Institution: Teesside University		
Unit of Assessment: 12		
Title of case study: Developing best practice and generating new insights for archaeology and forensic science.		
Period when the underpinning research was undertaken: 2014 to 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:**
Tim Thompson	Associate Dean (Academic)	Feb 2007 to present
David Errickson	Senior Lecturer in Forensic Science	Oct 2015 to Jan 2021
Gillian Taylor	Principal Lecturer (National Horizons Centre)	Nov 2010 to present
Caroline Orr	Principal Lecturer (Staffing and Resources)	Oct 2011 to present
Period when the claimed impact occurred: 2017 to 2020		
Is this case study continued from a case study submitted in 2014? N		

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

Research on 3D models and visualisation undertaken at Teesside University's Centre for Sustainable Engineering has led to the development of new guidelines for the use of structured light systems by both the Archaeological Data Service and the British Association for Biological Anthropology and Osteoarchaeology. The application of this technology within archaeological and forensic contexts has also led to new archaeological insights and enhanced public understanding and interpretation of archaeological objects (York Archaeological Trust; Durham Museum of Archaeology, Vindolanda) as well as engaging new audiences with archaeological and forensic investigation (Channel 5).

2. Underpinning research (indicative maximum 500 words)

Since 2010 there has been a growing use of 3D imaging techniques across many disciplines as devices become less expensive, more portable, and easier to use. Much of this work has been ad hoc, yet the implications are significant, with the US National Institute of Justice highlighting in 2017 the role it will play in forensic investigations. Our research into the development of alternative structured light systems (SLS) has been demonstrated to be more cost effective, safer, highly accurate, and provide better qualitative results when compared to more widely utilised laser-based approaches.

Prior to our work, no research had addressed the underpinning theories and principles of SLS 3D documentation and, therefore, no guidelines were in place. No validation studies had been undertaken to verify the accuracy and efficacy of such scanning methods. In some disciplines where this approach is of use, such as forensic science, it is critical to understand the methodological approach undertaken and present statistical verification of results, especially if evidence will end up in a court of law. In 2020, the project 'From Crime Scene to Court: The Application of 3D imaging to Forensic Science" was initiated to address this gap in the literature. Our work was the first to address and develop best practice for 3D documentation and the overall implementation of 3D technology to applied contexts, such as forensic science. In 2014, our first paper set the agenda for this area by demonstrating the acceptance of this method in the courtroom [3.1]. Following this, our next set of unique experiments were able to define the optimum and limiting conditions for SLS use, such as lighting, expertise of the user, post-processing work, use of metadata. There results were then developed to create the first international guidelines that were incorporated into accredited documents for use in heritage and archaeology and peer-reviewed journals [3.2].

The fundamental work has influenced the discipline by providing standardised scanning methods which our research has statistically validated for use in the heritage and forensic sectors. Three projects have since built upon these foundations and developed groundwork for three separate disciplines (forensic medicine, crime scene science and heritage management respectively). Subsequent studies have focused on the validation and verification of the analysis from the 3D models and have shown that SLS is more accurate than standard photography, that the results can be interpreted in legal contexts, and that it is safe for use on living people. Our resultant publications have formed the basis for all other SLS applications. Our research produced the best practice guidelines for the use of 3D structured light scanning in the monitoring of traumatic injuries in the living in forensic medicine settings and (through a collaboration with Sheffield Teaching Hospitals NHS FT) demonstrated that it is a more accurate measure of pedal dimensions and footwear artefacts than the current accepted methods [3.3, 3.4, 3.5].

We have since been able to develop our approach for use in the heritage sector, and our recent experiments have allowed us to scan increasingly larger objects (human remains before reburial from Fewston, North Yorkshire; the metatarsus of elephant birds; rare objects from Vindolanda Roman Fort; and Stephenson's original Locomotion engine) as well as 3D print the results [3.6].

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

[3.1] Errickson D, Thompson TJU, Rankin BJ. 2014. The application of 3D visualization of osteological trauma for the courtroom: A critical review. Journal of Forensic Radiology and Imaging. 2:3,132-137. https://doi.org/10.1016/j.jofri.2014.04.002

In 2015, this paper was used in the 2016 INTERPOL International Forensic Science Managers review document.

[3.2] Errickson D, Grueso I, Griffith SJ, Setchell JM, Thompson TJU, Thompson CEL, Gowland, RL. 2017. Towards a best practice for the use of active non-contact surface scanning to record human skeletal remains from archaeological contexts. International Journal of Osteoarchaeology. 27:4, 650-661. https://doi.org/10.1002/oa.2587

[3.3] Shamata A, Thompson TJU. 2018. Using structured light three-dimensional surface scanning on living individuals: Key considerations and best practice for forensic medicine. Journal of Forensic and Legal Medicine. 55, 58-64. https://doi.org/10.1016/j.jflm.2018.02.017

[3.4] Thompson TJU, Norris P. 2018. A new method for the recovery and evidential comparison of footwear impressions using 3D structured light scanning. Science & Justice. 58:3, 237-243. https://doi.org/10.1016/j.scijus.2018.02.001

[3.5] Crowther M, Reidy S, Walker J, Islam M, Thompson TJU. 2020. Application of non-contact scanning to forensic podiatry: a feasibility study. Science & Justice. 61:1, 79-88. https://doi.org/10.1016/j.scijus.2020.08.005

[3.6] Williams R, Thompson TJU, Orr C, Birley A, Taylor G. 2019. 3D imaging as a public engagement tool: Investigating an Ox cranium used in target practice at Vindolanda. Theoretical Roman Archaeology Journal. 2:1, 1-16. https://doi.org/10.16995/traj.364

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

This research has led to new good practice guidelines and standards for the heritage and forensic sectors. The Archaeology Data Service (ADS) is the UK's accredited open-source digital repository for heritage data supporting research, learning and teaching and promoting good practice in the use of digital data while providing technical advice to the heritage community and deployment of digital technologies. The standards for ADS are the benchmarks routinely used by academic and field archaeologists, as well as those from commercial archaeology companies and units, across the globe. In 2015, the ADS incorporated a best practice case study and guideline written by Errickson and Thompson and based on their research: Reduction of Noise using a Surface Scanner for Digitising Human Osteological Remains [5.1]. The case study and guideline have been accessed 206 separate times between 2015 and 2020 [5.2]. Figure 4.1, provided by ADS, shows the countries that have accessed these standards:

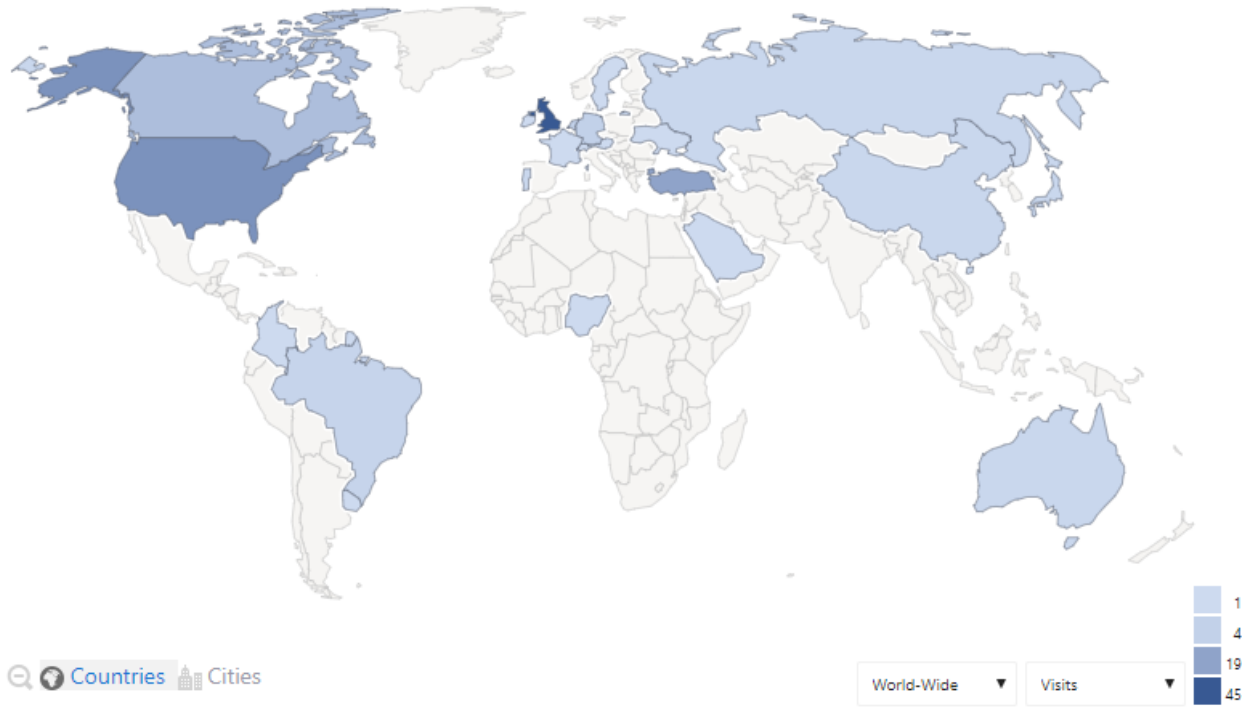

Figure 4.1: Global use of our heritage standards.

In addition, the research [3.1, 3.2] was used in 2019 to underpin the BABAO (British Association for Biological Anthropology and Osteoarchaeology) recommendations on the ethical issues surrounding 2D and 3D digital imaging of human remains (listed on the BABAO website as Guidance Document on Digital Imaging, 2019) [5.3]. This is the first guidance document that solely focusses on 3D technologies and addresses rising ethical concerns in these areas. These documents (written with input from Errickson) provide guidelines on how to obtain the best results from 3D scanning for academics, museums, and professionals working with archaeological human remains. The President of BABAO confirmed the pivotal contribution of our research to the development of the guidance: The research of Prof Thompson and his group at Teesside University formed a crucial part of the foundations of this document. His work to develop technical standards combined with his discussion of the ethical and legal impacts of 3D imaging served as core for our professional Guidelines… foster[ing] discussion and provide guidance for conducting work in an ethical and professional manner [5.4].

The research team have also worked directly with heritage partners, applying best practice techniques to create 3D models and 3D printed replicas that have enabled museums to enhance public engagement and interactivity and deepen understanding of archaeological objects. Through a Museums and Universities Partnership Initiative grant (MUPI) with the Museum of Archaeology (Durham), the research team created 3D models of valuable (and fragile) Roman sculptures which were then 3D printed at Teesside University and hand-painted by an archaeologist. These models were put on display in a special student curated exhibition called Decay which ran from June to October 2017. The research enabled visitors to handle the printed objects in a way in which the originals could not. This allowed for a greater appreciation and understanding of the Roman period. For the curator at Durham Castle and Museum of Archaeology, 'the model made the link between the tangible heritage and intangible visible to those visiting the exhibition. It enabled them to clearly imagine what the object might have looked like in the past and helped to address some of the stereotypes around clean and clinical sculpture' [5.5]. One of 3D model prints is now permanently installed in the museum and is used to explain that Roman stone artefacts were once coloured [5.5].

Our research on structured light scanning has also supported ongoing collaborative work with York Archaeological Trust on the interpretation of human remains from Roman gladiators that were discovered in York [5.6]. Unusual traumatic injuries to one victim were difficult to interpret, and so we used our non-contact structured light scanning technique to create models to support

interpretation. These models confirmed previous suggestions that the deceased had been attacked by a large animal. By modelling the injuries and a variety of animal skulls, we could identify the animal as a large carnivore, such as a lion. This new technique revealed how marks on the bones were left by animal attacks, confirming the use of animals in gladiatorial combat. The findings went on to inform a Channel 5 documentary Ancient Mysteries: The Headless Gladiators of York, which featured an interview with Thompson that explored how our scanning technique allowed us to make this interpretation when other approaches could not [5.7]. This was also broadcast on the Smithsonian Channel as Secrets: Headless Gladiators of York [5.7].

An exhibition with Vindolanda Trust at their world-renowned site in Northumberland explored how Roman soldiers trained for combat. The Digitising Vindolanda exhibition was led by the team at Teesside University and was based on structured light scanning approach outlined in the underpinning research [3.1-3.6]. The exhibition was on display from 24th to 26th August 2019 and included interactive sessions by the research team. During the August bank holiday weekend, 635 visitors engaged with our sessions and completed one of our surveys. Of those, 80% felt that the digitised and printed artefacts were more useful and interesting than the original objects displayed in the museum. One hundred percent of visitors felt that they had learned something new from our interactive exhibition, and 95% felt that they had specifically understood better the work and life of Roman soldiers. For the curator at Vindolanda Trust: 'the 3D printed skulls have been very useful for the Vindolanda Trust. We have been able to use them for our handling sessions especially an event that we hold every October during the school half term call[ed] 'Bare Bones' in which we use our zooarchaeology collection as well as our human printed skulls. We have also had additional benefits from the skulls. The human remains are very fragile but we received a number of requests from documentary film companies to film the skulls as there is a lot of interest due to the dating and find spot. The companies want to handle and talk about the skulls which was proving difficult due to their fragility. We can now offer the companies the 3D printed skulls. This has fulfilled their needs as well as to preserve the archaeological artefact' [5.9].

Teaching and learning in skeletal anatomy has also benefitted from the research. Working with Prof Gowland (Durham University) and the International Committee of the Red Cross (ICRC), a unique online resource for forensic practitioners in the field was developed. With a workforce dispersed across the globe and often in remote locations, training can be challenging. Thus, we collaboratively developed a 6-week online course which is delivered via Future Learn and relies heavily on 3D models generated with the methods we developed. Our research provided the validated methods necessary for the creation of these anatomically accurate models, and also fed into the academic content of the course in the lessons on visualization of forensic evidence [5.10]. As stated by the Regional Forensic Manager for Eurasia in the foreword for the course: 'both Durham and Teesside Universities have excellent reputations in the fields of forensic archaeology and forensic anthropology and their training is internationally recognised. We believe this new online course will make a valuable contribution to the training resources available to us. It provides an excellent overview of the disciplines and innovative technologies to assist learning for a wide range of practitioners of various backgrounds. The ICRC is pleased to be able to offer this course to the forensic practitioners that we work with' [5.10].

The course was launched in 2019. The first cohort had 6,269 students from 148 countries. The second cohort in 2020 had 8,084 learners from 141 countries. The course continues to run throughout the year and now has had over 20,000 learners. Comments from the learners demonstrate how 3D models enhance anatomical and archaeological understanding. Participants remarked that: 'I particularly loved being able to interact with the 3D models online; these allowed me to visualise the things being discussed in a way that is almost as effective as having the specimens in front of me' and 'the very nature of this design of course is genius. I can sit on the other side of the Atlantic, at 3 am, and hold a 3d model of a skull and manipulate as though actually holding it. Genius Technology, but genius online learning design' [5.11].

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

[5.1] Case Study and Guidelines (pdf and link). Archaeology Data Service / Digital Antiquity. Guides to Good Practice. 2019. An Optimum Guide for the Reduction of Noise using a Surface

Scanner for Digitising Human Osteological Remains. Available at: https://guides.archaeologydataservice.ac.uk/g2gp/CS_StructuredLight

[5.2] Website Data (pdf). Archaeology Data Service. Page visits and reach for Optimum Guide for the Reduction of Noise using a Surface Scanner for Digitising Human Osteological Remains. Data received February 2020.

[5.3] Guidelines (pdf or link). British Association for Biological Anthropology and Osteoarchaeology. 2019. BABAO recommendations on the ethical issues surrounding 2D and 3D digital imaging of human remains / Guidance Document on Digital Imaging. Available at: https://www.babao.org.uk/publications/ethics-and-standards/

[5.4] Signed Letter (pdf). Testimonial from the President of the British Association for Biological Anthropology and Osteoarchaeology. Received on 11 November 2020.

[5.5] Email Correspondence (pdf) from Curator at Durham Castle and Museum of Archaeology. Received on 21 February 2021.

[5.6] Webpage (pdf or link). York Archaeological Trust. 2019. Gladiators. Available at: https://www.yorkarchaeology.co.uk/new-blog/gladiators

[5.7] Webpage (pdf or link). Channel 5 and. Ancient Mysteries: The Headless Gladiators of York. Season 4, Episode 3. First broadcast on 10 May 2017. More information at: https://www.channel5.com/episode/the-headless-gladiators-of-york/. Also shown on the Smithsonian Channel. Secrets: Headless Gladiators of York. First broadcast on 15th May 2017. More information at Internet Movie Database: https://www.imdb.com/title/tt7925356/.

[5.8] Evaluation Data (pdf.) Survey results for the Digitising Vindolanda workshop. Responses collected August 2019. Visitors were handed one token each to place into a box (traditional vs digital vs printed) and asked to complete a short survey on an iPad. Most visitors voted and approximately 25% completed the survey. Evaluation conducted by Teesside University.

[5.9] Email Correspondence (pdf) from Curator at Vindolanda Trust. Received on 4 March February 2021.

[5.10] Webapge. Futurelearn. Durham University and Teesside University. 2019. Course Contents and Foreword. Web pages retrieved 13.03.21.Available at: https://www.futurelearn.com/courses/forensic-archaeology-and-anthropology and https://www.futurelearn.com/info/courses/forensic-archaeology-and-anthropology/0/steps/67854

[5.11] Futurelearn Screenshots (pdf). Futurelearn. Exported and aggregated course registrations and post-course free text comments for Nov 2019, Apr 2020 and Jul 2020 course on Forensic Archaeology and Anthropology.