

Impact case study (REF3)

Institution: University of Liverpool		
Unit of Assessment: 11 (Computer Science and Informatics)		
Title of case study: AI research co-creates critically-acclaimed AI-inspired art, and increases public awareness and understanding of AI technologies		
Period when the underpinning research was undertaken: 2006 – 2017		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof Katie Atkinson	Lecturer – Professor	2005 – Present
Dr Louise Dennis	Research Associate – Lecturer	2006 – 2020
Prof Michael Fisher	Professor	2001 – 2020
Prof Karl Tuyls	Professor	2013 – 2017
Period when the claimed impact occurred: August 2013 – December 2020		
Is this case study continued from a case study submitted in 2014? No		
1. Summary of the impact <p>AI technologies will transform society over the coming decades. Recognising the importance of raising public awareness and understanding of issues related to ethics, communication, and trust that may arise due to the widespread adoption of such technologies, the University of Liverpool's AI research has underpinned a strategic programme of public engagement that:</p> <ul style="list-style-type: none"> • Inspired and enabled the co-creation of the <i>Sprung a Leak</i> art installation that received wide critical acclaim and engaged [text removed for publication] people at major art galleries and museums in the UK, Belgium, Germany, and Japan. • Increased public awareness and understanding of AI technologies through the creation of interactive robotics outreach workshops that engaged 7,176 people in primary schools, secondary schools, and at science festivals, and the televised Royal Institution Christmas Lecture series that reached over 1.8 million viewers on the BBC. 		
2. Underpinning research <p>This case study is underpinned by research conducted at the University of Liverpool's Computer Science Department on AI, and its application to robotics and law, including the work of:</p> <ul style="list-style-type: none"> • Tuyls and the smARTLab on robot localization, navigation, and collision avoidance; • Fisher and Dennis on the development and use of belief-desire-intention (BDI) agent programming languages; • Atkinson on the development and application of computational argumentation theory in the legal domain. 2.1 smARTLab research on robot localization, navigation, and collision avoidance <p>The smARTLab (swarms, multi-Agent, Robot Technology, and Learning Lab) at the University of Liverpool was founded in 2013. Major research topics include robot perception, navigation, and sensing. Led by Tuyls, the smARTLab team won the 2014 RoboCup@Work [3.1] and the RoCKIn2015@work competitions. Both competitions tested the performance of robots in navigation tasks (in particular, mapping, localization, path planning, and obstacle avoidance), and also in manipulation and transportation tasks. The smARTLab team developed new types of modules for these capabilities which were then combined using state machines.</p> <p>The <i>Sprung a Leak</i> art installation by Cécile B. Evans was created and developed in collaboration with the Unit's smARTLab. Based on methods developed in their research [3.2], the smARTLab team provided advice, implemented technical software, and significantly influenced the final design of the <i>Sprung a Leak</i> art installation. In particular, the research carried out for RoboCup@Work [3.1] enabled the smARTLab team to optimise robot navigation (path planning and obstacle avoidance), synchronization, and human-robot interaction.</p>		

2.2 Research on the development and use of BDI agent programming languages

The Unit has been conducting research in the development and use of BDI agent programming languages for over 15 years. BDI languages represent the decisions taken by a computational agent in terms of the agent's beliefs about the world and its desires about what it wants to achieve. Based on its beliefs and desires, it forms intentions which specify how it plans to achieve its desires given its beliefs. A key output of this research is the MCAPL (Model Checking Agent Programming Languages) Framework [3.3], first published in 2009. The framework has been under continuous development ever since and consists of a toolkit for developing BDI languages together with a model-checker for verifying programs written within the framework. The year 2009 also marked the start of research by Fisher and Dennis into the use of BDI languages to program the core decision making modules in autonomous systems [3.4].

BDI languages tend to be logic-based while autonomous systems naturally involve manipulating continuous information from sensors. Fisher and Dennis proposed the use of an abstraction layer between the BDI decision-maker and the continuous parts of the system [3.5]. In many applications it is the capacity of an autonomous system to make decisions that is the key novel component separating it from traditional cyber-physical systems and so methodologies for verifying this component represent a key advance. The Unit's BDI research directly influenced and underpinned the development of the Lego Rovers and Pyrobots outreach workshops that were created and delivered by Dennis.

2.3 Research on the development and application of computational argumentation theory in the legal domain

The Unit has been conducting research on computational argumentation frameworks and their applications in the legal domain for more than 20 years. In [3.6], Atkinson demonstrated how a computational model of argument could be used to capture reasoning about the facts and application of legal rules to replicate the decision made in a legal case. The case, of Popov v. Hayashi, concerned a dispute in 2001 over possession of a valuable baseball in the US and the research reported in the paper demonstrates how the judge's legal reasoning can be faithfully captured within the computational model. Such models can be transformed into software programs to automatically decide and explain outcomes of legal cases, given the set of facts relevant to a particular case. Atkinson discussed her research on applying legal reasoning to the Popov v. Hayashi case [3.6] in the 2019 Royal Institution Christmas Lecture series.

3. References to the research

3.1. B Broecker, D Claes, J-D Fossel, **K Tuyls**: Winning the RoboCup@Work 2014 Competition: The smARTLab Approach. RoboCup 2014: 142-154. [DOI: 10.1007/978-3-319-18615-3_12](https://doi.org/10.1007/978-3-319-18615-3_12)

3.2. E Cucco, **M Fisher**, **L.A. Dennis**, C Dixon, M Webster, B Broecker, R Williams, J Collenette, **K Atkinson** and **K Tuyls**. [Towards Robots for Social Engagement](#). Workshop on Human-Robot Engagement in the Home, Workplace and Public Spaces (HRE) at IJCAI-2017.

3.3. R.H. Bordini, **L.A. Dennis**, B Farwer and **M Fisher**. Automated Verification of Multi-Agent Programs. Proceedings of Automated Software Engineering (ASE), 2008. IEEE. [DOI:10.1109/ASE.2008.17](https://doi.org/10.1109/ASE.2008.17)

3.4. **L.A Dennis**, **M Fisher**, N.K. Lincoln, A Lisitsa, and S.M. Veres. Declarative Abstractions for Agent Based Hybrid Control Systems. Proc. of Declarative Agent Languages and Technologies (DALT 10), 2010. Springer LNAI 6619. pp 96-111. [DOI: 10.1007/978-3-642-20715-0_6](https://doi.org/10.1007/978-3-642-20715-0_6)

3.5. **L.A. Dennis**, **M Fisher**, N.K. Lincoln, A Lisitsa, S.M. Veres. Practical Verification of Decision-Making in Agent-Based Autonomous Systems. Automated Software Engineering 23(3), 305-359, 2016. [DOI: 10.1007/s10515-014-0168-9](https://doi.org/10.1007/s10515-014-0168-9).

3.6. A Wyner, T Bench-Capon and **K Atkinson** (2007): [Arguments, values and baseballs: Representation of Popov v. Hayashi](#). *Legal Knowledge and Information Systems*. JURIX 2007: The Twentieth Annual Conference, Leiden, The Netherlands, pp. 151-160. Frontiers in Artificial Intelligence and Applications, Vol. 165. IOS Press, Amsterdam, The Netherlands. ISBN: 978-1-58603-810-6.

4. Details of the impact

To raise public awareness and understanding of issues associated with the widespread adoption of AI technologies, the Unit's AI research has underpinned strategic public engagement that has:

- **Inspired and enabled the co-creation of the *Sprung a Leak* art installation** by multi-award-winning artist Cécile B. Evans that toured major art galleries and museums in the UK, Belgium, Germany, and Japan, and engaged [text removed for publication] visitors
- **Increased public awareness and understanding of AI technologies** through robotics outreach workshops and the televised 2019 Royal Institution Christmas Lecture series

4.1 Inspired and enabled the co-creation of the *Sprung a Leak* art installation

To engage the public with ethical issues related to AI technologies, the Unit's computer scientists inspired and enabled the co-creation of the *Sprung a Leak* art installation by internationally-acclaimed and multi-award-winning artist Cécile B. Evans. The *Sprung a Leak* art installation is a three-part, fully-automated play performed by three Pepper robots and three humans [5.1, 5.2]. It explores issues related to the movement of data, AI, and the relationship between humans and machines through an art installation that is part performance and part exhibit. *Sprung a Leak* was born out of a collaboration between Evans, Tate Liverpool, and the smART lab, and was underpinned by the Unit's research on robot localization, navigation, and collision avoidance [3.1, 3.2, 5.2]. Tate Liverpool stated that it "simply wouldn't have been possible without the collaboration with the University of Liverpool" [5.1].

Sprung a Leak opened at Tate Liverpool in October 2016 and ran until March 2017, and engaged [text removed for publication] visitors [5.1]. The exhibition significantly raised public awareness of ethical issues related to AI and robotics for visitors, creating a lasting impact [5.2]. "I still get emails from members of the public who saw *Sprung a Leak* and say that it's really stuck with them on an emotional level," said Evans [5.2].

The collaboration changed creative practice for Tate as an organisation. "*Sprung a Leak* also changed the way in which Tate thinks about the power of digital and AI as well as the ways that it can be used," said Tate Liverpool's Curator of Exhibitions & Displays [5.1]. "This has changed the way in which Tate is thinking about the forms of artistic expression... *Sprung a Leak* allowed the art world to recognise that Tate Liverpool is [supporting] contemporary artists to address issues which are cutting edge" [5.1].

Sprung a Leak at Tate Liverpool was very well received by national and international media, and attracted "20 pieces of coverage within prestigious outlets such as *The Guardian*, *London Review of Books*, and *Berlin Art Link*" [5.1]. Vice Magazine [5.3a] described *Sprung a Leak* as, "a vision of the near-future", offering "a more positive perspective on AI technology."

Sprung a Leak was then exhibited worldwide; first as a solo exhibition at Museum Leuven in Belgium between June 2017 and November 2017 ([text removed for publication] visitors) [5.4], and then as part of large exhibitions at Haus der Kunst in Munich, Germany between March 2018 and August 2018 ([text removed for publication] visitors) [5.3b], and at Art Tower Mito in Ibaraki, Japan between February 2018 and May 2018 ([text removed for publication] visitors) [5.4]. In total, [text removed for publication] visitors engaged with *Sprung a Leak* around the world. "The reaction... within the art world was amazing," said Evans, "we really managed to achieve something unique" [5.2].

At Museum Leuven, *Sprung a Leak* "was a big success with visitors", said their Curator [5.4]. "The robots performing *Sprung a Leak* became the public's favourites at M – Museum Leuven: people would come back several times to show *Sprung a Leak* to friends or family." Due to its success, in 2017 *Sprung a Leak* was "nominated by the Belgian Association of Art Critics as one of the three best shows of the year in Belgium" [5.4].

At Art Tower Mito in Japan, *Sprung a Leak* "made visitors aware of the issues that the advancement of digital technologies, such as artificial intelligence, can also introduce," according to their former Curator who commissioned the installation in 2018 [5.5]. "Thanks to the work of the Liverpool University computer scientists, *Sprung a Leak* was the first time that Pepper robots were able to demonstrate such a high level of activity and wide range of movements to the

Japanese public, which was very unique and innovative... The exhibition was covered by the mainstream press and media in Japan and received positive reviews by many editors from art magazines worldwide. Over two years on, there are still artists and art critics in Japan talking about this exhibition,” said the former Curator at Art Tower Mito [5.5].

Sprung a Leak directly impacted on Evans as an artist, inspiring, and changing her creative practice. *“Sprung a Leak really gave me the confidence to work with very complex networked systems and programming systems, and how that relates to a lot of the ideas and more emotional aspects that my work deals with,”* said Evans [5.2]. *“Sprung a Leak was a powerful collaboration that developed Cecile B. Evans’ artistic practise”,* said the Curator of Exhibitions & Displays at Tate Liverpool [5.1]. *“Her world changed because of the collaboration involving the University of Liverpool”* [5.1].

Evans stimulated and participated in public debates at Tate Liverpool, Museum Leuven, and Haus der Kunst to explore the ethical and social issues related to AI technology and robotics that her work addressed [5.2]. In total, Evans delivered talks dedicated to or featuring *Sprung a Leak* at over 30 major art institutions worldwide, including in China, Switzerland, and the UAE [5.2].

4.2 Increased public awareness and understanding of issues related to AI technologies

To increase public awareness and understanding of ethical issues related to AI technologies, the Unit’s AI researchers embarked upon a programme of public engagement activities which included hands-on robotic outreach workshops that directly engaged 7,176 people, and the 2019 Royal Institution Christmas Lectures that showcased AI and law research to 1.8 million viewers.

Increasing understanding through robotics outreach workshops for schools and science festivals

Underpinned by the Unit’s research on BDI and the MCAPL Framework [3.4], Dennis designed, created, and delivered robotics outreach workshops for schools to provide a real-life application of AI. The outreach workshops comprised of two activities: Lego Rovers and Pyrobots.

Lego Rovers is a bespoke, hands-on robotics and AI outreach workshop that allows young people to navigate their own space rover, learn about time delay effects between the Earth, the Moon, and Mars, and experiment with logical rules based on the Unit’s research on BDI [3.4]. Lego Rovers is delivered in schools to primary and secondary pupils, engaging 4,704 young people between the ages of 7 and 14 between 2015 and 2020 [5.6a]. Lego Rovers is also demonstrated at UK science festivals and events including the Cheltenham Science Festival, Manchester Science Festival, and at the Science and Industry Museum, that engaged a further 1,992 people between 2015 and 2020 [5.6a].

Feedback from teachers indicates that the Lego Rovers workshops stimulated discussions around AI and robotics, created an awareness of the way that robotic systems work, and increased interest and enthusiasm for programming and computer science. *“The workshop was great and in particular the children really enjoyed the scientific discussion about how Lego rovers are similar to those used in space,”* said one teacher, *“They developed their understanding of different inputs and outputs and also it helped them with their debugging skills”* [5.7].

Other school teachers described the workshops as a *“wonderful experience”*, commenting that their children were *“instantly captivated by the LEGO Rovers”*, noted that they *“added to the children’s enthusiasm and enhanced the topic greatly”*, that *“pupils were inspired by... being able to see how robotics were used in real life”*, and that the *“discussions relating to science and space were interesting, relevant and helped to join up their understanding”* [5.7].

Pyrobots is a robotics outreach workshop that engages secondary school pupils with the Python programming language through the control of a small robot using Raspberry Pis (the Initio and the Pi2Go). The workshop is delivered by the Unit’s researchers, either within a classroom or on the University campus, and engaged 480 secondary school children from 2018 to 2020 [5.6a].

The Pyrobots workshop was delivered by Dennis in 2020 as part of the OxNet national access and widening participation initiative *“that engages young people from non-traditional higher education backgrounds”* [5.8]. The OxNet workshop engaged Year 12 pupils from *“regions of social deprivation”* in the North West and London. The pupils were able to put their *“learning into practice and gain invaluable experience in programming and robotics from home. This is thanks*

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to Dr Louise Dennis,” according to OxNet’s Administrator [5.8]. One pupil commented that “with Dr. Dennis and this course, we were able to actually write our own [...] algorithms... until finally we were programming the learning rate of this amazing little robot” [5.8].

The software for Lego Rovers, together with manuals and workbooks, is available for students and teachers to download for free, and has been used by NASA (2014) and the FAIR-SPACE Hub (2019) [5.6b] – the UK’s national research centre on autonomous robotics for space missions. Lego Rovers was featured as an example of outreach best practice in two YouTube videos published by the STEM Ambassador scheme in 2014 that are used as training materials for their UK network of 19 STEM Ambassador Hubs [5.6c].

Increasing public awareness through the Royal Institution Christmas Lecture series 2019

The Royal Institution’s “*engaging and mind-expanding*” annual Christmas lectures for children and adults have been running since 1825, and are also the “*oldest science TV series in the world*.” Recognising her AI and Law research expertise, the Royal Institution invited Atkinson to take part in their final 2019 Christmas lecture, which explored the limits of maths and issues around ethics and trust [5.9]. Atkinson used the Popov v. Hayashi case and her research on modelling it using computational argumentation frameworks [3.6] to engage the public with trust and ethical issues in AI. Atkinson emphasised the need to account for arguments based on social values in AI decision support software for legal applications; a key feature of her research.

“We [were] delighted to have Prof Atkinson contribute to the 2019 Christmas Lectures on the important and engaging topic of trust in AI and Law research and applications,” said the Royal Institution’s Head of Education [5.9]. The lecture was broadcast on BBC Four in December 2019 and streamed on BBC iPlayer for seven days. The broadcast was watched by 1.8 million people and was “one of the most watched factual programmes on BBC Four for the entire year” [5.9], and has since been viewed 44,329 times on the Royal Institution’s YouTube channel [5.10].

5. Sources to corroborate the impact

5.1. Testimonial from the Curator of Exhibitions & Displays at **Tate Liverpool**, evidencing the impact of Sprung a Leak on Tate Liverpool, artist Cécile B. Evans, and the global art community.

5.2. Testimonial from artist **Cécile B Evans**, evidencing the impact of the Sprung a Leak art installation and the impact the collaboration with the Unit made on her creative practice.

5.3. Evidence relating to the touring Sprung a Leak art installation by Cécile B. Evans:

- a) Vice Magazine article, entitled [‘Robots Won’t Destroy Us—Humans Will’: An Artist’s Vision of the Near Future](#), published on 8 January 2017, evidencing the critical reception to Sprung a Leak, [Accessed 7 December 2020].
- b) Emails from **Haus der Kunst** in Munich, Germany, evidencing visitor numbers.

5.4. Testimonial from Curator at **Museum Leuven** in Belgium, evidencing the impact of Sprung a Leak at Museum Leuven.

5.5. Testimonial from former Curator at **Art Tower Mito** in Japan, evidencing the impact of Sprung a Leak at Art Tower Mito.

5.6. Evidence supporting the impact of the Unit’s robotic outreach workshops:

- a) Summary of total engagement numbers for Lego Rovers and Pyrobots (2015-2020).
- b) Webpages from **NASA’s** International Space Apps Challenge and the **FAIR-SPACE Hub**, evidencing their use of Lego Rovers.
- c) **STEM Ambassador** YouTube videos showcasing Lego Rovers as best practice.

5.7. Collated **feedback from teachers** on the impact of the Unit’s robotic outreach workshops.

5.8. Testimonial from Administrator at the **OxNet** widening participation initiative, evidencing the impact of robotic outreach workshops delivered in April 2020.

5.9. Testimonial from Head of Education at the **Royal Institution**, evidencing the impact of Atkinson’s participation in the 2019 Christmas lectures.

5.10. Screenshot of the views for the third 2019 **Royal Institution Christmas lecture** on YouTube to evidence the reach of Atkinson’s appearance [captured on 16 December 2020].