Digital Recording in a time of Iconoclasm, Mass Tourism, Celebrity Culture and Anti-Ageing

By Adam Lowe

Image 1: *Head of Christ* made from a C12th original in Musée Cluny, Paris.
Wood, resin, polychrome. 2016. Made with permission of the Musée Cluny, Paris for Rachid Koraichi
Exact facsimiles can now replicate both shape and surface in the original materials. This facsimile was produced using 3D scanning, composite photography, 7 axis 3D routing into wood, 3D SLS printing and manual skill in terms of colour application.

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Introduction

The Factum Foundation grew out of Factum Arte to develop and promote digital technology for the recording, documentation and dissemination of cultural heritage. Factum Arte is a 21st century workshop in Madrid that bridges new technologies and traditional skills. Through the mediation and transformation of digital information, physical objects are produced for artists and clients around the world. Factum Arte has financially supported Factum Foundation since its inception, working outside the institutionalised professions tasked with protecting cultural heritage. This has allowed the forging of a new, original approach to documentation and preservation based on practical experience in both the workshop and the field.

This essay briefly reflects on the history of cultural preservation and outlines ways in which the wider application of a direct, frontline engagement can offer a much more effective, financially efficient and socially sustainable method. In an age with so many threats to our cultural heritage, we are now at a critical point and need to universally determine a new way forward. It is possible to record in colour and 3D and to re-materialise objects with very similar qualities, but this requires people with diverse skills, uniting both technology and craft with digital and physical artisans working together.

The purpose of this text for the British Council Cultural Preservation Fund is several-fold: first, it aims to clarify the current position of the practical recording of vulnerable cultural heritage sites and objects.[1] It suggests the most cost effective approach to recording the best data that can be archived safely and still satisfy the needs of the heritage preservation community in the future. Finally, it sets up practical guidelines and identifies areas needing urgent attention.

Technology in Focus – A practical introduction to scale, distance and resolution

3D scanning and composite photography are changing the ways in which cultural heritage is recorded, but the technologies are unfamiliar to most involved in heritage management. Moreover, misinformation is resulting is wasted opportunities. This is an overview of some of the systems currently in use, focusing on their strengths and weaknesses in different applications.

Between 2011 and 2013 Factum Arte recorded the carvings by Jacopo della Quercia, Amico Aspertini and others that adorn the doors of the Church in San Petronio in Bologna. Different types of recording were used to capture different aspects of the carvings. The whole façade was recorded from Piazza Maggiore using a FARO Focus 3DX 330 scanner (LiDAR scanner), while white light scanning with the Nub 3D Sidio recorded the surface of each sculpture from scaffolding that covered the façade during cleaning and restoration work: both are often referred to as high-resolution scanners. LiDAR technology is mainly used for topographic mapping, architectural recording and visualisations. The Nub3D was designed for reverse engineering and precise surface inspection. Taking the resulting 3D files from both systems and re-materialising their data at actual size using precision CNC milling, the resolution of the recorded information is clear. If photographic data is mapped over the relief, both look similar when viewed virtually on a screen. In the physical world they are dramatically different.

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[1]Technical details can be found elsewhere: Factum Arte and Factum Foundation websites both aim to provide objective and commercially impartial information about recording and output technologies.

Image 2: CNC carved data from a FARO Focus 3DX 330 scanner a LiDAR scanner (left image) and same section of the façade of the Church of San Petronio recorded with a Nub3DWhite Light scanner (right image)

However, the comparison is not entirely fair: while the scale of the object is the same, the recording distance is not. LiDAR systems are good for recording large objects like buildings or terrains, but less good for recording surfaces. To demonstrate, we set up a direct comparison between 3D files recorded with the Faro Focus 3DX 330,working at highest resolution at its minimum distance from the object (1.4 meters) and the same surface recorded with the Lucida Laser scanner (designed by Manuel Franquelo with the Factum Foundation) at its normal working distance of about 10 cm from the surface, recording black and white video using two cameras. In all recording, of critical importance is the relationship between information (what you are trying to record) and noise (interference as a result of the limitations of the recording system as information is transformed from one state to another). The aim of high-resolution recording is to 'capture' an object so that the data has the closest possible correspondence to the original in terms of shape, surface and colour.
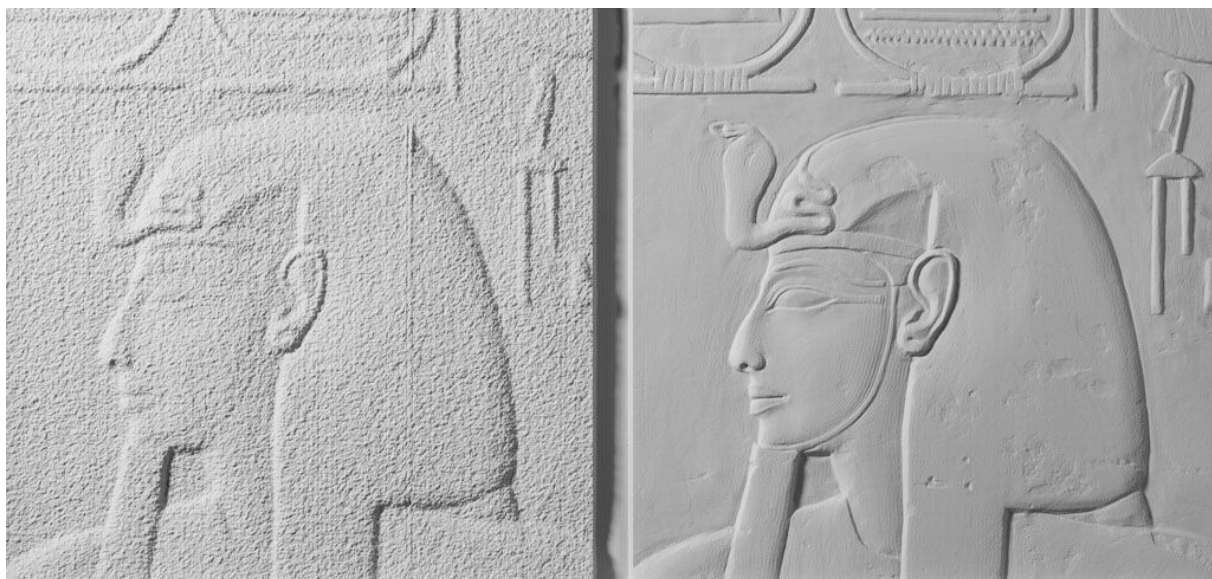

Image 3: Maximum resolution recorded with the Faro scanner working at its minimum distance (left image) and the same section of the tomb of Seti I recorded with a Lucida scanner designed by Manuel Franquelo with the Factum Foundation (right image)

Different scanning systems do different things: some are mainly for screen-based applications, others for re-materialising objects in three dimensions. The most dramatic developments are going on with software used in photogrammetry (Autodesk Re-make, Agisoft Photo Scan and RealityCapture) and composite photography (PTGui, Adobe Lightroom and Adobe Photoshop). In a recent experiment at the British Museum, Factum Foundation, working with James Fraser (Project Curator, Ancient Levant) and Jessica Pocock (founder of the charity, Making Light) recorded the calcite sculpture of Idrimi, King of Alalakh. The sculpture, found in Tell Alchana and dated to the sixteenth century BC, is covered with Idrimi's biography written into a weathered, veined white stone in detailed cuneiform. The script is legible to specialists, but requires epigraphic skills to extract individual characters from background information. One application of high-resolution recording in colour and 3D involves virtual RTI, optical character recognition systems and computer vision technology to enhance data and extract content. The work being done at the École Polytechnique Fédérale de Lausanne (EPFL)in Venice with the *Venice Time Machine Initiative* and recording of the photographic archive at the Fondazione Giorgio Cini, demonstrates the potential here to redefine the relationship between the past and the present.

Idrimi was recorded with a Breuckmann Smart Scan 3D, a white light scanning system that costs about 50,000 euros, requires an expensive commercial software and a skilled operator. It was also recorded with a Canon 5DSR with a variety of lenses, a tripod and two LED lights where the entire setup cost 12,000 euros. While 'premium' level photogrammetric software requires a license fee, the data can also be processed at reasonable quality using free software, or stored as images and only processed as a 3D file at maximum resolution when required. But there is always a relationship between time and cost, portability and size of equipment, electrical and other operational requirements. In the British Museum the white-light scanning took just under five hours to record and the same to process, while the photography took 13 hours to record and a further three days to process. The quality is very similar both on screen and when milled or printed as physical objects. The photogrammetry is probably slightly better.
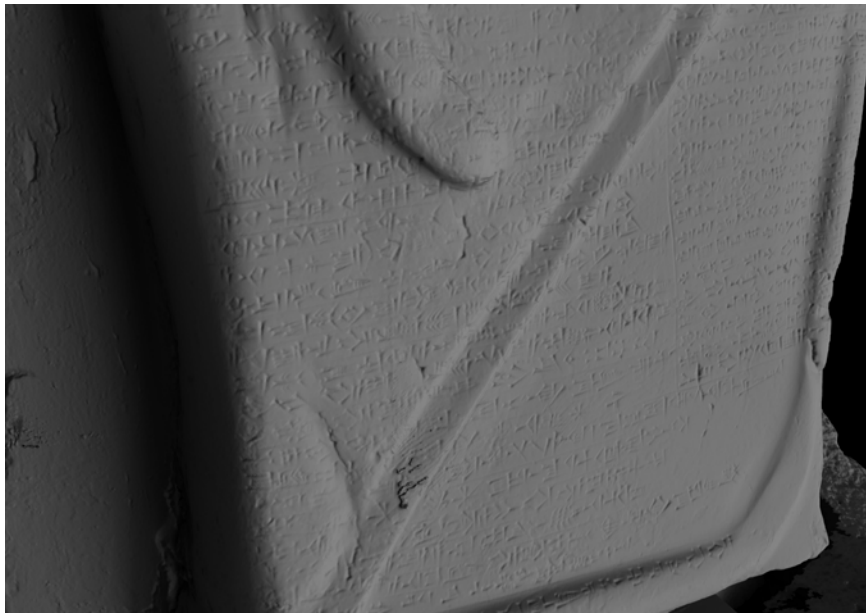

Image 4a: Comparison of 3D models of the statue of King Idrimi in the British Museum. The detail above was recorded with the Breuckmann scanner

Image 4b: Same detail recorded with photogrammetry

Recording Image and Form– A Brief History

2017 is the 150th anniversary of Henry Cole's *Convention for Promoting Universally Reproductions of Works of Art for the Benefit of Museums of all Countries*[2] that resulted in the creation of the Cast Courts at the Victoria and Albert Museum. To celebrate the anniversary the V&A, with the Peri Foundation, have launched ReACH (reproduction of Art and Cultural Heritage) 'a year long programme of events devoted to the drafting of a new convention regarding the role of museums in digital preservation and the dissemination of works of art and culture.'

The V&A originally intended to be a hub promoting the union of craft and technology in an age of photographic recording, casting and electro-forming.[3] In the *Convention*, Henry Cole optimistically claimed that these methods do not harm the original. This is true in the case of photography, but not of casting and electroforming where both require a mould. Making moulds of the Portico de la Gloria damaged the fragile polychrome surface and caused physical damage to other remote sites that were rematerialized in plaster and moved to London where they could inform and educate. The nineteenth century was the age of copying, and the importance of cultural artifacts lay in the complex stories they communicated about people who lived in different places at different times, held different views and

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[2] We have been through a period of modernism, which saw some of the great artists of the time actively involved in smashing the evidence of the past. Josef Albers personally destroyed the Yale collection of plaster casts to release the students from the responsibilities of engaging with the past. The key points of Cole's convention are worth revisiting, and are reproduced here, paraphrased and truncated:

    1.   Knowledge is necessary for the progress of art and reproductions are a good means for public instruction.
    2.   The task of recording and replicating should be controlled by each country.
    3.   Following the first two points,
            a.   Local selection of objects valued within the culture
            b.   Communication between governments and fair trade
            c.   Openness in exchange of casts.
            d.   Political support – the Royalty and aristocrats who signed the convention committed themselves to promote and realise its aims.

[3] The *Convention* was conceived at a time when photography was emerging. 'Photo-*graphy*', or '*writing* with light' has produced a vast number of images that condition our ways of seeing and thinking. 150 years later it is 'photo-*grammetry*', or '*measuring* with light', which is allowing a fundamental shift in the relationship between image and form. This shift has profoundly changed the agenda and can transform how we record and present the evidence and meaning of the past in the face of revisionist iconoclasm and mass tourism.

believed in different gods. Objects were seen as a means to access knowledge and understanding; they were not seen primarily for their commercial worth.

Before cheap flights and mass tourism, it was easier to move copies of architectural sculptures to London than it was to move people to remote sites. Now the situation is reversed. Millions of people each year want to visit sites of cultural interest. Many, like the tombs in the Valley of the Kings, were never intended to be visited and cannot take vast crowds without incurring significant damage. Tourism, while vital for local economies, is now one of the main causes of the change and decay of our shared cultural heritage. It is increasingly difficult to balance the complex demands of protecting sites while providing access to them. Other causes of damage and destruction include, war, natural disasters, climatic change, pollution, political apathy, vandalism, accidental damage, fire, iconoclastic attacks and commercial interests. Recently attention has focused on iconoclastic acts of destruction that attract media attention. Cultural protection needs to address all the above, and to acknowledge inevitable changes over time. The recording of both natural and cultural heritage is essential to monitor and understand these changes. If done properly, recording facilitates a deeper and more accurate understanding of the articulate artefacts left by previous generations. It is essential that politicians and heritage managers are aware of the positive opportunities that are currently being opened up.

Political Provocation

"We are here today in the spirit of defiance, defiance of the barbarians, who destroyed the original of this arch…! How many digits to do you think Daesh deserves? I think two digits to Daesh from the Institute of Digital Archaeology and from London!"
From Boris Johnson's speech, accompanied by an abusive hand gesture at the unveiling of
a copy of the Arch of Palmyra, Trafalgar Square, April 2016

Cultural heritage, normally neglected by politicians, is increasingly put at risk by simplistic statements. Boris Johnson's triumphant comments when unveiling a copy of the central section of the Arch of Palmyra in Trafalgar Square were deliberately provocative and set out to politicise the act of recording cultural heritage. This is dangerous: it puts both the technology and the people who operate it into a position of aggressive opposition to radicalised iconoclasts, making the former a direct target. This 'exact copy' of the Arch of Palmyra was, in fact, merely an interpretation of the original. It was not accurate in terms of scale or material, but more importantly, neither was it in terms of the language of decoration and architectural ornament. It turned the arch from a specific architectural monument into a generalized symbol that focused on defiance rather than communication.

Fortunately a French team from Iconem and a Russian team that included experts in mine clearance, both bravely working on the ground soon after Islamic State was forced out of Palmyra in March 2016, used aerial photogrammetry to record the whole site at levels of accuracy of a few centimeters (http://iconem.com/temple-of-bel/). When Daesh retook the site in December 2016, the Roman theatre that had not been significantly damaged in their initial iconoclastic attacks became the first target on their return. It should not need to be stated but recording should be financed and carried out in times of peace. War zones are not conducive to subtle, detailed and often slow work.

The Biography of 'The Original'

'Before we get into the "how-to" element of identifying condition, it is worth understanding why pictures can become damaged in the first place. Time, fire and water are of course bad for any painting's health. But the sad fact is that two groups of people have done more damage to paintings than anything else: those who sell art and those charged with looking after it.' Brendor Grosvenor, The Art Newspaper, 9 March, 2017

After a period of political and intellectual neglect, the Cast Courts at the V&A are again a focus of attention and interest. While moulding caused significant damage to the originals, the resulting casts contain detailed information about the surface of the object as a snapshot of the time the mould was made. Comparing a 19th century cast of one of the figures from the Parthenon frieze to its 'original' in the British Museum reveals a difference: the surface is not the same. The mould contains forensic evidence that reveals a meaningful biography of the object. The eroded chisel marks that were traces of the manual skills of the classical craftsmen have been replaced with the marks of the drills used by the conservators in the museum in 1938. It is a widely held view that objects are safe in museums. That the only evidence left of the Northwest Palace, Nimrud is now found in museums around the world after the destruction of the site bears this out. But it doesn't mean that objects in museums do not change. The Nimrud Lamassu and the decoration from the Throne Room of Ashurnasirpal II arrived at the British museum with colour in 1848; they are now the grey green of the Mosul marble with only a trace of pigment occasionally visible in indented areas. The Sarcophagus of Seti I in Sir John Soane's Museum was white with blue infill when Belzoni shipped it from Luxor to London. It is now various tones of honey brown. The figure of the attendant in Veronese's *Wedding at Cana* was an orange red when first painted; 'stupide rouge marron' following a restoration in 1851[4] and it is now a dark copper green following the restoration completed by the Musée du Louvre in 1991.

Recording and understanding change is central to understanding the nature of an object, its history, where it has been and how it has been viewed. Mark Jones in his exhibition *Fake? The Art of Deception, 1990, British Museum,* states, "…*it can be argued that fakes, scorned and passed over in embarrassed silence by scholar, dealer and collector alike, are unjustly neglected; that they provide unrivalled evidence of the values and perceptions of those who made them and of those for whom they were made.*" Restoration does the same.To a trained eye the place and date of a restoration is often discernable even when records are patchy. To some degree restorations turn the original into a reproduction of itself blurring the difference between autograph mark and interpretation. The surface of a painting reveals many things about how a painting has been cared for and aged, yet it is still rare that painting surfaces are scanned in three dimensions before, during or after restoration.

Recording and Monitoring Change

All things change over time, yet the commonly held idea of 'an original object' is of something with fixed qualities that are integral to its being and character. While there is seldom an instant moment of creation, there are often periods of rapid change in its career. A series of actions and decisions, normally made by more than one person, are required to bring an object into being. This is then followed by decay, conservation, preservation, relocation, revaluation, imposition, addition, correction, alteration and 'improvement'. In a digital age, diverse recording methods can accurately fix the object in a moment of time. The resulting archive acts as a record by which change can be measured. Originality is not a fixed state of being, it is a process in which many agents work together.

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[4] Francesco Valcanover's description at the time of the 1989-91 cleaning following a accident during the restoration when the painting fell from the wall and was seriously damaged.

Image 5: Recording Ferapontov Monastery near Lake Beloe, part of a collaboration with the Peri Foundation

Zooming In

Recording happens at various scales from the macro to the micro, with different resolutions and very different levels of funding. As part of the multi-billion-euro earth observation programme, the Sentinel-2A and Sentinel-2B spacecraft orbit the earth creating a complete map every five days. They carry cameras to record forms of approximately 10 meters across in both colour and with an infra-red filter. Together they produce four terabytes of data per day. 'Big Data' is a reality, and everything generated needs to be stored requiring governmental levels of funding and years of planning. This data will reveal natural disasters, the speed at which glaciers are retreating, sea levels are rising, agricultural patterns are changing and urban infrastructure is expanding.

Very big things and very small things tend to be expensive to record. At a nano-scale recordings have transformed medical imaging and our understanding of the human body. At a macro-scale, a profoundly expanded knowledge of the globe is now easily available. But these technologies have been taken up slowly and with reluctance in the cultural sphere. Photography, X Ray and Infrared spectrometry are now used in most museums. Accurate surface recording is happening at the Rijksmuseum and the National Gallery in London but still, surface recording is very rare.

The *Theban Necropolis Preservation Initiative* by Factum Foundation and the University of Basel has recorded the surface of some of the tombs in the Valley of the Kings that have since been re-materialized at a scale of 1:1. To the naked eye, from a normal viewing distance, they are indistinguishable from the original. To date, the recording and rematerialisation of the Tomb of Tutankhamun in the Valley of the Kings, the restoration of a Hasan Fathy building that will be used as an on-site training and archiving centre and the equipping and training of a local team, has cost approximately 500,000 euros. Not only are the surfaces of tombs being recorded in colour and three dimensions with over 100 million un-interpolated, ordered spatial points per square metre, key skills and technologies are simultaneously transferred to the local community. As the project develops the data generated will be stored locally and disseminated globally. It will reveal change to the surface, paint loss and alterations caused by the impact of tourism and restoration attempts to halt the tomb's decay. Hopefully it will also lead to new discoveries about the tombs themselves.

Digital Passports

Freely available, interactive, multi-layered archives for paintings, sculptures and low relief objects are a core outcome of all Factum Foundation projects. They are an essential part of part of the preservation of any object, acting essentially as 'digital passports' for works of art at a specific moment in time. The 3D scan of the surface is dimensionally accurate allowing all types of photographic data to be aligned in perfect registration and selected at will. Direct comparisons (side-by-side or overlaid) reveal why paintings look as they do. In a major research project with the Museo del Prado, all Goya's Black paintings were recorded using a 3D surface scanner, composite photography, X Ray, infrared and ultra violet spectroscopy, supplemented by historical photographs taken of the paintings in the 1870s. The files have been layered together and when made public they can be viewed on a normal computer, via the internet, without specialist software or advanced skills. This can change scholarship and inform restoration practice.

For sculptures, the presentation of 3D data at high resolution still causes difficulties. Sketchfab and other visualisation software can help but often the high-resolution files are still too 'heavy' for easy viewing in 3D and colour on normal computers without downloading specialist software. With the recordings of the Cochno Stone (a project with the University of Glasgow) and the recording of rock carvings in the Ennedi Plateau, Chad and Icom monoliths in Nigeria (both projects with the Trust for African Rock Art, TARA) different approaches have been taken to data presentation. Both are freely available.[5]

Image 6a: David Coulson recording with photogrammetry rock monoliths in Nigeria

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[5]At the time of writing, a BBC report has just revealed that one of the sites in the EnnediPlateau, has suffered significant vandalisation. While it may not be possible to protect every remote site, it is possible to fully document them. If this is done through training and equipping local people it can be both cost effective and beneficial to a local community in need of new sources of income. http://www.bbc.com/news/world-africa-39332438
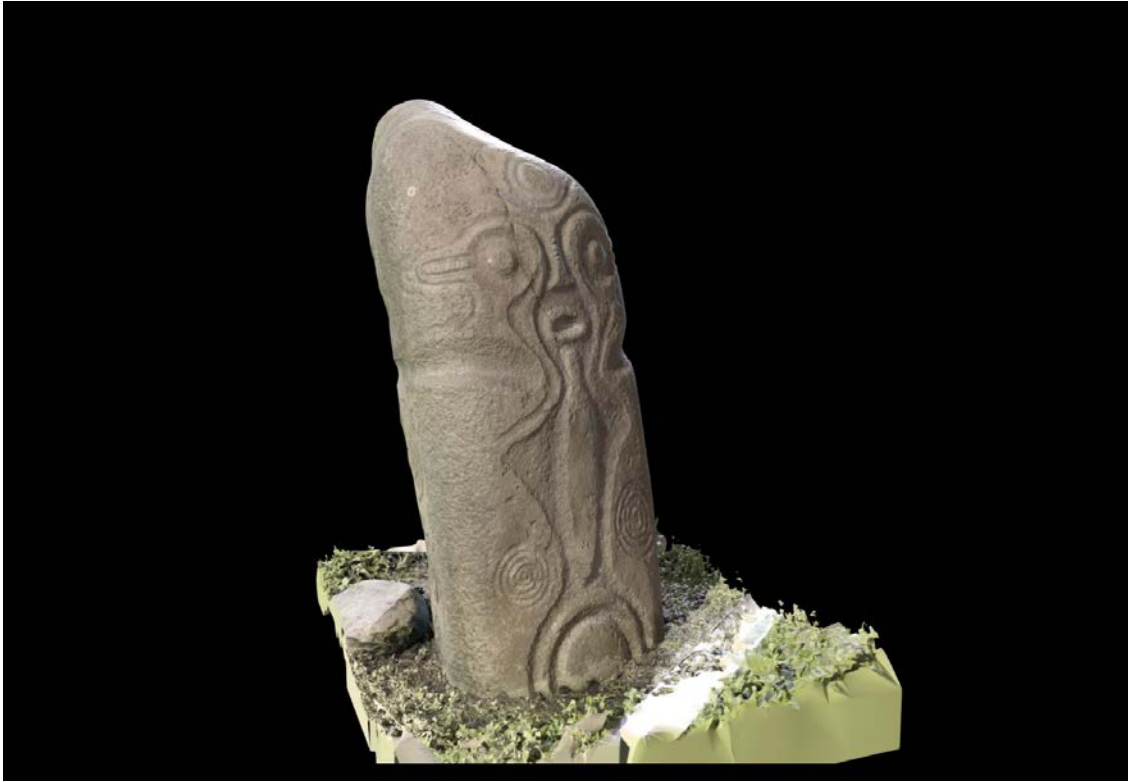
Image 6b : Screenshot of Sketchfab 3D model made of Nkrigom monolith

Technical support, Processing and Archiving

The goal is to digitally record for preservation. All work is 100% non-contact and – critically - the object is not damaged or altered in any way. As with all technologies, technical and 'chat-room' support are essential to help people with problems on the ground. They address both technology and content issues from equipment malfunction to what, and how, to record. Recording heritage requires operators sensitive to the vulnerable nature of the object. Imparting this is often more difficult than teaching technological skills.

In some cases data processing can be done on site. In others, it is better to archive raw data and process it later. Many systems abstract the data as it is recorded. This means the resolution of the data is fixed. It cannot be reprocessed later at a higher resolution as technology evolves. In contrast, the Lucida Scanner and photogrammetry both record images: one black and white video, the other colour photographs, a major advantage as they can be stored as images and processed into three dimensional meshes or point clouds as required.

Long-term archiving is a large topic outside the scope of this text. It is essential that there are distributed servers capable of storing data in a secure format for many years, even in the absence of an electrical supply. The dissemination of data is another topic that requires in-depth analysis and political agreement. Who has access to the data, how it can be used, when it is freely available and when commercialized, how it is used in conservation and restoration in the event of damage and who should control it are all issues for top-level heritage managers. The whole question of when it should be re-materialised as a three dimensional, physical object is emerging as a topic of great importance. There is also an urgent need to establish guidelines based on quality.

Image 7: Replica 360 Recto/Verso Recording System developed by Factum Arte and the Ecole Polytechnique of Lausanne in partnership with the Fondazione Giorgio Cini

Image 8: With the support of the Peri Foundation, Factum Arte designed a book scanner that is currently scanning the manuscript collection of the Institute of History, Archaeology and Ethnography (IHAE) in Makhachkala (Dagestan).

Digital Restoration

'Digital restoration' is rapidly developing as a form of non-contact preservation that allows various opinions to be projected onto a work of art without interfering with the original. High-resolution recording is critical for its success. Factum Foundation has been working with Columbia University, The Metropolitan Museum (Cloisters) and Museo Numantino de Soria to carry out a detailed digital restoration of the Hermitage of San Baudelio. The traces of the wall paintings that were removed are being recorded in-situ, and all known paintings relined onto canvas in the late 1920s are being recorded and reintegrated onto the surface of a virtual model of the Hermitage. We are also working on the aesthetics of digital restoration and heavily damaged sections of the wall are being reconstructed. The goal is to demonstrate the difference between subjective interventions and objective facts. The Baudelio research aims to focus on how the walls of the Hermitage have altered, provoking discussion between different professional groups before the surface of the walls are touched again. The 19th century was a time of the romantic adventurer/discoverer and cultural pillaging. The 21st century could see the

emergence of an ethical and responsible approach. The debate should not be primarily about ownership, but about meaning, understanding and sharing.

Recording Technologies: Definition, Resolution and Application

150 years after Henry Cole's Convention, attention has shifted from reproducing works of art to diverse methods of recording them. Without correct digital data it is not possible to meaningfully replicate an object, in the same way that without a good mould you cannot make an accurate plaster cast. There are few guidelines that cover the various types of digital recording and enormous misunderstandings. At the most fundamental level the definition should be: *'digital recording should be carried out using various technologies at a resolution sufficient to make an accurate copy of the original object should the original be lost, damaged or destroyed'*.

The term, 'high-resolution' requires definition to ensure a stable frame of reference for all those using it. Establishing common terms and precise definitions is one of the most pressing subjects for academic study and practical application. Factum Foundation is setting up a model for this at the *3D Scanning, Archiving and Training Centre* that opened in Stoppelaëre's House on the West Bank in Luxor in February 2017 (as part of the *Theban Necropolis Preservation Initiative*), and developing similar initiatives with the Peri Foundation in Russia, with the École Polytechnique Fédérale de Lausanne, the Fondazione Giorgio Cini in Venice and the Community Jameel in Jeddah and Dubai. In each case, high quality information is a product of the practical application of the technologies. The training of local operators is at the heart of these initiatives, merging political approval, technological understanding and academic discipline.

Image 9: Inaugurated in February 2017 as part of the Theban Necropolis Preservation Initiative, the 3D Centre in Luxor will maintain an archive of digital data recorded by local technicians trained in operating and troubleshooting the latest technologies for heritage documentation

Understanding the mediations and transformations that take place during the recording, processing, archiving and re-materialisation of an object is essential. This requires the collaboration of electronic engineers, designers, artists and technicians to develop new hardware and software. The emphasis is placed on building bridges between different skills and professional disciplines, between the traditional arts that celebrate the transmission of knowledge through manual repetition, and the digital arts that express the same understanding through algorithms and electronic engineering.

A Plan of Action

Over recent years Factum Foundation has put 3D scanning at the heart of a coherent, non-contact approach to the documentation of cultural heritage. 3D recording is essential to create an objectively accurate framework onto which other types of information can be mapped. This needs to happen on the scale of buildings to an accuracy of a few centimeters, and at micron level, recording surfaces at high-resolution. Different types of recording take different amounts of time and cost varies greatly. There needs to be collective agreement about what data is needed for each application. There is no excuse for wasting opportunities to carry out recording as well as possible, and future generations will judge us harshly if we do. The field is developing fast and requires operators who understand both technology and art. Fortunately for people born in the last 25 years, this is not as rare as it was in a pre-computer time. The proposal is simple: record at the highest resolution possible using systems that capture the colour, shape and surface of an object. Photogrammetry by an experienced operator with the right software for processing the data comes closest to being the system that can record all three at the same time. But other systems still have important roles to play.

As recording technologies undergo rapid evolution, they become cheaper and more accessible. These are the five essential major areas of practical recording :

1. **Composite Photography** for photogrammetry and high-resolution colour recording
1. **Long and Medium Range LiDAR**
2.
3. **Scanning to Record Shape:** For survey recording of sites and buildings.
4. **High-Resolution Close-Range Scanning to Record Surface**: To produce approximately 100 million ordered, measured points per square meter. Various approaches to this require different systems.
5. **Multi-Spectral Photography:** For recording various non-visible frequencies of light to reveal things invisible under normal conditions.
6. **Adapting and Designing Bespoke Hardware and Software:** Most technology is not developed for cultural applications and there is an urgent need to develop both hardware and software to satisfy specific needs. This can range from subtle adaptations to radical re-thinking.

Composite Digital Photography: Positives without negatives

Composite photography requires a good DSLR camera (Canon 5DSR), a variety of high-quality lenses (Sigma Arts 50mm, Sigma Arts 30mm, Canon EF 180mm, and in certain cases Canon EF 300mm), a tripod, Flash (Prophoto D1) or LED light panels, a laptop computer (CUDA Graphic card required and 16 GB memory). Processing at high-resolution requires a powerful computer (two CUDA graphic Cards, 128 Gb RAM) and processing software (Reality Capture) costing about 15,000 euros. Processing at lower resolutions with fewer images can be done with free or relatively cheap software.

Basic training to record objects and buildings can be done in a relatively short time depending on the photographic skills of the operator. Training to use drones or training in data processing can take years of experience. The skill of the operator and attention to detail during processing conditions the quality of the data. The task of recording data, archiving the photographs and processing the 3D and colour files can be separated. The processing can be very time consuming; the processing of the Sarcophagus of Seti I recorded in Sir John Soane's Museum took a skilled operator working with the software writers several months. The resulting 3D model is made from five thousand 58 megabyte images and consists of 13 billion polygons.

Other recording systems are more expensive and demand specialist software. These should be held in centralized pools and loaned (with trained operators) for specific purposes to ensure efficient and effective use. As technology is advancing so quickly, it has a short operating window and it is therefore a mistake to put too much investment into hardware and software that is not intensively used. The data processing can be done locally or at the central point where the equipment is stored. Remote operation of computers has transformed how the technology can be used in the field. In a pilot project that is being carried out with Community Jameel in Jeddah and Asir, Pedro Miro and Otto Lowe from Factum Arte and Factum Foundation will record buildings and architectural details with a LiDAR scanner and high-resolution photogrammetry. They will process the data both on site and using the powerful computers in Madrid. At the same time the team in Madrid will be able to support their work on the ground where they will be training local operators while actually recording several important sites.

Cost Effectiveness

This text should demonstrate that technology can be very expensive but doesn't have to be. The Factum Foundation, working with Factum Arte, has already enacted and is developing alternative models that succeed. The secret lies in collaborations with local communities. The cost effective way to carry out recording is to train and empower local people. Working in Daghestan with the Peri Foundation has resulted in the training of two highly skilled operators, Shamil Gadzhidadaev and Gennady Viktorov. The forthcoming work of the Peri Foundation to record Dionisy's frescos at Ferapontov Monastery in northern Russia will result in the training of more local people. This is an exponential model based on transferring core skills, providing equipment and software, putting people on the ground, supplying a helpline and remote access and supporting the archiving and data processing. This approach works. It is happening in Luxor (Egypt) and Makhachkala (Daghestan). Initiatives are being developed in Cross River State (Nigeria) and the Ennedi Plateau (Chad) where we are working with TARA to identify talented and highly motivated individuals who can be equally capable (and are often more ingenious) than Oxford or Harvard graduates.

Image 10: Factum Arte's Carlos Bayod and Aliaa Ismail, the Foundation´s Egyptian trainee in digital recording, scanning with the Lucida Scanner the tomb Seti I in Luxor, a project part of the Theban Necropolis Preservation Initiative

Conclusion

[An] immaculate eye for detail is typical of the work of Factum Arte, a Madrid-based studio whose combination of digital analysis with assiduous craft is transforming the way we see art. I've been watching their work develop for nearly a decade. I am now convinced it is the most important thing happening in 21st century art – because it can quite literally save civilisation."

Jonathan Jones, *"Factum Arte: the art copyists giving the Renaissance a renaissance"*
Guardian Newspaper, March 2017

New recording technologies are providing increasingly accurate 3D,colour and multispectral data. This is objective information facilitating forensic and digital analysis that allows experts from many different disciplines to work together. Digital and physical artisans are working alongside historians, scientists, restorers, museum directors, dealers, collectors, curators and others: there are many interested parties and different points of view to consider before physical interventions are made to an original object. In this environment a new type of digital connoisseur is emerging, where knowledge and fact exist with curiosity and communication for a deeper understanding of our cultural heritage.

Now is the time to focus part of the Cultural Preservation Fund on the documentation of sites and objects alongside (and in support of) the archaeologists and experts working on the ground.Factum Foundation proposes a practical, effective initiative that directly addresses the pressing need for cultural heritage recording in the MENA region. The Foundation is in a position to provide training and equipment for high-resolution digital documentation to both young enthusiasts and experienced professionals working in the region. Technical and operational support will be supplied at all stages from non-contact data capture, through methods of securely saving the raw data, to the processing and archiving of high-resolution 3D and colour data of cultural heritage objects and sites.

The aim is to train two or three candidates from each country and equip them with 'composite photography kits'. Photogrammetry (the method of extracting 3D information from 2D images) is the most cost effective and easily portable method for both medium and close-range recording in the field. It also requires minimal training and allows 3D and colour data to be recorded at the same time. The first round of candidates would go on to train other suitable candidates, ensuring the sustainability and growth of the initiative. The candidates will record specially selected sites in their country and process the data in software stations administered by local partnering institutions. All will be archived in a purpose-built network of servers that will grow to accommodate the volume of digital information being recorded, processed and made available.

To strengthen the infrastructure, a pool of more expensive specialist equipment, including Factum Foundation's bespoke scanners and commercially available systems, will be freely accessible for loan with operators on an 'as-needed' basis to ensure that the best quality recording is always achieved. The equipment varies according to the task. The goal is to record a range of culturally significant objects, from buildings to relief panels, paintings, artefacts and fragile manuscripts.

An operational 'helpline' in the form of a user-generated forum, phone access to Factum experts and instructional literature / media will be continuously developed to support the growing network. A project specific website will disseminate all content and the data will be presented on high-resolution web viewers, accessible to all, to help promote the archive and support in-depth study and research. Experts with remote access will ensure that the hardware is kept fully operational and will help solve software issues. Finally, conferences will be organised to disseminate the project and present the data to professionals in a wide range of sectors, promoting an awareness of the potential and importance of preserving cultural heritage.

Extraordinary things are possible when technical experts and cultural managers share the same goals, speak the same language and acknowledge each other's core skills. We must urgently establish the most effective way to transfer skills and technologies to local communities while ensuring that data is securely archived. Local communities need to benefit from preserving their own heritage, and funds generated from current and future revenue streams should be reinvested into heritage recording and preservation on a local level. This is now a proven model that works.

Factum Foundation is dedicated to kindling the flame; to the application of digital and physical technologies to reveal how we relate to, learn from and understand the articulate evidence we have inherited from the past.[6]

'Tradition is not the worship of ashes, but the preservation of fire'.
Attributed to Thomas More and Gustav Mahler. Used as an epigram by the Fondazione Giorgio Cini

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[6] It is worth noting that this whole article was written without mention of UNESCO, whose role it is to preserve cultural heritage. UNESCO pioneered the World Heritage Sites and the scheme has been successful in attracting attention and visitors to many fragile sites in diverse parts of the world. Perhaps one of UNESCO's roles should now be to ensure high standards are established for the documentation of these sites. UNESCO is also in a position to ensure that long term archiving is effective, freely available and distributed.

APPENDIX:

The Factum Foundation

The Factum Foundation grew out of Factum Arte, created to promote and develop digital technology for the recording, documentation, archiving and dissemination of cultural heritage. Factum Arte is a 21st century workshop in Madrid that bridges new technologies and traditional skills. Through the mediation and transformation of digital information, physical objects are produced for artists and clients around the world. To summarise: the Factum Foundation's work takes several forms:

- The development and application of specially designed, bespoke technologies for cultural applications.
- Building bridges between digital technologies and traditional manual skills.
- Using facsimiles as a means of protecting works of art, especially those that were meant to last but not to be visited.
- Changing attitudes to the relationship between originality and authenticity
- Revealing the stories contained within things.
- Transferring skills and technology to local communities.
- Education and dissemination of the importance of digital preservation.
- Communication and contexualisation.