Institution: Aberystwyth University

Unit of Assessment: 11: Computer Science and Informatics

Title of case study: Robots for the Real World

Period when the underpinning research was undertaken: 2009-2020

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:
Professor Dave Barnes	Reader; Professor	1 August 2005- 25 July 2014
Dr Fred Labrosse	Lecturer; Senior Lecturer	1 September 2000- present
Professor Mark Lee	Professor	1 September 1974- 31 March 2014; 1 April 2015- 30 June 2018
Dr Helen Miles	Lecturer	1 August 2019– present
Dr Mark Neal	Lecturer; Senior Lecturer	1 September 1997- 31 August 2017
Dr Patricia Shaw	Lecturer	1 September 2013– present
Professor Qiang Shen	Professor	1 August 2004- present

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Aberystwyth University's Intelligent Robotics research group (IRG) has substantial expertise in producing integrated hardware and software systems for real-world applications with significant impact, including in the space industry. Members of IRG are responsible for developing several key systems of the ExoMars programme and providing data for industry partners. Furthermore, they have been actively engaging with the general public. Through varied activities appealing to a diverse range of audiences along with the award-winning robotics club, they have interacted with thousands of people inspiring youngsters and changing perspectives on the future and potential of robotics.

2. Underpinning research (indicative maximum 500 words)

The Computer Science (CS) department at Aberystwyth University (AU) has a long track record of research in robotics since the Department was formed, with 2020 marking its 50th Anniversary. During this time, AU's robotics research has played a significant role in a wide variety of applications from sea all the way to space, with an overarching theme of operating in unconstrained environments, with strong interdisciplinary collaborations. IRG includes researchers who provide a wealth of expertise in the areas of robotics, optics, computer graphics, and computer vision, enabling the effective development of integrated hardware/software systems for the real world.

In particular, IRG has developed many systems for real-world applications in collaboration with end-users, which are internationally recognised. For example, survey robots were developed and deployed with world-leading geographers to allow better and more frequent data acquisition, including a survey boat to safely and accurately build 3D models of calving glaciers in Greenland [3.1] and a survey off-road vehicle to build 3D models of flooding riverbeds in New Zealand, which was made possible thanks to the automation of the data acquisition [3.2]. Our work on autonomous passive vision-based driving on tracks was integrated in QinetiQ's solution to the Dstl Autonomous Last Mile Resupply project [3.7]. A planetary scouting rover was developed and tested, containing state of the art hardware and software systems to follow a pre-established plan and opportunistically look for science and re-plan accordingly, in an EU-funded international collaboration [3.3; 3.8]. Work on planetary science detection was also carried out with a number of novel methods, for example Mars image interpretation [3.4] and visualisation [3.5]. Fundamental research on robot learning inspired by infant development was also carried out, with significant EPSRC support [3.6; 3.9]. The research conducted by IRG is recognised internationally, with industrial endorsement and both direct and indirect contributions.

A main theme of our robotics research is conducted through international collaboration with space industry. Initially led by Barnes, IRG was involved in several aspects of the 2003 British Beagle 2 Mars Lander, and owing to the expertise gained, the group now has key roles to play within the ESA/Roscosmos ExoMars rover mission. Barnes passed away in 2014, but IRG continued and extended this research. This includes work on three of the rover instruments, including the Panoramic Camera (PanCam) [3.4], designing and implementing radiometric and colourimetric image processing pipelines, and software to work with the images. The need to design, develop and test the calibration procedures and image processing software led to the group building the Planetary Analogue Terrain Laboratory (PAT Lab) **Error! Reference source not found.**(through funding from the Higher Education Funding Council for Wales, Science Research Investment Fund) and AU PanCam Emulator (AUPE) which functionally mimics the detector, optics and filter wheel elements of the eventual flight instrument. Through the development of AUPE, new expertise in the area of optics and multispectral imaging were gained, along with collaborations with physicists, geologists and astrobiologists who want to develop the procedures for using PanCam to search for life on Mars. Since its initial creation in 2009, AUPE has been through three major cycles of development and has participated in over 15 field trials across the world (e.g.,[3.3]).

3. References to the research (indicative maximum of six references)

3.1 **M Neal**, T Blanchard, A Hubbard, N Chauche, CR Bates, J Woodward, "A Hardware Proof of Concept for a Remote-Controlled Glacier-Surveying Boat." Journal of Field Robotics, 29(6), pp. 880–890, 2012. DOI: 10.1002/rob.21420

3.2 R Williams, J Brasington, D Vericat Querol, DM Hicks, **F Labrosse**, and **M Neal**. "Chapter Twenty - Monitoring Braided River Change Using Terrestrial Laser Scanning and Optical Bathymetric Mapping." Developments in Earth Surface Processes, Geomorphological Mapping: Methods and Applications. MJ Smith, P Parson and JS Griffiths (eds.). Elsevier, Vol. 15. p. 507–532, 2011. DOI: 10.1016/B978-0-444-53446-0.00020-3

3.3 G Paar, M Woods, C Gimkiewicz, **F Labrosse**, A Medina, L Tyler, **D Barnes**, G Fritz, and K Kapellos. "PRoViScout - a Planetary Scouting Rover Demonstrator". In Proc.SPIE; Intelligent Robots and Computer Vision XXIX: Algorithms and Techniques, 2012. DOI: 10.1117/12.906122

3.4 C Shang and **D Barnes, "**Fuzzy-rough feature selection aided support vector machines for Mars image classification", Computer Vision and Image Understanding, 117(3), pp. 202–213, 2013. DOI: 10.1016/j.cviu.2012.12.002

3.5 **H Miles**, M Gunn, A Coates**, "**Seeing Through the "Science Eyes" of the ExoMars Rover", IEEE Computer Graphics and Applications, 40(2), pp. 71–81, 2020. DOI: 10.1109/mcg.2020.2970796

3.6 J Law**, P Shaw, M Lee,** and M Sheldon, "From Saccades to Grasping: A Model of Coordinated Reaching Through Simulated Development on a Humanoid Robot", IEEE Transactions on Autonomous Mental Development, 6(2), pp. 93–109, 2014. DOI: 10.1109/TAMD.2014.2301934

Example Research Grants

3.7 **F Labrosse** "Autonomous Last Mile Resupply Phase 2 - Autonomous road driving", QinetiQ, 2018**–**2019, GBP88,452.00.

3.8 **D Barnes** (PI, Led by Joanneum Research), **F Labrosse**, **M Neal** "PRoViScout: Planetary Robotics Vision Scout", EU FP7 2009**–**2012, EUR237,000.

3.9 **Q Shen**, **M Lee**, **P Shaw** "Developmental Algorithms for Robotics", EPSRC, 2015**–**2018, GBP559,077.

3.10 **F Labrosse** "Technocamps", ESF/WEFO 2011–2013, GBP1,200,000 (AU's budget, in collaboration with Swansea, Bangor, and Glamorgan universities).

3.11 M Kurki, **P Shaw** "From Grassroots Robotics to Sustainable Development: Robotics Clubs, Informal Education and Technological Development in Iraq", CIDRA Seed Grant, Higher Education Council of Wales 2019**–**2020, GBP11,800.

3.12 **F Labrosse** "ExoMars Mars Terrain Simulator", ALTEC / DATASAT Europe Ltd. 2015**–** 2017, GBP115,000.

4. Details of the impact (indicative maximum 750 words)

Contributions to International Space Industry

IRG has "played a key role in the development, calibration, and testing of PanCam and ISEM" [5.1], impacting on commerce and the economy, contributing to innovation and entrepreneurial activity in the UK and European Space Industry through the design and delivery of the Mars Terrain Simulator (MTS) and AU PanCam Emulator (AUPE). This work has also led to impacts on practitioners and delivery of professional services: AUPE allows industrial (as well as academic) collaborators across Europe to develop new processes and methods to analyse the data from PanCam, with IRG providing consultancy for a number of projects, while MTS is used by industrial European and Russian research collaborators involved in the ESA ExoMars mission to improve their techniques and processes [5.1][5.2]. IRG's "quick and efficient work […] has enabled industrial contractors to maintain their tight schedule" and due to the results produced, ESA "have great confidence in the flight instruments' ability to fulfil their mission objectives" [5.1].

> *"[T]he involvement of AU staff in preparing ExoMars has and continues to be fundamental for improving mission design, processes, streamlining operations, and getting us closer, in the not too distant future, to hopefully being able to find traces of life on Mars" [5.1].*

Leading experts at Joanneum Research (JR) conclude that IRG "continues to be one of the most important international R&D partners of the JR Space Robotics and Instruments team" [5.2].

IRG was awarded the contract to produce the sensor systems for the Mars Terrain Simulator MTS, based at ALTEC in Italy 0[5.3]. Pre-launch, MTS facilitates the testing of aspects of

missions, and post-launch, MTS is set to be used to practice and troubleshoot operations during the mission, "provid[ing] a key capability for ground testing during the surface mission" [5.1]. "[W]orking with the [IRG], has allowed [5.4] to develop a facility that is essential to technical aspects of the ExoMars mission, but also allows public engagement activities centred around the mission" [5.4]. Another internationally renowned contribution is based on IRG's powerful 'Shape from Shading' computer software to provide detailed 3D images of the area on Mars (from images taken by the HiRISE camera on NASA's Mars Reconnaissance Orbiter) where the Beagle 2 Mars Lander (which was lost on Christmas Day 2003) were believed to have landed. This has successfully led to the discovery of the remains of Beagle 2 in the proximity of that area in 2015, as reported by BBC [5.9].

> *"AUPE has underpinned over a decade of field trials in preparation for Rosalind Franklin's mission [and] has allowed developing analysis tools and techniques, rehearsing operations, and training investigators. [AU's] development of an instrument for field testing has proven critical for the design and success of the mission"* [5.1].

> *"AUPE has been used for numerous laboratory and field trials over the last decade, which have provided test and reference data for [JR's] processing pipelines and analysis tools, provided benchmark data for end-to-end validation of workflows and support for field test campaigns to rehearse mission operations and train operators, and enabled industry to calibrate rover instruments, validate the calibration assets, and verify the instruments' performance"* [5.2].

Engagement with Robotics for STEM Development

IRG has made a profound impact on the understanding, learning and participation of science and engineering through organising and regularly taking part in a variety of events to showcase current robotics research with the general public. This has allowed us to target different types of audiences in age, gender, and geographical location, with different levels of understanding and preconceptions about robotics. In the four years between 2016 and 2019, we have visited over 70 different schools and colleges across the UK engaging over 7,000 children of different ages, as well as speaking to nearly 30,000 members of the general public at various events [5.5] and contributing to a national outreach programme which has reached over 310,000 visitors to science museums across the UK [5.6].

In 2013 the Aberystwyth Robotics Club [5.7] was established for STEM engagement with local school children (initially as part of the Technocamps project delivery 0), teaching a wide range of skills for developing robotics systems and inspiring future generations of scientists and engineers. From the first intake of students, over 2/3rds have since gone on to pursue degrees in STEM subjects. The Club has won national awards for STEM engagement, including an award for the Best Use of a STEM Ambassador in the 2016 STEM Clubs Week involving approximately 3,000 schools across the UK, showcasing the creativity, problem-solving and employability skills that STEM activities offer. IRG's initiatives in developing Robotics Club has provided a template for the establishment of clubs elsewhere. The most recent was created through funding for international development to form a robotics club with 20 local school children in Karbala, Iraq, engaging and addressing social and political divides 0.

The form of our robotics research-led public engagement activities range from traditional talks and Q&A sessions, to Film and Panel discussions during the annual Robotics weeks from 2018 to 2020; raising awareness of, and showcasing, state of the art of robotics research and applications via actively participating in events such as Jodrell Bank's bluedot festival and the National Eisteddfod of Wales Science Village (attendance approximately 150,000 annually) and UKRI-organised science and engineering promotion activities [5.5]. IRG won the first prize in EPSRC Science People Photo Competition consecutively in 2015 and 2016, and the third prize in 2017 (Figure 1), cherishing outstanding achievements of UK engineering and physical

sciences. This led to radio and TV appearances, including an ITV programme on "My Robot Helper" (April 2018). The long-term impact of these events is evident from the feedback attained

> *"I attended the film and Q+A for the robotics week last year which initially sparked my interest in robots and artificial intelligence. I returned this year with a greater understanding… Both events significantly increased my interest in robotics and have inspired me to pursue my own research on the topic."* [5.8]

Figure 1: 'iCub and Eve' taken by Sandy Spence, People and Skills, Engineering and Physical Sciences Research Council (EPSRC) science photography competition 2017

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1 Letter from ExoMars Project Scientist, European Space Agency (ESA)
5.2 Letter from pace Robotics and Instruments Team Lead, Joanneum Research (Austria)
5.3 Letter from Director of Datasat (UK)
5.4 Letter from ROCC programme manager at ALTEC (Italy)
5.5 Visitor engagement numbers, 2016-2019
5.6 Letter from the Space and Physics Project Manager, Association of Science and Discovery Centres (UK)
5.7 Robotics Club Information
5.8 Feedback from Robotics Week
5.9 Email regarding discovery of Beagle2 and image analysis work