Australian Government
Australian Research Council

EI 2018 ENGAGEMENT AND IMPACT

Engagement and Impact 2018

University of Technology Sydney

UTS09 (ST) - Impact

Overview

Title

(Title of the impact study)

The robotic future of abrasive blast cleaning – keeping maintenance workers safe

Unit of Assessment

09 - Engineering

Additional FoR codes

(Identify up to two additional two-digit FoRs that relate to the overall content of the impact study.)

Socio-Economic Objective (SEO) Codes

(Choose from the list of two-digit SEO codes that are relevant to the impact study.)

88 - Transport
86 - Manufacturing
87 - Construction

Australian and New Zealand Standard Industrial Classification (ANZSIC) Codes

(Choose from the list of two-digit ANZSIC codes that are relevant to the impact study.)

31 - Heavy and Civil Engineering Construction
69 - Professional, Scientific and Technical Services (Except Computer System Design and Related Services)
23 - Transport Equipment Manufacturing
24 - Machinery and Equipment Manufacturing
32 - Construction Services
94 - Repair and Maintenance

Keywords

(List up to 10 keywords related to the impact described in Part A.)

Robots

Grit-blasting

Robotic automation

Infrastructure

Maintenance

Bridges

Maritime

Sensitivities

Commercially sensitive

No

Culturally sensitive

No

Sensitivities description

(Please describe any sensitivities in relation to the impact study that need to be considered, including any particular instructions for ARC staff or assessors, or for the impact study to be made publicly available after EI 2018.)

Aboriginal and Torres Strait Islander research flag

*(Is this impact study associated with Aboriginal and Torres Strait Islander content?
NOTE - institutions may identify impact studies where the impact, associated research and/or approach to impact relates to Aboriginal and Torres Strait Islander peoples, nations, communities, language, place, culture and knowledges and/or is undertaken with Aboriginal and Torres Strait Islander peoples, nations, and/or communities.)*

No

Science and Research Priorities

(Does this impact study fall within one or more of the Science and Research Priorities?)

Yes

Science and Research Priority	Practical Research Challenge
Advanced manufacturing	Cross-cutting technologies that will de-risk, scale up, and add value to Australian manufactured products.

Impact

Summary of the impact

(Briefly describe the specific impact in simple, clear English. This will enable the general community to understand the impact of the research.)

In collaboration with NSW Roads and Maritime Services (RMS) from 2006-2013, this project formulated breakthrough solutions - including sensing technology, exploration and mapping algorithms, collision avoidance method and planning algorithms - that facilitated the development of an autonomous abrasive blasting robot, a world first. Two such robots have been deployed since 2013 to carry out maintenance of the Sydney Harbour Bridge (SHB). The technology has revolutionised steel bridge maintenance, minimising the time workers are exposed to OHS risks from abrasive blasting, while improving efficiency, productivity and quality. The start-up SABRE Autonomous Solutions has been commercialising this technology since 2013, tapping into the $1.2 billion global abrasive blasting market.

Beneficiaries

(List up to 10 beneficiaries related to the impact study)

1) Roads and Maritime Services NSW

2) SABRE Autonomous Solutions Pty Ltd

3) Burwell Technologies Pty Ltd

4) Clemco Industries Corporation

Countries in which the impact occurred

(Search the list of countries and add as many as relate to the location of the impact)

Australia
France
United States of America

Details of the impact

(Provide a narrative that clearly outlines the research impact. The narrative should explain the relationship between the associated research and the impact. It should also identify the contribution the research has made beyond academia, including:
- who or what has benefitted from the results of the research (this should identify relevant research end-users, or beneficiaries from industry, the community, government, wider public etc.)
- the nature or type of impact and how the research made a social, economic, cultural, and/or environmental impact
- the extent of the impact (with specific references to appropriate evidence, such as cost-benefit-analysis, quantity of those affected, reported benefits etc.)
- the dates and time period in which the impact occurred.

NOTE - the narrative must describe only impact that has occurred within the reference period, and must not make aspirational claims.)

UTS robotics research is helping define the future of abrasive blasting and has already had a significant impact on how the iconic Sydney Harbour Bridge (SHB) is maintained.

Abrasive blasting is regularly used across many industries to remove rust, scale and paint for surface preparation. It involves accelerating grit (typically garnet or steel shot) with compressed air or water through a blasting nozzle, to provide a stream of high-velocity particles to clean surfaces such as steel bridges or provide a texture to poured concrete.

The blasting process is an important and necessary part of manufacturing and maintenance work but presents a significant risk to workers, who may be exposed to fine dust, lead-based paint or asbestos, as well as injury and fatigue. Studies have shown that proximity to dust and the number of times workers are exposed - particularly without suitable protective equipment - can substantially increase health risks. For example, Conroy et al (1996) found that, over three blasting seasons, 18 of 22 workers surveyed had blood lead levels above 25ug/dl, far exceeding Australian workers' exposure standard of 10ug/dl.

NSW Roads and Maritime Services (RMS) wanted to minimise the time its workers were exposed to hazardous abrasive blasting at the SHB maintenance site; however, no solutions suitable for that complex environment existed. With manual blasting, three workers were required at the site at all times, to deploy the blasting gun and provide safety back-up if necessary. The work was physically demanding, with workers requiring regular breaks. They had to wear full protective gear and safe breathing equipment to avoid inhaling lead particles.

After seven years of intensive R&D, the world's first autonomous grit-blasting robots (each operating one blasting gun) began work on the SHB in 2013. Over 150 days, they blasted about 3500 square metres of steel surfaces, equivalent to nearly 16 tennis courts. Work practices were reviewed and changed as a result, with workers no longer required within the blasting environment (except to hand-blast small areas which the robots cannot reach). One worker monitors and supports the operation of up to two robots at a time.

The robots have brought significant productivity gains, particularly when performing tasks difficult for manual workers, such as blasting hard to reach areas. In such environments, where workers are limited by fatigue and the need to concentrate on the blasting direction, the robots can be up to six times more productive per hour - meaning an area can be covered in a fraction of the time (with the associated cost reductions), or a significantly greater area can be covered at the same cost (with the associated additional value for end-users).

The biggest advantage, though, is a dramatic reduction (up to 90%) in worker exposure time, compared to manual blasting. While no data is available yet on the decrease in OHS incidents, removing workers from the potentially dangerous blasting environment has clear safety benefits, which also result in cost savings.

The robots' deployment in the field to improve worker safety has inspired efforts to further develop the technology for wider applications. A testament to this research's economic impact is the technology's successful commercialisation.

In 2013, UTS spin-out company SABRE Autonomous Solutions Pty Ltd was formed to commercialise the technology, with major investment from Australian company Burwell Technologies. SABRE has raised more than $2m to fund the commercial development of the technology and establish international distribution.

“When we saw what the robots were capable of doing, we knew we were witnessing the future of the abrasive blasting industry and [we] had to be involved in taking the technology to the world market," says Damian Williams, SABRE's CEO and a Burwell director.

SABRE has four staff focusing on commercial development and has achieved the first commercial product sales of three robot systems into the US and France, generating approximately $500,000 in revenue. It has also established a distribution partnership with the world’s largest abrasive blasting equipment and supplies company, Clemco Industries Corporation.

Clemco and SABRE are integrating the robots into a system able to blast inside hazardous confined spaces, meaning workers will no longer need to operate inside those spaces - an innovation attributable to the technology developed through UTS research.

The robots are being used in other commercially-in-confidence applications. One of Europe’s largest surface preparation and rehabilitation contracting companies is using them to rehabilitate a series of large lock-gates, where workers previously had to operate inside confined spaces to blast surfaces manually.

An American company is working with SABRE to adapt the technology to blast inside large water storage tanks. It currently deploys more than 100 crews nationally to maintain more than 6000 tanks, resulting in lengthy employee exposure inside the tanks during blasting.

These applications demonstrate that the technology is addressing a key challenge in the international abrasive blasting industry. For the first time, there is a practical alternative to placing workers at prolonged risk through manual blasting. As a result, end-users have enjoyed, and will enjoy, cost savings from fewer workplace injuries and illnesses, as well as substantial productivity gains.

With interest in the robots gaining momentum worldwide, SABRE has contracted research back to UTS to help with the next stage of technology development: multi-robot collaboration and robot inspection of blasting quality in real-time. The collaboration is helping to ensure SABRE stays at the forefront of the development of autonomous technologies for hazardous work environments, with the company further refining the core technology so it can be adapted for other markets and for applications other than the SHB.

Associated research

(Briefly describe the research that led to the impact presented for the UoA. The research must meet the definition of research in Section 1.9 of the EI 2018 Submission Guidelines. The description should include details of:
- what was researched
- when the research occurred
- who conducted the research and what is the association with the institution)

For robots to function in unknown, unstructured, complex 3D environments, more sophisticated sensing and control solutions and enabling methodologies were needed. Research challenges included:

[A]. Robotic exploration of complex structural environments, 3D map building and environmental awareness. Many structures lack CAD drawings. Formulating knowledge (i.e. a map) of the environment is crucial for a robot to operate. A sampling-based exploration approach, a surface growing algorithm for map building and a simultaneous mapping and surface identification method were developed and implemented in the robotic systems.

[B]. Efficient on-line planning: For the robot, the environment is continually changing, since it needs to move its blasting from section to section. Efficient and rapid algorithms for grit blasting and robot motion planning were developed and implemented.

[C]. Real-time collision detection and avoidance: In a complex structural environment, collision detection and avoidance are critical. A 3D force field method and a collision detection method have been developed for effective, real-time collision detection and avoidance, enabling the robot to automatically explore an unknown or partially known complex environment safely.

Since 2006, the UTS-RMS collaboration has yielded four PhD completions, two Masters' Degrees and 16 undergraduate projects, 27 journal and conference papers, two best paper awards, two research excellence awards and one patent application.

FoR of associated research

(Up to three two-digit FoRs that best describe the associated research)

09 - Engineering

References (up to 10 references, 350 characters per reference)

(This section should include a list of up to 10 of the most relevant research outputs associated with the impact)

[1]. Andrew To, Gavin Paul and Dikai Liu (2016), “An approach for identifying classifiable regions of an image captured by autonomous robots in structural environments”, Robotics and Computer-Integrated Manufacturing, Vol.37, pp. 90-102, Feb. 2016 DOI: 10.1016/j.rcim.2015.07.003

[2]. G. Paul, D.K. Liu, N. Kirchner and G. Dissanayake (2009), “An effective approach to simultaneous mapping and surface-type identification of complex 3D environments”, Journal of Field Robotics, Vol 26, Issues 11-12, Nov-Dec, pp. 915-933 DOI: 10.1002/rob.20317

[3]. Andrew To, Gavin Paul, Dikai Liu (2014), “Surface-type classification using RGB-D”, IEEE Transactions on Automation Science and Engineering, Vol. 11, Issue 2, pp. 359-366, April 2014 DOI: 10.1109/TASE.2013.2286354

[4]. G. Paul, N.M. Kwok, D.K. Liu (2013), “A novel surface segmentation approach for robotic manipulator-based maintenance operation planning, Automation in Construction, Vol. 29, pp. 136-147 DOI: 10.1016/j.autcon.2012.08.007

[5]. P. Chotiprayanakul, D.K. Liu, G. Dissanayake (2012), “Human-robot-environment interaction interface for robotic grit-blasting of complex steel bridges”, Automation in Construction, Vol. 27, pp. 11-23 DOI: 10.1016/j.autcon.2012.04.014

[6]. N. Kirchner, D. Hordern, D.K. Liu and G. Dissanayake (2008), "Capacitive sensor for object ranging and material type identification", Sensors and Actuators A: Physical, Vol.148, Issue 1, pp. 96-104 DOI: 10.1016/j.sna.2008.07.027

[7]. G. Paul, S. Webb, D.K. Liu and G. Dissanayake (2011), “Autonomous Robot Manipulator-based Exploration and Mapping System for Bridge Maintenance”, Robotics and Autonomous Systems, Vol. 59, Issues 7-8, July-August, pp. 543-554 DOI: 10.1016/j.robot.2011.04.001

[8]. N. Kirchner, D.K. Liu, G. Dissanayake (2009), “Surface type classification with a laser range finder”, IEEE Sensors Journal, Vol. 9, No. 9, pp.1160-1168 DOI: 10.1109/JSEN.2009.2027413

[9]. N. Kirchner, D.K. Liu, G. Dissanayake (2006), “Bridge maintenance robotic arm: capacitive sensor for obstacle ranging in particle laden air”, Proceedings of the 23rd International Symposium on Automation and Robotics in Construction 2006 (ISARC 2006), October 3-5, 2006, Tokyo, Japan, pp. 596-601, Best Paper Award DOI: 10.22260/ISARC2006/0112

[10]. P. Chotiprayanakul, D.K. Liu, D. Wang, G. Dissanayake (2007), “A 3-dimensional force field method for robot collision avoidance in complex environment”, Proceedings of the 24th International Symposium on Automation and Robotics in Construction (ISARC 2007), 19-21 Sep 07, India, pp.139-145, Best Student Paper Award DOI: 10.22260/ISARC2007/0026

Additional impact indicator information

Additional impact indicator information

(Provide information about any indicators not captured above that are relevant to the impact study, for example return on investment, jobs created, improvements in quality of life years (QALYs). Additional indicators should be quantitative in nature and include:
- name of indicator (100 characters)
- data for indicator (200 characters)
- brief description of indicator and how it is calculated (300 characters).)

Name

Awards won

Indicator Data

2013 Engineering Excellence Awards Sydney (R&D category), Engineers Australia, “Autonomous Robotic Systems for Steel Bridge Maintenance” UTS/RMS; R&D, Control Systems & Communication categories

Indicator Description

Engineers Australia, “Autonomous Robotic Systems for Steel Bridge Maintenance” UTS/RMS; R&D, Control Systems & Communication categories

Name

Awards Finalists

Indicator Data

Finalists for three awards - AEEA, Australian Museum Eureka Prize, IEEE/IFR Invention & Entrepreneurship in Robotics and Automation

Indicator Description

(1) 2013 Australian Engineering Excellence Awards (AEEA)
(2) 2013 Australian Museum Eureka Prize for Innovative Use of Technology
(3) 2013 IEEE/IFR Invention & Entrepreneurship in Robotics and Automation (IERA) Award (one of the three finalists)

Name

Patents

Indicator Data

Provisional patent.

Indicator Description

Provisional Patent No 2007904898 (software) - 10/9/07 - N. Kirchner, D.K. Liu, G. Dissanayake, “An algorithmic extension to laser based range finders that introduces the novel function of non-contact material type identification”