl, Germany, co-hosted by Mark d'Inverno (with Australian AI researcher and artist Jon McCormack and UK cognitive scientist Maggie Boden) in 2009. The workshop and resulting edited book included contributions from a range of Goldsmiths researchers [R1]. Based on this work, and through their own experiences as arts practitioners, d'Inverno and McCormack set out to explore the critical distinction between conceptualising AI as a stand-alone system able to produce novel content, on the one hand, and as a creative collaborator provoking new kinds of human creative activity, on the other [R2]. This work has deepened our understanding of creativity and how computational technology can be incorporated into human creative processes. The goal is to create systems where the computer is neither an independent generator of creative content nor a simple tool, but instead as a collaborator with its own creative agency.</p> <p><b>Gesture recognition and machine learning for creative musical expression:</b>  Machine learning has typically been designed for use by other machine learning specialists. Rebecca Fiebrink challenged this model with the release of the Wekinator, initially conceived in Princeton in 2009. She later reconceived and rewrote Wekinator at Goldsmiths as part of Rapid-Mix EU Horizon 2020 Innovation Action project, (Fiebrink, 2015-2018 [G2]). The Wekinator software allows anyone to use machine learning to build new musical instruments</p>		

or gestural controllers. The Wekinator interprets and learns from an individual's physical gestures and then adapts these gestures to become an interface for a new musical instrument designed by and for the user [R3].

In 2014, Marco Gillies and Mark d'Inverno took Fiebrink's research ideas into the domain of real-time interaction with supervised machine learning to design a system that reacts to the moment-to-moment interaction of performing artists in dance, movement and music. This work was supported by the EU FP7 PRAISE project grant (d'Inverno & Gillies, 2013-2017) [G3]. The design approach involved a sustained process of participatory design with professional practitioners from the performing arts. This approach allowed users to experience an ongoing 'in the moment' collaborative engagement with the gesture recognition system that had not been possible before. This system shifted control of machine operation from system designers to performers who could explore ways of engaging the system in creative ways and as "*fluid interaction gesture designers*" [R4]. This work's success critically relied on Gillies and d'Inverno having strong embodied knowledge in the performing arts – the practice-based experience providing contextual artistic authenticity and science elements enabling technological innovation.

#### **Collaborative AI in Improvised music performance:**

The idea of an ongoing moment to moment interaction with AI is built into Matthew Yee-King and Mark d'Inverno's research in the design of AI systems to enable improvisation between human and machine in real-time. The goal is to sustain ongoing creative performances allowing new kinds of creative expression. Focusing on human/AI improvisation also requires a moment to moment, sustained collaboration to take place. Yee-King and d'Inverno used machine learning to build statistical musical models of the human improviser which becomes more complex over time, supporting co-improvisation where the human can decide to ascribe creative agency to the machine during performance [R5]. There is a strong practice-based element in this work where, through different kinds of professional performance contexts, d'Inverno as an established and critically acclaimed pianist, takes on the role of musician and improviser. This allows for the performance of jazz compositions written by AI and supporting others to navigate the conceptual, creative and ethical issues involved in using AI to produce new cultural artefacts and performance contexts.

#### **AI systems for collaborative ideation:**

An essential part of most creative processes is ideation or the development of ideas which provide a framework or canvas for creative content generation. In 2013, Simon Colton with Maria Teresa Llano and Rose Hepworth developed the "*What If Machine*" a system that could generate ideas in the form of fictional narratives which could become a basis for human-created artistic artefacts such as a poem, a painting, or a film. The project, funded by an FP7 grant [G1], developed an approach to altering and combining facts from knowledge bases to generate fictional settings that provided a springboard for further artistic development [R6].

### **3. References to the research**

[R1] Jon McCormack and Mark d'Inverno, [Computers and Creativity](#), Springer Verlag, 2012

[R2] Mark d'Inverno and Jon McCormack, [Heroic versus Collaborative AI for the Arts](#), Proceedings of the Twenty- Fourth International Joint Conference on Artificial Intelligence Palo Alto, California: AAAI Press, 2438-2444, 2015.

[R3] Rebecca Fiebrink, [The Wekinator](#), 2015. [website]

[R4] Bruno Zamborlin, Frédéric Bevilacqua, Marco Gillies and Mark d'Inverno. [Fluid gesture interaction design applications of continuous recognition for the design of modern gestural interfaces](#), ACM Trans on Interactive Intelligent Systems, vol. 3, 30-45, ACM Press, 2014 [Submitted to REF2]

[R5] Matthew Yee-King and Mark d'Inverno, [Experience-driven design of creative systems](#), 7th International Conference on Computational Creativity (ICCC 2016), Paris, France 2016.

[R6] Maria Teresa Llano, Simon Colton, Rose Hepworth and Jeremy Gow, [Automated Fictional Ideation via Knowledge Base Manipulation](#). Cogn Comput 8, 153–174, 2016.

\*All references to research are available online or on request.

**Selected research grants**

[G1]: Colton [Scientific Coordinator] [EC Grant WHIM \(FP7 grant 611560\) 2013-2016](#), Goldsmiths allocation, GBP428K (EUR:GBP: 1 Oct 2013).

[G2]: Fiebrink [Co-I], [RapidMix \(real-time adaptive prototyping for industrial design of multimodal interactive expressive technology\)](#), Innovation Action, H2020-ICT Project ID 644862, 2015-2018, Goldsmiths allocation, GBP450K (EUR:GBP: 1 Feb 2015).

[G3] d'Inverno [PI], Gillies [Co-I] [Practice and Performance Inspiring Social Education](#), PRAISE, FP 7, 2012-2016, Goldsmiths allocation, GBP499K (EUR:GBP: 1 Oct 2012).

**4. Details of the impact**

In this REF period, this research has had the following impacts:

**[i] Changed how humans and machines collaborate for creative expression and creative content generation leading to new kinds of outputs and performances**

Our research has led to new cultural performances and productions built on collaborations between human creative and AI machine. In 2015, Yee-King worked with BBC Radio 3 Producer and Programmer, Sushil Dade, and one of the UK's leading saxophone players, Martin Speake, to improvise live on-air with an autonomous AI system. The live show "*Why Music? Live from the Street*", was recorded at the Wellcome Trust in London and broadcast on BBC Radio 3. Dade confirms it was the first time the BBC had ever broadcast a performance between an AI and human improvising together [S1].

In opening up new forms of musical expression and experimentation, Fiebrink's Wekinator software (R3) has been used in dozens of creative projects between humans and machines, a selection of these are detailed on the Wekinator website [S2a]. Examples include use by electronic composer and performer Laetitia Sonami to build her Spring Spyre instrument (performed at Ars Electronica 2020 opening ceremony); Analema Group to build *KIMA: The Wheel* (Roundhouse, London 2016) and in exploring the collaborative potential of computers interacting with human singers, the play *Frida's Ashes*, (Bristol, 2019) used an electronic score mixed by Wekinator [S2b-S2d]. The commercial adoption of Fiebrink's research has also provided new creative opportunities for music performance composition. George Wright used the Wekinator to design a virtual voice-to-midi controller called the Dubler. Wright sells the Dubler through his company Vochlea and user reviews on the website demonstrate its ability to inspire and encourage new musical experimentation: "It has taken my creativity to another level" [S2e, S9].

In 2016, Goldsmith's research on AI-inspired cultural production informed the central premise of *Beyond the Fence*, a west-end musical that, according to the production company's website, Wingspan productions, initially set out with the aim to perform the "first complete show ever to be written by a computer" [S3]. Simon Colton's What-If Machine (WHIM, G1, R6) provided the play's central premise. Executive Director of Wingspan, Archie Baron, confirms that they chose the What-If Machine, "as the tool to propose storylines to the human creative team who led on the overall production of the new musical. This AI-generated output became the central proposition for the musical and from this "Beyond the Fence" was born - inspiring the human creators to set the play at Greenham Common during the anti-nuclear protests of the 1980s" [S4]. The show was performed 15 times at the Arts Theatre in London to an audience of over 3,000 people. Testament to the success of this novel musical production, audience feedback showed that over 86% (of those polled) rated the show highly and a review in the *Independent* newspaper claimed that "Despite my reservations I was won over". Every major UK newspaper reviewed the show and highlighted the show's "unusual origins" in their analysis, with many making explicit reference to the role of the What-If Machine [S3].

**[ii] Changed audience and user perspectives on how human and computers can work together to generate music and performances**

The story behind the making of *the Beyond the Fence* Production was captured in a two-part documentary *Computer Says Show* by Wingspan. This programme first aired on Sky Arts in 2016 and has remained available to view via Now TV and Amazon Prime throughout 2017-

2020. The producers estimate it has been seen by several hundred thousand viewers, impacting viewers' understanding of the creative and ethical questions of using AI systems in the creative process [S4].

The programme fundamentally challenged the audiences' ideas about whether creativity is a uniquely human attribute and gave viewers an “intriguing glimpse into how technology is changing music evolution” (Edgar Jones, Director of Sky Arts). As an advisor on the project, d’Inverno’s research underpinned the Wingspan production team’s perceptions about the creative capacity of computational systems, as Archie Baron explains:

“His [d’Inverno’s] research gave us, the musical’s wider team and later the television audience a conceptual framework that enabled us to frame our specific experiment and television narrative in order to help us tell the right story and more broadly support the audience in grappling with complex ideas, dilemmas and ethics surrounding the wider debate when using computers as lone creatives or as creative collaborators.”

Reflecting on the long-term impact of the project, Baron continues: “[Our project] seems to have become a case study in the wider discourse around the philosophy, ethics and implications of the field – using many of the arguments and frames of reference to which Mark d’Inverno first introduced us” [S4].

Further examples of Goldsmith's research in human/machine collaboration contributing to debates about the use of AI in creative and cultural practices include d’Inverno’s concerts at the New Scientist Live Festival and London’s Vortex Jazz Club (one of the leading jazz clubs in the UK) in 2016. Billed as “the first concert anywhere in the world to consist almost entirely of music composed by computer”, coverage of d’Inverno’s performance at the Vortex was broadcast on the BBC’s News at Ten. The performance created an opportunity for audiences and musicians to reconsider their perception of computers as creative collaborators, as confirmed by two music journalists reviewing the show in *The Times* and *The Verge* [S7]. According to Sumit Paul-Choudhury, commissioning Editor in Chief of the New Scientist at this time, d’Inverno and his band’s performance and subsequent discussion of the potential of machine-human collaboration was received with “delight and puzzlement of the audience”. He went on to say, “I have no hesitation in claiming that it will have made thousands of visitors to the show re-valuate the boundaries of computing” [S5].

Reflecting on Yee King’s improvised performance at *Why Music? Live from the Street* (Wellcome Trust/Radio 3, 2015), producer Sushil Dade, confirms that an experience that “changed the participants’ and audiences’ perspective on how synthetically produced music and improvisation melds and interacts with human music-making” [S1]. (The standard reach of Radio 3 is given as “(000s) 2,070”, Source: RAJAR, Q3 2015.) Yee King’s research on AI and Performance has gone on to inform media debate about ‘deep fake music’ and coverage in the Guardian (9/11/20) and on BBC Radio 5 Live (30/11/20), which has contributed to the public’s awareness of the role that AI can play in changing creative practices [S6].

Finally, in making machine learning more accessible and expanding ethical debate about AI’s role in society, our research has been adopted as an educational tool. According to the Creative Director at Google Creative Lab, Alexander Chen, Fiebrink’s Wekinator enabled him to “interact with machine learning algorithms” for “the first time” and became “one of the points of inspiration” for Google’s Teachable Machine project. This project is being used by ‘teachers across the United States and internationally ... all the way from elementary [through] to college levels.’ Teachable Machines provide “a hands-on way to help spark conversations around the ethics and fairness of AI models” [S7].

**[iii] Impacted the design and manufacture of new kinds of instruments and software for music professionals and amateur musician makers.**

Fiebrink, Gillies and d’Inverno’s research on sustained moment-to-moment interaction with AI were formative to the conceptualisation and development of the Mogeos musical

instrument. A company with the same name commercialised the instrument. According to the company's founder, Bruno Zamborlin, Mogeas is a computational device based on gesture recognition technology that turns the vibrations people make when they touch physical objects into sound. This technology resulted in novel 'instruments' that do not require musical or technical ability to 'play'. To date, Mogeas have sold an estimated 60,000 devices worldwide, including strong sales in continental Europe, Japan and the US. The company has received over GBP 1.5 million from private investors and an excess of GBP 200,000 from Crowdfunding campaigns in 2014, 2015, 2016, generating interest from over three and a half thousand backers. According to Zamborlin:

"The single most important factor that enabled me to gain the trust of the investors has been the fact that I had a working prototype that originated from d'Inverno, Gillies and my research into modern gestural interfaces ... This provided the 'wow' factor needed to raise that initial investments which enabled the consequent snowball effect" [S8].

The revenue indicates the support and enthusiasm for the product, allowing Mogeas to employ up to 25 full-time staff members and expand the business. In 2017, Zamborlin launched a second spin-out, HyperSurfaces, which enables users to transform any object or surface of any material, shape or size into an intelligent device that can recognise physical interactions. Hypersurfaces has attracted a further GBP 2.6 million in private investment, with clients including Daimler, Opp, Bosch-Siemens and Whirlpool. Zamborlin confirms that, to date, devices have been "used for concerts with more than 5,000 people and artistic installations with hundreds of thousands of visitors, inspiring new musical creations, entertaining audiences, introducing the public to new technologies and changing the way people make music" [S8].

In a different commercialisation project, George Wright cites the importance of Wekinator in the Dubler's early proof of concept stage [S9]. Wright went on to establish Vochlea Music in 2017 and now sells the Dubler Studio Kits to an international market including UK, USA, Canada, Australia and New Zealand. Vochlea's commercial sales figures are confidential, however in 2019 a Kickstarter campaign for the Dubler Studio Kit attracted 1,128 investors and raised GBP 218,493 (exceeding its original GBP 50,000 target), which is indicative of the commercial success of the venture [S9].

##### 5. Sources to corroborate the impact

S1: Statement, Sushil Dade, BBC Producer [transcript].

S2: See examples of application of Wekinator in creative practice; a) the [Wekinator website](#) (2016); b) Sonami, '[The Sound of You](#)', Ars Electronica Festival (2020) p.3. c) [Kima: "The Wheel" at Curtain Call](#), Roundhouse, London (2016); d) [Frida's Ashes](#) MAS Productions Bristol (2019); e) [Dubler user reviews](#), Vochlea website (2020) [grouped source].

S3: See, 'Beyond the Fence' and evaluation: a) Wingspan/Sky Arts, 'Computer Says Show' (available on request); b) Wingspan news item, '[Beyond the Fence – the world's first computer generated musical!](#)'; c) Anna Jordanous (2017), '[Has computational creativity successfully made it 'Beyond the Fence' in musical theatre?](#)', *Computational Creativity*, 29/4, pp.350-386 [documentary, article: grouped source].

S3: Statement, Executive Producer, Archie Baron, Wingspan Productions [testimony].

S5: See, a) James Vincent (2016) '[A Night at the AI jazz club](#)' *The Verge* 12 October; b) Oliver Moody (2016) '[Self-taught computers call the tune in jazz club debut](#)' *The Times*, 15 October and, c) statement, Former Editor-in-Chief, New Scientist/Founding Creative Director New Scientist Live, 2016 [articles, testimony: grouped source].

S6: See, Derek Robertson (2020) '[It's the screams of the damned!](#)' *The eerie AI world of deepfake music* *The Guardian*, 9 November; Radio 5 Live (2020), [Colin Murray with Ben Zand](#), 30 November [articles: grouped source].

S7: Google's [Teachable Machines](#) (citation on website/PDF, p.3); statement from Creative Director, Creative Lab, Google [web text and testimony: grouped source].

S8: Statement from Bruno Zamborlin, founder of Mogeas [testimony].

S9: Statement, George Wright, Vochlea Music and Kickstarter campaign; [Dubler Studio Kit: Your voice into MIDI, instantly](#), (2019) [testimony and webs source; grouped source].