Grave-to-cradle: a paradigm shift for heritage conservation and interpretation in the era of 3D laser scanning

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Abstract

The capacity to record cultural heritage through 3-dimensional (3D) laser scanning has grown rapidly over the past ten years alongside an increase in the number of places inscribed on heritage lists. Offering both challenges and opportunities, this paper examines the possibility of a grave-to-cradle approach where a place may be left to physically decay while simultaneously experiencing a rebirth in digital form. We examine other uses of scanning-acquired data, including in the ongoing management of heritage places and the archiving of data for future interpretation and study. The implications of digital databases and virtual reality versions of historic places include concerns that physical fabric and intangible characteristics will be devalued by ubiquitous digital versions of places, leading to place neglect. The concept of aura is used to discuss perceptions of authenticity in relation to scan data, and how people experience and value heritage places in the midst of data proliferation. Best practice heritage scanning and visualisation examples, as well as a more modest case study project, explain how heritage sites are recorded using scanning data. We argue that scanning, visualising and archiving places of historic significance will allow a digital version of some places to be sustainably maintained, while the physical version is allowed to decay naturally, a grave-to-cradle approach.

Introduction

Historically significant places and activities are under pressure to develop into self-sustaining operations, within a context of tightening public funding, increasing visitation numbers, and expanding community expectations. This complex situation was interrogated in the 2006 Productivity Commission inquiry into the conservation of Australia’s historic built heritage. The Commission found that a reliance on regulation as the primary heritage protection mechanism had resulted in ‘insufficient account being taken of the costs of conserving heritage places when selecting places for listing and insufficient incentives for their active conservation’ (Productivity Commission 2006: xviii). While criticised for its focus on economic imperatives, the Commission also recommended that heritage lists be regularly updated, including ‘the deletion of inappropriate entries’ (ibid.: xxxiii). This latter point has recently been argued by Harrison (2013: 579) who suggests there exists a “crisis” of accumulation’, with implications for the longer-term sustainability of heritage places and activities.

The Burra Charter defines conservation as ‘all the processes of looking after a place so as to retain its cultural significance’ (Australia ICOMOS 2013 [2000]: 2). Given the changing context described above, is it time to re-think what we conserve and how with a view towards a more sustainable future for heritage sites? A growing community of architectural historians,
archaeologists, heritage managers and related disciplines have been using 3D laser scanning, amongst other digitising techniques such as photogrammetry (using either stills and video imagery) (Pavlidis et al. 2006) and thermal imaging (Cabrèlles et al. 2009), to record and analyse historic sites. However, few to date have used newest versions of scanning—hand-held mobile devices that capture whole structures and their contexts, or small-scale scanners that capture objects and interior spaces—to record heritage sites. This paper initially describes one new mobile 3-dimensional (3D) scanning technology, the Australian invention Zebedee, and the benefits and limitations of this technology for the management of fragile historic environments. Based on this foundation, a case study of the mobile scanning and archiving a heritage site in Queensland is briefly explored. Using Benjamin’s (1992 [1968]) concept of aura, the paper then examines the accuracy, longevity, applications and perceptions of 3D scanned heritage data, and discusses the value of archiving a digital version of some places, while the physical version is allowed to decay naturally in an approach we term ‘grave-to-cradle’. In this approach a heritage site destined for a physical ‘death’, is enabled a digital ‘re-birth’ through digitization, archiving and digital interpretation.

### 3D laser scanning for digital cultural heritage

3D laser scanning of heritage sites has been growing in past decades with interest beginning initially in archaeology and spreading into more general use in the assessment and management of historic places. The adoption of this new technology began with archaeologists in the early 2000s with projects such as the photogrammetric recording of Pompeii (Balzani et al. 2004) and Herculaneum (Xiao et al. 2007), scanning and analysing degrading sites under threat such as the ruins at Ancient Merv (Barton 2009), and the launch of the CyArk cultural heritage database in 2003 (CyArk 2014) with its plethora of digitally scanned and interpreted heritage sites. The recording, archiving and presentation of historic places and activities using digital means bring both challenges and opportunities for heritage management that are evolving as rapidly as the technology advances and the repercussions can be examined.

3D laser scanners measure and record the distance from the scanner to a material surface using a laser beam that spins tens of thousands of times per second. Each laser-measured distance is defined by a point, and potentially tens of millions of points are recorded in a given scanned environment (Bosse et al. 2012). These points are arranged in a 3D formation called a ‘point cloud’, representing the surface of the environment through the arrangement of the points. The first generation of terrestrial laser scanners, typically still used in the recording of heritage places, are tripod-mounted and take some minutes to complete a 360° sweep of a given environment. Scans are repeated at several ‘station points’ with common ‘targets’ located in each scan to ensure a known overlap. Individual scans are then ‘stitched’ together, based on the targets, and a holistic recording of the physical measurements comprising the environment is created.

An English Heritage guide on the measurement and recording of heritage sites describes the limitations of these first generation terrestrial scanning technologies. These include the need for many station points, which can lead to inaccuracies in the acquisition of a holistic dataset for a large area; large data file sizes and difficulty in data manageability; insufficient point cloud density and the need for specialised interpretation skills and software (Andrews et al. 2010: 20). The guide also identifies best practices and explains the standards that should be expected from 3D laser scanning of heritage sites. Andrews and colleagues explain that a key drawback of terrestrial tripod-mounted scanners are the occlusions caused by objects blocking the laser’s path, leading to ‘shadows’ of un-scanned areas in an environment. This is almost inevitable in a single-point scan, and, while multiple station point scanning attempts to eliminate this problem, few environments are able to be captured completely using terrestrial scanning techniques.

More recently, hand-held mobile laser scanners such as CSIRO’s Zebedee and the commercial version Zeb1 (Bosse et al. 2012), car-based mobile scanners such as the Google Streetview Car (Anguelov et al. 2010), and very small, inexpensive infrared tablet scanners such as DotProduct’s DPI-7 (Jahraus 2015), have become important for recording historic places and heritage objects.
Mobile scanning devices all but eliminate the problem of occlusion because the operator can move while scanning to gain access to all parts of a site that require capture. However, these mobile scanners are currently unable to match the accuracy of terrestrial scanners. A new generation of accessible scanning technology means that heritage professionals will soon be able to capture places and objects with unprecedented ease and increasing accuracy, raising a broader question about what this advance in scanning technology might mean for heritage places and their management. Other techniques for digitally capturing sites, such as increasingly advanced photogrammetry practices, are an important part of the repertoire of digital recording techniques, but are not the focus of this paper.

The implications of mobile 3D laser scanning for heritage management, beyond the technical capabilities of recording and visualising sites, have been little considered to date, though many authors explain the value of scanning more broadly to site management and archiving efforts (Tait et al. 2016; Kadier et al 2016) while some note the problems with occlusions in terrestrial scanning (Shukor 2015). We see potential in mobile 3D laser scanning and the digital visualisation of historic environments to radically change the approach to the growing number of places inscribed on heritage lists, and in doing so to provide a response to what Harrison refers to as a “crisis” of accumulation (2013). Conservation in the digital era may not always involve preservation of the physical fabric itself, but preservation of a new, digital version of a heritage place. Changes in scanning cost, speed, novice usability, and data interpretation makes the possibility of scanning many heritage places more achievable than ever before. Nevertheless, digital laser scan files do themselves require preservation through archiving that, to be sustainable, must include regular updating of file formats to avoid data obsolescence and, ideally, the incorporation of searchability functions and accompanying interpretive material.

The creation of a digital aura

Laser scanning of heritage buildings has achieved noteworthiness with the recording of a series of famous landmarks by the Scottish Ten in conjunction with CyArk (Wilson et al. 2013). Scanning in these instances produced a digital recording of an important site that can be accessed by interested parties from around the world on the CyArk website. In this case, buildings are recorded and viewable as 3D point clouds, fly-throughs and digital models created from the 3D scanning data to provide a contextualised version of the heritage place. This contextualisation of places within the digital repository speaks to Benjamin’s original use of the term ‘aura’ (1992 [1968]: 211-244), a term that recognises the authenticity and context of an artwork or a natural landscape. Aura, he argued, is palpable and unique, and signals proximity to an impressive and important object or setting. Benjamin argued that the aura of an artefact would be diminished in the age of mass reproduction by the abundance of replicas that corrode the singularity of the original. In contrast, Latour and Lowe (2011) argue that copies can in fact increase the aura of an original when a reproduction is of sufficiently high quality. From low-quality plastic key chains and snow cones to high-quality 3D digital models in a virtual reality environment, heritage sites, especially significant architectural buildings, are continually reproduced. Latour and Lowe argue that such “[f]acsimiles, especially those relying on complex (digital) techniques are…the most fruitful way to explore the original and even to redefine what originality is’ (2011: 278). They go on to explain that copies of original works can increase both the aura and the ‘trajectory’ or ‘career’ of a work of art. Such copies can, in certain cases, provide more meaningful insights than the original for contemporary people who encounter a copy. How might such ideas work with 3D laser scanning of buildings? Could the copy, the virtual reality interpretation, ever become more meaningful than the original place and under what circumstances?

The popularity of visiting real historic places mirrors the appetite for inscribing such places on heritage lists. Visitors to historic European sites, such as Gaudi’s unfinished La Sagrada Familia basilica in Barcelona or the Leaning Tower of Pisa, are so numerous that the experience of the place could be said to be dominated by other tourists rather than the buildings themselves. Similarly, the dominant activities undertaken at such places are now most often technologically mediated experiences, such as photographing oneself with a phone camera (Figures 1 and 2) or
undertaking an audio-headset tour in the language of your choice (Figure 3). There are no pure, unmediated experiences of place. Places are experienced through the social, the interpretive, at a particular time and under specific conditions, and contemporary technologies merely make this more apparent than ever before.

Critically though, as Latour and Lowe argue, it is the quality of the reproduction that increases or decreases the aura of the original. A key example of digital scanning technology increasing the aura of an original is the exhibition titled *Pure Land: Inside the Mogao Grottoes at Dunhuang* and *Pure Land: Augmented Reality Edition*. Here the digital reproduction of a place, the Mogao Grottoes in Dunhuang China, has become accessible to significant numbers of tourists who would otherwise want to visit the original but cannot, because their human physical presence would destroy the fragile caves and rapidly deteriorate the cave paintings within.

Figure 1: A tourist being photographed ‘holding up’ the Leaning Tower of Pisa. (Photograph from the original ‘Los turistas en la torre de Pisa’ by Ramiro Ramirez, Flikr. Modified to be black and white. Image: https://goo.gl/Py1pRa).

Figure 2: Tourists enjoy capturing their image using a ‘selfie stick’ at St Peter’s in Rome. (Photograph from the original ‘Three Men and a Selfie Stick’ by Joe Shlabotnik, Flikr. Modified to be black and white. Image: https://goo.gl/E4fxZB).

Figure 3: The author Kelly Greenop and her son listening to an audio tour at Scarborough Castle, an English Heritage Site in Yorkshire, 2016. (Photograph by Jonathan Roberts, used with permission).
At the Mogao Grottoes, the high-quality scans of the original cave images, experienced in a virtual reality ‘cave’, have been digitally restored by collaborative teams of artists and scientists (see for example ALiVE 2012). Augmented reality animations, including 3D digital models of 2D images, help to interpret the original paintings and explain the social and historical context of what is being seen, while virtual reality glasses give each viewer personal control over the ‘window’ through which they see. Kenderdine, a digital cultural heritage theorist and part of the production team for the Pure Land exhibition, argues that these virtual reality experiences do indeed provide an enhanced and more meaningful experience for tourists than that available at the real site (2013). Similarly Kargon and Gharipour argue that digital technologies can ‘stimulate’ the magnification of experiences at memorial sites (2012).

Place, aura and authenticity

A key characteristic of place is that its meanings are dynamic. Benjamin argues that aura can never be separated from the authentic setting in which an artwork (or cultural heritage site) exists (1992 [1968]: 217), thus the aura of a digital place is linked to its authentic representation. The corollary of mutable place meanings is that the aura of a place or artwork in that place is also continually in flux. Places change with social use and the activities that occur at a location (Lynch 1972). They can also change subtly, or dramatically, over time through physical degradation, renovation and, sometimes, places are destroyed completely (Read 1996). Digital versions of place, that can now represent not only the physical qualities of a place, but some of its experiential qualities, also offer the possibility to capture or create alternative versions of a place’s aura, potentially providing a unique and authentic experience if the quality and nature of the digital version is compelling enough. Aspects of place that are no longer current could be recreated, with several versions of a place being possible in the digital realm, making the layered nature of place attributes more easily understood.

Kenderdine explains that the accuracy and care taken in the case of the Mogao Grottoes is second to none, but as Hughes, in her book Architecture of Error (2014) argues, the twentieth century’s increasing obsession with architectural precision, beyond what any builder or material can sensibly be expected to produce, is based on the anxious avoidance, even fear, of error. With this in mind, we call for an exploration of digital scanning techniques that are accurate and precise as far as is necessary, but also offer the possibility of usefulness and the presentation of aura through their interpretation. We argue for the creation of accuracy through authentically representing both, the object or site in context, and also potentially through incorporating other qualities to aid interpretation, be they experiential, historic characteristics or through representing other significant place attributes.

While a high-quality virtual and augmented version of a place, such as the Mogao Grottoes, is a gold standard for cultural heritage interpretation, its cost, both in terms of recording the place qualities and the later visualisation, require a specific technology-enhanced location into which the images can be projected and substantial investment in visualising technologies. This level of conservation is out of reach for many heritage places. The current generation of mobile 3D laser scanners do, however, offer possibilities for less expensive visualisation that is still worthwhile in terms of digital conservation, and may be useful into the future as virtual reality (VR) techniques become more accessible.

In addition to the possibility of developing a VR versions of a site, scans made with mobile hand-held scanners provide a rich repository of data that can be archived, and then examined again and again, and potentially re-processed in future with improved computing power and software algorithms. The speed and relatively low cost of capturing sites using this technology enables repeated scanning, allowing for comparison of heritage environments over time and potentially revealing changes that are difficult to assess using photography or hand-measuring alone.
Case study of a 3D laser scanned heritage site

3D laser scanning of sites using mobile hand-held scanning technology, CSIRO’s Zebedee and the commercial version by GeoSLAM’s Zeb1 and DotProduct’s DPI-7, have been used to scan and create digital records of heritage sites in Brisbane by University of Queensland School of Architecture staff and students and partner organisations (Zlot et al. 2014). The project team gained access to the pre-commercialisation version of the Zebedee mobile hand-held 3D laser scanner developed by CSIRO, Australia’s national science agency, and used the opportunity to test its capabilities in scanning heritage sites with complex, fragile and remote cultural heritage settings that are difficult to record by hand or using terrestrial laser scanners.

The Peel Island Lazaret is an early 20th Century encampment which was used for the medical internment of leprosy sufferers and was abandoned in the late 1950s. Its significance is listed on the Queensland Heritage Register, including a rare aesthetic quality of abandonment and its unique status as the only surviving lazaret in the state (Queensland Heritage Register 2015; for more information see Juckes et al. 2013). The site’s timber buildings are falling into dilapidation and are all but impossible to comprehensively record using conventional techniques (Figure 4). Our project has scanned the site five times, in 2012, twice in 2014, and twice in 2016, each time collecting mobile 3D laser scanning data in hours rather than days, and with a comprehensiveness not possible using hand-measuring techniques. Although the full extent of the large site was not scanned each time, the critical central areas that were documented in each of the five scans allowing for a comparison of the condition of the site’s fragile buildings over time, and an analysis of the specific ways in which the fragile timber buildings are degrading.

Our laser scanning of Peel Island followed a hand-measuring project of the same site that produced conventional measuring techniques and drawings of a small number of buildings. These drawings were compared with the laser scan data acquired by Master of Architecture students whose disciplinary knowledge allowed for an architecturally informed approach to visualising the point cloud data. Instead of a clear line of surface typically represented in a drawing, point cloud data from a mobile 3D laser scanner produces a scatter of points from which, at the most dense zone, a surface is inferred (Figure 5). The interpretation of point cloud data alongside photographs from the same field trip helped to avoid any confusion that may have arisen, similar to a measured drawing being completed with the aid of photographs from a site measure field trip.

Point clouds produced by the scanner were comparably accurate with the hand-measured and produced drawings and aerial photography, and were sufficient for the cultural heritage management purposes of the site, which we discuss at more length elsewhere (see Zlot et al.)
While terrestrial scanners are more accurate in terms of measurement precision, the extent of scanning is usually less complete and often cannot include a broader setting within which buildings are sited. The setting of a heritage building or the totality of a heritage site is, as we discussed earlier, a critical element in the ‘migration of aura’ (Latour and Lowe in Kenderdine 2012:203). In the case of Peel Island, the setting is listed as part of the heritage significance of the site. The capturing of encroaching bushland, the large empty spaces between buildings where now lost structures once lay, and the remnants of buildings almost destroyed, is important in recording the site’s current condition. The point clouds and their interpretation through CAD systems, screenshots and other means are, therefore, concerned not only with accuracy, but with representing the place in a manner that conveys its significance.

A heritage site that is mechanically reproduced alone can never provide a sufficient interpretation. There is no automatic way to reproduce a place without some element of judgement as to how its physical structures are presented. Bianchini et al. (2012) discussed the need for intelligence and disciplinary knowledge to interpret ‘data’ and transform it into what they term ‘profound knowledge’ (Bianchini et al. 2012, 510). Kenderdine’s example of the caves at Dunhuang are a case in point: the order in which sites and wall paintings are presented, the lighting conditions created within the space and even the choice of sites on display, all represent a set of expert decisions, far from the assumed objectivity and distance of a digital version of place. Hence precision and accuracy alone are not sufficient, authenticity also become critical. Authenticity relies on accuracy—we must be able to recognise and rely on the representation of the site and its details—but objective precision in isolation is insufficient to allow for the migration of aura. Nevertheless, visitor interpretation is only one use of digital technologies. The management of historic sites and the ability to produce drawings for maintenance or to interrogate the site historically are also important activities where 3D laser scanning can assist.

Peel Island’s managers now have access to a several, very complete snapshots of the island’s buildings over a relatively extended period of time. This had not been possible previously because of the time and cost of a metric survey based on hand-measuring or terrestrial survey techniques, (see Figure 6 for one visualisation of this laser scanning data). This record could allow managers, located remotely, to quickly and easily explain to staff the condition of each building, using the point cloud as an interface. Drawings and digital models of buildings can be produced from the original point cloud when needed. This has been demonstrated by student projects that produced traditional documentation of a small building from mobile 3D laser scanning point cloud data and photographs (Sidonio 2014). While making drawings is the traditional method for recording historic architecture, there is an argument that the overall point cloud data as a set is equally important, if not more so, because of the capability to revisit that repository of data at later times, either for comparison, to make drawings relevant to a particular purpose, or to compare with a later set of scan data. Nevertheless, as Shukor and colleagues (2015) argue, the transformation of point clouds into digital models is
not always necessary, if the point cloud interpretation is of high enough quality. Future software is planned for the Zeb1 that will allow comparison of scan data sets to automatically detect changes in the environment (Roberts 2013).

Limitations and the future of 3D scanning technology

Andrews et al. (2010) commented on the limitations of 3D laser scanners and these limitations are largely still in place. The cost of laser scanning technology remains a significant barrier to uptake with a base-level Leica terrestrial scanner costing in the order of A$100 000 and a Zeb1 mobile 3D laser scanner in the order of A$30 000. These are significantly cheaper than past versions, but nevertheless an expensive purchase. However, the use of consultancies that own various scanners, similar to the hiring of a surveyor to undertake a boundary and identification survey, is becoming increasingly affordable.

Scan data collected still requires processing (at a cost per cubic metre of data scanned in the case of the Zeb1, or using custom software for most terrestrial scanners) and, as Andrews et al. noted, there is no simple ‘out-of-the-box’ software that meets all point cloud processing needs. While custom software accompanying proprietary terrestrial scanners has improved the stitchability of individuals scans, like the Zeb1, additional manipulation through software is required for the point clouds to become useful in practice to architects and heritage practitioners.

Despite recent advances in software, there is still not an automated or even standard solution for visualising point cloud data and manipulating it for heritage interpretation. The need to interpret data using human rather than machine intelligence will remain an issue because of the need for disciplinary knowledge to translate ‘objective’ point cloud data into a meaningful interpretation, that allows for the creation of aura. Large data sizes and the need for significant computing power have been somewhat addressed, but remain an issue.

The critical issue of scan completeness, that is minimising occlusions and maximising the context in scan data, has been dramatically improved with the advent of mobile 3D laser scanning technologies. As these mobile devices become more accurate, through the invention of smaller lasers with the same accuracy as terrestrial scanners, there promises to be a radical improvement in what can be captured with increasing accuracy.

Grave-to-cradle through digital cultural heritage

Recent calls to address the ‘crisis of accumulation of the historic past’ can be answered in part through a rethinking of how heritage can be documented, stored and archived using 3D digital scanning as a starting point. For sites such as Peel Island, preservation of the physical fabric of the buildings is impractical given their current dilapidated state and lack of funding for maintenance, and would work against the significance of the site, which includes the quality of abandonment. The digital files that we have to date for the site allow managers, and possibly in the future visitors, to examine the buildings in their context in a way that is not only accurate enough for interpretation, but includes the setting in such a complete way that an ‘authentic’ version of the site is created. The Peel Island point cloud data and accompanying material, including film footage from the time when the site was in use, interviews with patients and staff, and photographs, will be archived onto the CyArk database in 2017. At US$10 000 per site for archiving onto CyArk this may seem an expensive exercise. However, CyArk will update file formats in perpetuity giving the virtual site a sustainability that is otherwise impossible for the physical site. This digital archiving cost is, however, far cheaper than maintaining the site in physical form, and provides a digital ‘cradle’ when the site itself is becoming a physical ‘grave’ for the heritage buildings. The complete dataset of all original scan data is also being archived onto the University of Queensland’s data management site eSpace, to ensure that it will be available into the future, and accessible to researchers.

Planning for the demise of the physical fabric is both practical for some historic sites and overcomes the difficulties that arise through natural decay or catastrophic events. 3D laser scan files can be used after a disaster to either experience the lost site virtually or, in cases where
the significance is extremely high, assist in rebuilding efforts. The Korean Gate of Sungnyemun, which burned to the ground in a 2008 arson attack, is one example of a significant site that was destroyed and subsequently restored (Greenop and Barton 2014). Other heritage issues that can be addressed through scanning and archiving include those posed by industrial heritage sites, which are often large, difficult to safely maintain and hard to adapt for sustainable re-use (Landorf 2009). These sites are usually destined for a heritage grave, but could instead be reborn through a digital process that is beginning to offer the attributes of aura and place authenticity. Furthermore, the multiple ways in which places can be presented digitally, such as in the Pure Land Magao Grottoes exhibition, offer possibilities for recognising the multiple meanings of places, and for re-creating alternative versions of heritage places that are fleeting or contested. Mass reproduction through digital media offers an opportunity to feed the desire for heritage experiences, supporting the migration of aura without necessarily maintaining the physical fabric of every historic place. Heritage site recording is fundamentally shifting, towards digitised, and immersive versions of heritage places, enabled by mobile and ever more cost-effective and comprehensive 3D laser scanning systems. The future of heritage place interpretation will be open to more people, to multiple and dynamic versions of places and through which a place’s aura, encompassing its context, recorded experiences, contested histories and ephemeral events, as well as physical characteristics of the place will be available to many.

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