TANGIBLE DIGITAL HERITAGE

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In this short article, we present the past, current, and potential future trends in digital technologies for the documentation and conservation of primarily built cultural heritage. The opportunities offered by digital media from 3D scanning to 3D visualisation and, as of late, 3D manufacturing may allow the reproduction of physical cultural artefacts which may transform the way we educate in academia, perform conservation in practice, and engage the general public as a whole.

We are currently transitioning into a new era of technological advancement in information technologies. Early struggles to adapt and integrate traditional computing – that is, a person in front of a computer – in academia, practice, and everyday life have largely been overcome. Norman (1998) predicted the emergence of the "Invisible Computer", what is now known as the "Internet of Things". Fundamental concepts such as autonomous decision making machines, artificial intelligence, and deep learning; the abundance of sensory data and processing that only fast number processing machines could handle – what we now call big data – were all seeded decades ago. We are once again entering exciting new times for research and design in technology both in the abstract, as with technological development for its own sake, as well as in a more applied manner, revisiting and addressing problems within domains of human activity that may benefit from this new capability.

Our backgrounds overlap the domains of architectural computing and architectural history, theory, and culture. The common ground of our joint research work is in the documentation of built heritage by developing specialised computer software applications and deploying digital technologies such as 3D scanning and printing (Fig. 1). What if the cost of 3D production – from data acquisition, digital processing, and printing – is a mere fraction of what it is today? What if advancements in 3D printing composite material reached parity or exceeded the performance of current building materials? How can digital technologies improve the process of historical documentation and conservation of built heritage from the perspective of professional experts? How can they inform the processes of educating prospective design students in architectural history, theory, and culture? How can these technologies enable general audiences to interact with heritage assets across the red tape and blue screen?

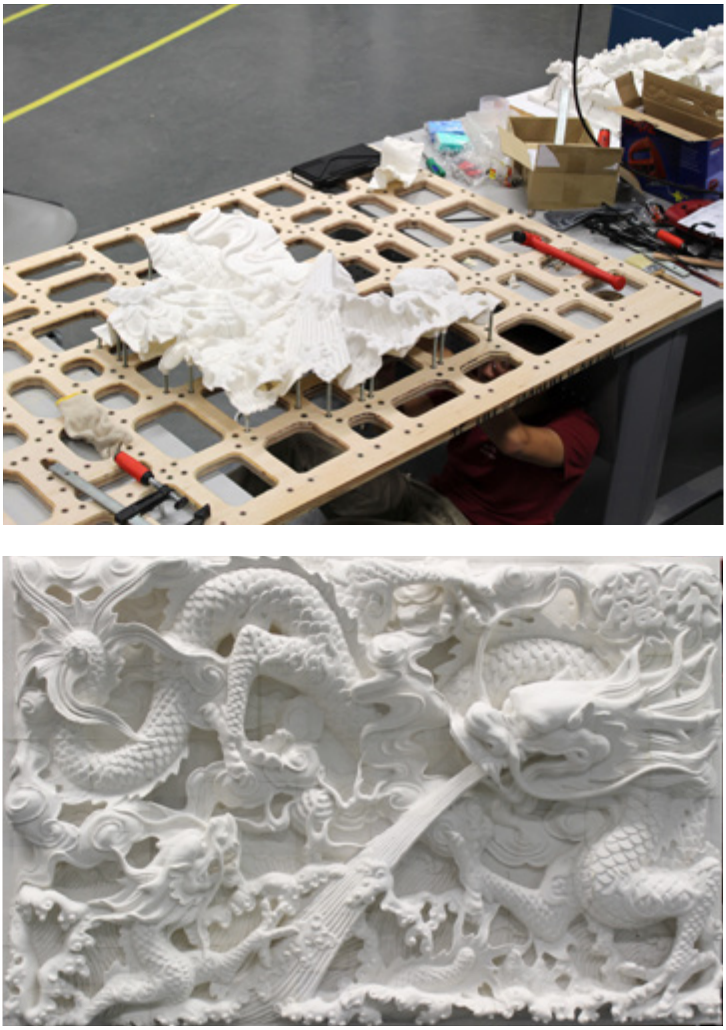

Fig 1. Real scale reproduction of the dragon wall once found at the Yueh Hai Ching Temple in Singapore using 3D scanning, 3D modeling, and 3D printing technologies, 2011. Images courtesy of Digital Heritage Lab.

Information technologies in heritage documentation

The predominant approach to the digital documentation of physical artefacts, including those of historical or heritage value, is offered by Computer Aided Design, Parametric or Associative Geometry, and Building Information Modelling. Artefacts are measured using conventional instruments and reproduced by the sequential application of geometric operations within computer software. While this process, also known as reverse engineering, is laborious and time-consuming, it affords the opportunity to capture not only the appearance of an object, but also potentially aspects of its design, fabrication, and assembly logic. For example, individual components may be semantically attributed and organised. A notable early example of digital conservation is the study of the Sagrada Familia Cathedral by Mark

Burry (1992) which investigated the tectonic dimensions, underlying logic, and production techniques that gave rise to Antoni Gaudí's architecture using parametric technologies. A unique aspect of digital modelling processes, which otherwise emulate or perhaps carry forward conventional recording techniques into the information age, is in their active fusion of documentation, approximation, and interpretation.

The proliferation of 3D scanning and visualisation technologies in the past two decades has expanded modes of experiencing cultural heritage artefacts and places through media such as synthetic computer imaging and interactive virtual or augmented reality systems. Until recently, these technologies were prohibitive in terms of capital costs for equipment and the requirements for specialised computing expertise. Today, however, basic forms of 3D scanning can be performed with nothing more than a mobile phone connected to the internet. What is remarkable about the process of 3D data acquisition using scanning equipment is the accuracy and speed with which it is possible to collect fragments of information, which in large volumes enable us to virtually reconstruct the geometry of the artefact documented. The Digital Michelangelo Project (Levoy 1992) offers a pioneering case study, already more than 20 years ago, in deploying 3D scanning for the documentation of historical artworks. Spectral imaging and Computer Tomography scanning, which currently remain quite unreachable for architectural heritage applications, offer the possibility to pierce beneath the surface of physical artefacts and capture their internal structure and material composition at extremely high resolutions.

Digital heritage in the age of big data

A few characteristics differentiate this new approach to heritage documentation from conventional methods. Firstly, it speeds up data collection, at least on site, in contrast to conventional measurement techniques. Nevertheless, post-processing copious amount of sensory data still requires significant amount of time investment. Secondly, the decoupling of semantics: 3D scanning data, also known as geometric soups of point and surface fragments, cannot inherently qualify the artefacts being documented. Clustering, segregation, and attribution are separate processes, and the automation of these processes is a cutting edge research problem for computer science. A third characteristic of this new approach to documentation is the deferment of interpretation, as the reverse engineering, rationalisation of geometry, and the processes that gave rise to it take place later. The implication of this is increased objectivity, accuracy, and dependability of information. Finally, the ability to uniformly document artefacts of extremely high spatial complexity such as works of art and intricate crafts. Building ornamentations, for instance, cannot be practically or meaningfully modelled using constructive geometry methods unless they were designed and produced as such in the first place.

There are two very interesting trends that result from the aforementioned characteristics: first of all, the ability to finally document faithfully what we previously considered "undrawable" architecture, that is, works of traditional craftsmanship that were never designed or fabricated using formalised processes of modelling, analysis, and evaluation. Secondly, algorithmic forensics that follows the availability of large volumes of precise information coupled with the need to computationally attribute and organise this information creates the context for automated feature extraction, classification, and pattern recognition. This capability enables the recognition of affinity between similar artefacts, as well as the extraction of tectonic principles. At this point, the approach will be able to demonstrate its true potential beyond quantitative technical benefits such as throughput and resolution.

Experiencing heritage beyond visualisation

Technological advances in recording and processing information have created the area of virtual heritage (Affleck and Kvan 2005; Rahaman and Tan 2009). For experts in this area such as historians and conservators, the methods and tools developed have eased processes of documentation and specification in restoration work; and in education, they have facilitated the exposition of the history of architecture and art to students of design. For general audiences, technological advances have provided new and unique opportunities to experience cultural heritage through virtual and augmented reality applications. While these are beneficial developments, there are other potential applications of this technology in heritage. Just as there may be knowledge value in uncovering the underlying tectonics from the process of modeling, there may also be benefits in the actual process of physically reconstructing heritage artefacts. Technologies that were once only affordable for advanced industrial manufacturing and military applications are today available for architectural studies as well as general public use. The rapidly developing area of digital fabrication technologies (Schodek et al. 2004; Kolarevic and Klinger 2008), namely computer numerical control manufacturing equipment as well as 3D prototyping and printing machines, have the potential to enrich heritage knowledge by offering an immediate and tangible experience of the physical dimensionality and materiality of heritage.

Digital fabrication technologies offer unique opportunities when applied to heritage. One such opportunity lies in the reproduction and archiving of physical replicas. These replicas could also assist in conservation work, for example by serving as references for the reproduction and replacement of damaged building components using traditional craft methods. Potentially – though this is an area of application in need of sensitive debate and nuanced discussion – digitally manufactured components may be used as direct replacements in restoration works. While the notion of substituting building components today with polymer lookalikes is troubling, the loss of knowledge in crafts paired with the rapid development in multi-material printing technologies may be the only option available, and therefore warrants consideration.

Digital fabrication also offers opportunities in education, allowing for a much more integrated and interactive approach to the teaching of art and architectural history. Training people to document and conserve built heritage and traditional methods of construction - which already incorporates extensive fieldwork - could be greatly enhanced by the use of 3D scanning, processing, and printing techniques spanning from conceptual design to the end-production. Finally, the ability to experience the physical and tangible aspects of heritage assets first-hand affords the general public a much more direct and powerful experience compared to purely visual materials such as books or websites. While notions of place and authenticity can never be substituted by these new technologies (Benjamin 1936), there is an opportunity to enrich and expand the reach of heritage. If the objective of such engagement is to raise appreciation of works of cultural production, perhaps this immediacy is a positive and effective step forward.

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