Institution:
Glasgow Caledonian University

Unit of Assessment:
UoA 11 - Computer Sciences and Informatics

Title of case study:
Computer Vision and Machine Learning for Structural Condition Monitoring

Period when the underpinning research was undertaken:
June 2015 - Present

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 Gordon Morison	Head of Dept. Computing	2010 - present
Professor Mike Mannion	Acting Dean	2000 - present
Dr Mark Jenkins	Lecturer, Computing	2015 - present
Professor Tom Buggy	Professor of Computing	1996 - 2018

Period when the claimed impact occurred:
2015 - present

Is this case study continued from a case study submitted in 2014?
No

1. Summary of the impact

Research into the application of Computer Vision and Machine Learning to Structural Condition Monitoring has provided impact through a change in methods utilised in inspection of structures such as railway tunnels, negating lengthy human exposure to potentially hazardous environments, minimising time and manpower requirements onsite and allowing for the time-consuming elements of the inspection to be completed remotely. This new approach allows skilled examiners to inspect more structures than they would be able to traditionally, ultimately leading to an increase in the safety of the general public who benefit from safer infrastructure as a result of this technology.

2. Underpinning research

Morison et al. have been working in the field of Computer Vision and Machine Learning for Structural Condition Monitoring for over 5 years and have made significant progress in the field. This work began in 2015 with a Knowledge Transfer Partnership (KTP) with Geckotech Solutions Ltd, a Specialised Access Solutions company, who in 2015 focused on the development of a data acquisition system and software package to assist examiners with the visual inspection and condition monitoring of railway tunnels.

This project focused primarily on effective data collection of the internal structure of railway tunnels and also included preliminary image processing-based analysis tools [R1, R2]. This involved the collection of visible and thermal spectrum data which was processed off-site using bespoke software packages developed during the KTP. This software consisted of several elements (including image processing and computer vision algorithms for automatic change detection, structure from motion and 3D modelling [R2, R3]) designed to present data to inspection engineers and clients or asset owners. This technology allows for the assessment of the structure to be completed remotely, with only the data collection requiring site access (utilising less manpower and on-site time which are both costly with site access alone costing several thousand pounds per shift) with the aim of increased efficiency and a higher quality of service for customers, as well as improved health and safety for the engineers in the field.

This led to continued research at both the industrial partner and the university. A second KTP, an Industrial Doctorate project funded by The Data Lab and a GCU PhD studentship (as well as numerous undergraduate and postgraduate projects) totalled £531k of funding. At this point, the focus of the research shifted significantly from data collection and traditional image processing analysis to the application of Artificial Intelligence and Deep Learning techniques to automate the assessment of surface conditions in structures [R4, R5].

To maximise the benefit of the analytics provided, focus was also given to visualisation of the output of these algorithms in a manner which is understandable and, most importantly, of benefit to the expert examiners and our customers who must be able to make maintenance decisions based on the information presented. This work in the 3D visualisation and Virtual Reality space focuses on extracting the information generated from our Deep Learning algorithms and projecting it onto detailed 3D models of the structures. This allows both examiners and customers to view the structures in 3D on their computers or using Virtual Reality hardware.

GCU have continued to work in the Structural Condition Monitoring space and new partnerships for further improving health and safety in the field are being formed. Two PhD projects running in the field (one in Artificial Intelligence and the other in Data Visualisation) continue to produce quality outputs with the most recent publication in the Digital Signal Processing journal [R6].

3. References to the research

- R1. Carr, T.A., Jenkins, M.D., Insa-Iglesias, M., Buggy, T. and Morison, G. "Road Crack Detection using a Single Stage Detector Based Deep Neural Network." In Environmental Energy and Structural Monitoring Systems (EESMS), 2018 IEEE Workshop on, IEEE 2018. Peer-Review Process: Anonymous. Citations to Date: 13 (Google Scholar).

- R2. Jenkins, M.D., Buggy, T. and Morison, G. "An Imaging System for Visual Inspection and Structural Condition Monitoring of Railway Tunnels" In Environmental Energy and Structural Monitoring Systems (EESMS), 2017 IEEE Workshop on, IEEE 2017. Peer-Review Process: Anonymous. Citations to Date: 10 (Google Scholar).

- R3. König, J., Jenkins, M.D., Barrie, P., Mannion, M. and Morison, G. “A Convolutional Neural Network for Pavement Surface Crack Segmentation using Residual Connections and Attention Gating” In 2019 IEEE International Conference on Image Processing (ICIP) (pp. 1460-1464). IEEE 2019. Peer-Review Process: Anonymous. Citations to Date: 8 (Google Scholar).

- R4. König, J., Jenkins, M.D., Barrie, P., Mannion, M. and Morison, G. “Segmentation of Surface Cracks Based on a Fully Convolutional Neural Network and Gated Scale Pooling.” In 2019 27th European Signal Processing Conference (EUSIPCO). IEEE 2019. Peer-Review Process: Anonymous. Citations to Date: 1 (Google Scholar).

- R5. Jenkins, M.D., Carr, T.A., Insa-Iglesias, M., Buggy, T. and Morison, G. "A Deep Convolutional Neural Network for Semantic Pixel-Wise Segmentation of Road and Pavement Surface Cracks." In 2018 26th European Signal Processing Conference (EUSIPCO). IEEE 2018. Peer-Review Process: Anonymous. Citations to Date: 25 (Google Scholar).

- R6. König, J., Jenkins, M.D., Barrie, P., Mannion, M. and Morison, G. "Optimized Deep Encoder-Decoder Methods for Crack Segmentation" Digital Signal Processing, Elsevier, 108, p.102907, 2020. Peer-Review Process: Anonymous. Citations to Date: 0 (very recently published).

4. Details of the impact

These projects were instrumental in positioning Geckotech Solutions Ltd as the only structural monitoring company in Scotland who are utilising Artificial Intelligence, Deep Learning and Virtual Reality to improve their services. The introduction, and continual development, of technology-based solutions to challenges faced by the company have resulted in a number of tangible and intangible benefits. Their partnership with GCU allowed the Company 'to offer services in a faster, safer, more accurate manner than was previously possible and the continued development of these enhanced services will be of great importance to the structural monitoring industry'. [C1]

The success of this project prompted Geckotech to launch their own R&D Department which, in collaboration with GCU, supported the second KTP, an Industrial Doctorate project funded by The Data Lab Innovation Centre and a GCU PhD studentship (as well as numerous undergraduate and postgraduate projects) totalling £531k of funding.

Financially, these projects resulted in significant growth for the company. Over the course of the projects the company saw an increase in sales turnover from £1.7 million to £3.6 million, an increase of over 100%. More impressively, the company increased their profit more than tenfold, from £18k to £200k while also increasing the number of full-time employees from 40 to 60, a 50% increase. At the end of the KTP project, the company predicted that they would increase their sales turnover by a further £2.2 million over the three years following the project. This increase was in fact achieved over the first year.

One project in particular was rated as 'Outstanding' by Innovate UK, shortlisted for the Scottish Knowledge Exchange Awards 2019 Powerful Partnership Award, the Engineering Excellence Award, and Best KTP Award at the Innovate UK KTP Best of the Best Awards 2019, where the project won the Best KTP Award. [C2, C3]

The intangible benefits of the project have been just as important as the financial success. Geckotech Solutions Ltd operate almost exclusively in dangerous and difficult to access environments. Before the KTP, Geckotech prepared for every job by preparing a risk assessment wherein the first question, 'is it necessary to send a human into this environment?', was always answered with 'Yes'. The technology introduced during and after the KTP has, for the first time in 10 years of business, allowed Geckotech an alternative to this in certain situations. This is a significant advance in the level of health and safety that Structural Monitoring companies are able to provide for their employees.

As well as increased health and safety for employees, it is expected that we will also see an increase in public safety through increased inspection frequency and optimisation of maintenance plans. The owners and managers of assets such as railway tunnels are always looking to minimise inspection frequency due to the excessive financial cost of closing such a structure in order to conduct an inspection. The use of new technology is allowing for faster inspection and therefore shorter closures and ultimately a lower cost to clients. By decreasing the overall cost of inspection and therefore increasing the frequency, Geckotech put customers in a much stronger position to optimise maintenance schedules which will not only minimise cost to the customer but also improve the overall safety of the structure.

Currently, GCU are in collaboration with new companies who would be interested in taking this work forward and allowing for the continual development of the impressive work already achieved in this space. A bid for funding through Network Rail and Innovate UK was submitted in collaboration with Inspire Structures Ltd who are one of the most prominent railway tunnel inspection companies in the UK. This funding is specifically targeted at railway tunnel inspection in which Inspire have a wealth of inspection experience and GCU have a very strong prototype system developed over previous projects.

We have also been contacted by CENSIS who connected us with Thales who are interested in the work which GCU have been conducting in the structural monitoring space. This is another very strong industrial connection who have the potential to allow for further collaboration in the

field of Computer Vision and Artificial Intelligence to Structural Condition Monitoring. Finally, we have been approached by Historic Environment Scotland who have an interest in our work from a preservation and restoration of Scotland's historic monuments and structures. This would be an exceptional opportunity for GCU to refocus the work being conducted in the Structural Monitoring space to an exciting new field.

5. Sources to corroborate the impact

- C1. Supporting Letter from Geckotech Chairman
- C2. The following link is to an article which provides evidence for the shortlisting for Powerful Partnership at the 2019 Scottish Knowledge Exchange Awards: https://www.insider.co.uk/news/interface-scottish-knowledge-exchange-awards-13854474
- C3. The following link is to an article which provides evidence for shortlisting for the Engineering Excellence Award and winner of the Best KTP Award at the Innovate UK KTP Best of the Best Awards 2019: https://www.ktpscotland.org.uk/ViewArticle/tabid/4421/articleType/ArticleView/articleId/13585/Geckotech-GCU-win-at-the-KTP-Best-of-the-Best-Awards.aspx