

Institution: University of Brighton		
Unit of Assessment: B11 Computer Science and Informatics		
Title of case study: Transforming access to cultural heritage through digital technologies		
Period when the underpinning research was undertaken: 2004 – to date		
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:
David Arnold	Professor of Computing Science	2002 – 2016* deceased
Roger Evans	Reader	1993 – to date
Jaime Kaminski	Senior Lecturer	2004 – 2019
Karina Rodriguez Echavarria	Principal Lecturer	2004 – to date
Ran Song	Senior Lecturer	2014 – 2019
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		
<p>Digital Cultural Heritage (CH) research at the University of Brighton (UoB) has transformed the practices of organisations and professionals in the global museum sector. Leading a network of over 100 experts across three continents, UoB researchers have created innovative digital technologies and methods that are now deployed by major heritage institutions across the UK, Europe and Brazil. Computational tools for creating tactile and audio-visual experiences have improved access to CH collections for thousands of users, resulting in enhanced societal wellbeing, a measurable increase in audience engagement, including a six-fold increase in visitor engagement with exhibits, and the ability to reproduce the 'real-world' for visually impaired users.</p>		
2. Underpinning research		
<p>Since 2001, UoB researchers have pioneered a new field of interdisciplinary research at the intersection of Computing Science, Cultural Heritage (CH), Art and History. Early UoB research focused on overcoming disciplinary fragmentation between researchers and practitioners from multiple contributing disciplines. Cross-EU projects [references 3.7, 3.8] led by UoB created new research and professional practice communities who co-created unique technologies and innovative research methods with a specific focus on improving deployment into CH organisations [3.1, 3.2]. These pan-EU programmes led to the consolidation of a new field of research in computer graphics for cultural heritage that is now a firmly established and thriving world-wide community within the Digital Humanities discipline.</p> <p>Between 2004 and 2012 UoB researchers led two major European projects: EPOCH (an FP6 Network of Excellence), and 3D-COFORM (an FP7 Integrated Project) [3.7, 3.8]. Bringing together over 100 universities, research centres and CH institutions across Europe and Egypt, EPOCH developed a joint agenda to address the digital needs of the CH sector [3.1]. Its successor, 3D-COFORM, developed affordable, practical and effective mechanisms for long-term documentation of tangible cultural heritage and techniques for the digitisation of CH artefacts. UoB research led a breakthrough in access to 3D CH content over the web, leading to the availability of the first 3D CH content through the Europeana web portal in 2011 (https://pro.europeana.eu/project/3d-content-in-europeana). Between 2011 and 2015, UoB was a partner of the V-MusT.net FP7 Network of Excellence [3.9] and led an EPSRC funded project [3.10], which enhanced the capacity of CH organisations to create digital experiences from digitised resources that are educational, enjoyable and sustainable. UoB developed digitisation workflows, web-based approaches and semantic technologies for facilitating access to previously inaccessible artefacts [3.3] in ways that are sustainable in a heritage context [3.2]. This research was subsequently deployed (2016–2017) in the National History Museum (NHM) in Rio de Janeiro to enhance access to collections, where UoB researchers co-developed web-based interactive exhibits of ivory artefacts [3.4].</p>		

UoB researchers developed computer graphics technologies for design and multi-sensory experiences of CH collections to support richer documentation and interpretation [3.5, 3.6]. Through the deployment of digital and fabrication technologies, this research created novel workflows for tactile and audio-visual experiences (eg fabricated physical 3-dimensional puzzles of authentic CH artefacts for visitors to assemble in the archaeology gallery at the Brighton Museum [3.5]). The fragmentation algorithm makes it possible for a museum to create a 3D puzzle by 'breaking' a digitised artefact into fragments that are later manufactured using 3D printing, without any damage to the original. UoB researchers co-led a programme that produced 3D-printed replicas that enabled blind audiences to experience works of art normally exhibited in glass cabinets and inaccessible to non-sighted visitors [3.6]. Through a partnership with Future Creators (an organization supporting the creative potential of young people), the research developed a novel approach for connecting young people with CH in their local area, by giving them access to museum collections. As a result, young people can create personal narratives in the urban landscape accessible via web-based Augmented Reality (AR) technology. Later research focuses on addressing pressing needs, including preserving heritage at risk, the decolonisation of UK collections acquired from communities across the world and digital inclusivity among international communities, including in Mexico, Brazil and Egypt. This recent work, through an ongoing partnership with FGV in Brazil, involves developing visualisation technologies for digital collections.

3. References to the research

[3.1] Arnold, D., (2008). Pasteur's quadrant: cultural heritage as inspiration for basic research in computer science. *Journal on Computing and Cultural Heritage*, 1(1). 1-13. ISSN 1556-4673. [Quality validation: A journal referee stated 'a seminal analysis of CH ICT research frameworks'].

[3.2] Kaminski, J., Rodriguez Echavarria, K., Palma, G., Arnold, D., Scopigno, R., Stevenson, J., and Proesmans, M., (2012). Insourcing, outsourcing and crowdsourcing 3D collection formation: perspectives for cultural heritage sites. In Proceedings of VAST12: *The 13th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage*. The Eurographics Association. <http://dx.doi.org/10.2312/VAST/VAST12/081-088> [Quality validation: this a refereed conference paper published in a volume based on ~30% acceptance rate].

[3.3] Rodriguez Echavarria, K., and Song, R., (2016). Analysing the Decorative Style of 3D Heritage Collections based on Shape Saliency. *Journal on Computing and Cultural Heritage*, 9(4), [20]. <https://doi.org/10.1145/2943778>. [Quality validation: output in a leading peer-reviewed journal].

[3.4] Marroquim, R., Medeiros e Sa, A., Rodriguez Echavarria, K., Balbio, V., and Zamorano, R., (2017). Digitising ivory artefacts at the National History Museum in Brazil. In Proceedings of Eurographics Workshop on Graphics and Cultural Heritage. Graz, Austria. <http://dx.doi.org/10.2312/gch.20171287>. [Quality validation: a refereed conference paper published in a volume based on ~30% acceptance rate].

[3.5] Rodriguez Echavarria, K., Samaroudi, M., and Weyrich, T., (2020). Fracturing artefacts into 3D printable puzzles to enhance audience engagement with heritage collections. *Journal on Computing and Cultural Heritage*, 13(1), [3351343]. <https://doi.org/10.1145/3351343> [Quality validation: article in an established journal and won best paper at an international conference].

[3.6] Samaroudi, M., and Echavarria, K. R., (2019). Learning through experiences: accessible fabricated dioramas for the visually impaired. In Beck D. et al (eds). Immersive Learning Research Network. iLRN 2019. Communications in Computer and Information Science 1044. Springer, Cham. https://doi.org/10.1007/978-3-030-23089-0_7 [Quality validation: peer-reviewed contribution to a leading conference].

Key research grants

[3.7] David Arnold [PI], EUFP6 Network of Excellence. [507382], 2004 – 2008, European Research Network on Excellence in Processing Open Cultural Heritage (EPOCH). Total funding: EUR7,800,000. UoB allocation: GBP717,240.

[3.8] David Arnold [PI], EUFP7 Integrating Project. [231809], 2008 – 2012, Tools and expertise for 3D collection formation (3D-COFORM). Total funding: EUR8,449,994. UoB allocation: EUR1,573,173.

[3.9] Jaime Kaminski [PI], EUFP7 Network of Excellence, 2011 – 2015, Virtual Museum Transnational Network (V-MusT.net), Total funding: EUR4,550,000. UoB allocation: EUR78,400.

[3.10] Karina Rodriguez Echavarria [PI], EPSRC. [EP/L006685/1], 2014 – 2016, Automatic Semantic Analysis of 3D content for digital repositories. GBP97,491.

4. Details of the impact

UoB researchers work with CH organisations, professionals, community/civic groups and cultural-education partnerships to transform how art and heritage collections, with their often fragile and carefully protected artefacts, are documented, accessed and experienced. To provide technological solutions with broad practical applications the research design is co-developed to respond to the shifting agendas and priorities of the CH domain. Partnerships with CH organisations are built at the local, national and international levels (eg Royal Pavilion and Museums Brighton and Hove, Sussex Archaeological Society, Victoria & Albert Museum (UK), Staatliche Museen zu Berlin (Germany), Royal Museums of Art and History (Belgium), Fundação Getulio Vargas, and the National History Museum (Brazil)). These organisations attract a combined total of ~13,000,000 visitors per year [Source 5.1]. This research has broadened access to 3D technologies for professionals and visitors, underpinned organisational strategies and laid the foundations for the development of multiple new projects.

4.1 Broadening access to 3D technologies and processes in the CH sector

The legacy of the learning from the 3D-COFORM project has continued across the whole census period. The Royal Museums of Art and History, Brussels (RMAH), have described the 3D-COFORM project as the 'leverage needed to generate change', acting as a 'catalyst' and a 'knowledge resource', for the expansion of research into an application of 3D technology [5.2]. At RMAH the learning has fed into a new strategy for the production and application of 3D digital objects, both on-site and online, with the 3D-COFORM project's tools still in daily use at the museum [5.2]. Together with KU Leuven, RMAH led the Pixel+ project (2018-2020), a direct descendant of 3D-COFORM and funded by the Belgian Science Policy Office. New technology developed in this project enables 3D depth images to be reconstructed, creating a better-defined resource to utilise, study and preserve heritage materials. This allows professionals and the public to view centuries-old objects and reveal hidden details, making artefacts more accessible, particularly during the coronavirus pandemic. This technology was used to study the figures in the 13th-century *Rijmbijbel* (the oldest preserved illustrated manuscript in the Dutch language), which led to the discovery that the heads of some of the figures were painted over at a later date. At the RMAH the technology was used to make heavily weathered texts on almost 4,000-year-old Egyptian figurines readable again. This technology is taking major steps forward in the documentation of CH and is an example of the standardisation of processes made possible by the 3D-COFORM project [5.2, 5.3].

The vision in 3D-COFORM evolved via the European portal for Cultural Heritage, Europeana, which has made provisions for the leading role 3D CH will play in education, research and the creative industries. In 2019-2020 a taskforce, with a cohort directly descended from the 3D-COFORM project, developed a framework and provided guidance on publishing 3D content for cultural institutions, data creators and aggregators. 3D technology requires new approaches to all aspects of digital CH, its production, documentation, management and exploitation. '*These realisations were made in 3D-COFORM and still form the bases for today's lines of thinking [...] without doubt, the ground-breaking work carried out in 3D-COFORM still resonates*' [5.2, 5.4]. The 3D ICONS project, led by Europeana, that comprises a programme that builds on the results of 3D-COFORM, has digitised architectural and archaeological masterpieces of world and European cultural significance providing over 1,000 3D models and related digital content to Europeana over the course of the project. The project focused on UNESCO World Heritage monuments and other monuments of outstanding value at European level, to illustrate a particular strand of Europe's history. It has become '*a trail blazer for the production and*

publication of 3D content' generating worldwide interest in the project's digitisation activities with 17,830 unique visits to the online material in 157 countries [5.5].

At the National Museums in Berlin the 3D-COFORM project led directly to 5 new projects and twenty new collaborations that built on this knowledge, with additional investment of approximately GBP500,000 through funding in the period. The tools and technologies developed within the 3D-COFORM project are still being employed within the organisation and the project has '*opened up the door to the National Museums in Berlin for the strategic development of 3D techniques in cultural heritage. At the same time, the bases of a steadily growing 3D repository were laid. As a result of the 3D-COFORM project, the topic of 3D reproductions and virtual representation has become one of the focal points of digital transformation.*' The 3D-COFORM project's materials have been a first reference for questions in the 3D sector that are still being discussed today [5.6].

4.2 Directing training to deliver changes in professional practice

Through training and dissemination events across Europe and Brazil, UoB researchers have engaged with over 1,000 CH professionals, and provided training for more than 100 CH professionals across 10 countries since 2014. The training was tailored to the specific needs of different institutions and drew on knowledge from European and EPSRC-funded projects and built capacity of CH practitioners on technological approaches for digitisation and reproduction of CH artefacts [5.7]. Individual professionals who engaged with the training reported that it was a 'game-changer', providing opportunities to find new ways to preserve heritage and explore roads to test and learn new photographic techniques for digitisation and the development of new ways of working [5.8].

The 3D-COFORM exhibition *Reshaping History* was brought to Rio de Janeiro in 2014 after a European tour. Hosted by the Getulio Vargas Foundation (FGV) the exhibition was accompanied by a one-day workshop that engaged with ~65 CH professionals. A broad set of processes and technologies for deploying 3D technologies were disseminated across the sector, many of which were more affordable and accessible to professionals. This motivated individuals and stakeholders to introduce or expand the use of 3D documentation methods in their work [5.8]. Thereafter, the National Museum and the National History Museum (Rio de Janeiro), commissioned projects deploying these technologies to capture, preserve and share knowledge on artefacts and collections with the public. A further two international workshops led by UoB and attended by 80 CH professionals from Brazil, Mexico and Egypt, took place in the UK and Brazil (2018 and 2019). The exchange of knowledge fulfilled the FGV's aim to enhance the potential that technologies have in safeguarding cultural heritage assets (sites, monuments, artefacts, intangible practices, craft etc) which might have suffered damage, are under risk or situated within vulnerable communities. This research collaboration has been recorded as 'invaluable' in the advancement of FGV's work with 3D technologies [5.8].

4.3 Improved digital plans enabling greater visitor access to heritage artefacts

UoB researchers have advanced exhibition design in the development of curation processes in museums and galleries. The Barbican House Museum and the Brighton Museum and Art Gallery feature Sussex archaeological findings including nationally significant human skulls and historical artefacts. UoB research provided a foundation for these organisations to create historically accurate 3D facial reconstructions by deploying digital workflows to produce 3D copies of human skull remains. Curators were able to display 13 previously inaccessible artefacts and had a greater flexibility of choice of artefact as a result of the digitisation process [5.9]. Through documenting and providing access to their collections UoB research has influenced the Royal Pavilion and Museums (RPM) Research Plan 2018 - 2022 and Digital Plan 2018 – 2022. The former identified UoB research as an enabler for developing new knowledge and enhanced access to RPM's collections whilst the latter confirmed UoB as a future partner to undertake further digitisation and build a rich narrative about RPM's collections, buildings and knowledge [5.9, 5.10]. UoB's approach to community engagement, in partnership with Future Creators, has led to positive impacts on children's wellbeing through building a sense of identity and place, enhancing learning and encouraging children's competencies [5.11]. Engagement activities involving over 190 children in primary schools between 2018 and 2020 showed improved connection with others, their communities and

living heritage. The evaluation, led by Future Creators, showed an increase of 45% in participants feeling happy, a 15% increase in participants feeling liked by other people, and a 15% increase in participants reporting they coped well in difficult situations. This engagement supported children through challenging transitions including from primary to secondary school. A plan is now in place to upscale this approach to a national level [5.11].

CH audiences benefit from improved access to fragile archaeological artefacts, natural history collections, architectural heritage and 3D artworks. This has affected certain demographics including children and young people, visually impaired and online museum visitors. The exhibits include interactive replicas (Brighton Museum/Booth Museum), and a web based ivory exhibit (NHM, Rio de Janeiro), together reaching more than 260,000 people per year. Interactive and multi-sensory exhibits developed using UoB research significantly increased interest and engagement, proving an effective way to expand the reach of collections; the average visitor time spent on an interactive exhibit increased from 34 seconds to 2.6 minutes [5.12]. The use of physical replicas in relation to user needs was tested at the Booth Museum and the Blind Veterans charity (Brighton) and the Centre for the Education and Rehabilitation for the Blind (CERB) in Thessaloniki, Greece (2019). Visually impaired users (18-60+) reported they felt actively connected with CH, that their knowledge about heritage was enhanced and they developed awareness about the physical, urban environment, and communities locally and abroad. Feedback showed that by recognising their needs these users felt valued by the museum, experiencing equal opportunities to other museum visitors; they were not only able to visit the museum but become part of it and the 'real-world'. Personal reflections from these users included an emotive connection: '*You almost felt that you are actually looking at the real thing.*' '*The relief gave me an understanding of putting back into a shape, back into my mind... what I was able to do in the recesses of my mind, it was to imagine...'. 'We would be able to "travel" to a world which is unknown to someone who cannot see*' [5.13].

5. Sources to corroborate the impact

[5.1] Resource pack including stakeholder map and visitor data with sources. PDF available.

[5.2] Testimonial from Royal Museums of Art and History, Brussels, that confirms the significant legacy continuing from the 3D-COFORM project.

[5.3] New dimensions take a deeper look at heritage. Pixel+ <https://www.heritage-visualisation.org/news.html> [Accessed on 12th January 2021]. This provides details of the impact of the Pixel+ project.

[5.4] 3D content in Europeana (2019). Europeana Pro. <https://pro.europeana.eu/project/3d-content-in-europeana> [Accessed on 12th January 2021]. This describes the task force delivering guidance on producing 3D assets.

[5.5] 3D-ICONS. (2014). Europeana Pro. <https://pro.europeana.eu/project/3d-icons>; <http://3dicons-project.eu/guidelines-and-case-studies/case-studies>; <https://cordis.europa.eu/docs/projects/cnect/4/297194/080/deliverables/001-D83FinalDisseminationreport.pdf> [Accessed on 12th January 2021]. These sources confirm the legacy of 3D-COFORM through the 3D-ICONS project.

[5.6] Feedback from National Museums in Berlin – PDF response available.

[5.7] Resource pack with evidence of activities, training and public engagement: list of training, public engagement and feedback from professionals.

[5.8] Testimonial from FGV Brazil on engagement outcomes with museums in Brazil.

[5.9] Testimonial from Royal Pavilion and Museums Brighton and Hove. Corroborates enhancement of user engagement with museum collections and input to Archaeology Gallery.

[5.10] The Royal Pavilion and Museums Research Plan 2018 – 2022/ Digital Plan 2018 – 2022.

[5.11] Testimonial from Future Creators. Corroborates positive impact on wellbeing on children through engagement with their cultural environment – and roll out of the AR maps across B&H.

[5.12] User evaluation on interpretative material at Brighton Museum Archaeology Gallery. Corroborates excellent experience of interpretative material. PDF available.

[5.13] User evaluation on blind audience engagement. Corroborates enhanced experience of interpretative material. PDF available.