The 13th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST (2012)
D. Arnold, J. Kaminski, F. Niccolucci, and A. Stork (Editors)

Insourcing, outsourcing and crowdsourcing 3D collection formation: perspectives for cultural heritage sites

Jaime Kaminski[1], Karina Rodriguez Echavarria[1], David Arnold[1],

Gianpaolo Palma[2], Roberto Scopigno[2], Marc Proesmans[3], James Stevenson[4]

[1]Cultural Informatics Research Group, University of Brighton, UK
[2]Istituto di Scienza e Tecnologie dell'Informazione (ISTI), CNR, Pisa, Italy
[3]Katholieke Universiteit Leuven (KUL), Belgium
[4]Victoria and Albert Museum, London, UK

Abstract

This paper presents three different propositions for cultural heritage organisations on how to digitise objects in 3D. It is based on the practical evaluation of three different deployment experiments that use different methods and business models for mass 3D-acquisition. These models are: developing the skills of in-house staff within an organisation, the use of external professionals and using crowdsourcing as a mechanism for developing the 3D collection. Furthermore, the paper provides an analysis of these models, lessons learned and practical recommendations for cultural heritage organisations. The analysis includes considerations of issues such as strategy, size of the organisation, skills, equipment, object accessibility and complexity as well as the cost, time and quality of the 3D technology. The paper concludes that most organisations are able to develop 3D collections but variations in the result will be reflected by the strategic approach they place on innovative 3D technologies.

Categories and Subject Descriptors (according to ACM CCS): K.1 [Computing Milieux]: The Computer Industry—Markets G.1.10 [Mathematics of Computing]: Applications—

Keywords: deployment and business models, insourcing, outsourcing, crowdsourcing

1. Introduction

Cultural heritage (CH) organisations are increasingly seeking to deploy 3D technologies for the documentation, preservation and communication of their tangible heritage assets. These organisations exhibit certain characteristics. Many have a large quantity of compelling content - much of which simply cannot be displayed to the public because of space constraints. This makes digitisation an attractive prospect. However, a disproportionate number have limited access to technical skills and many are in a relatively weak financial position. These factors will clearly influence how, and indeed even if, mass 3D digitalisation can be conducted.

This paper is based on a series of project trials designed to develop an understanding of how cultural heritage organisations specifically can engage with the mass digitisation of heritage objects in 3D. Specifically the focus is on the business and technical processes that underlie mass digitisation. When faced with the need to digitise objects in 3D, CH organisations have three principal models to choose from:

- In-sourcing: when a CH organisation invests in acquiring in-house expertise and equipment; 3D is strategic to the organisation.
- Out-sourcing: when a CH organisation prefers to delegate the implementation of 3D technology to an external expert or company; being interested only on the result of such implementation.
- Crowdsourcing: when a CH organisation delegates tasks involved in the use of 3D technology to a larger group of people either loosely or not associated with the organisation (e.g. a museum's visitors, general public).

Developing in-house expertise is a proposition some her-

DOI: 10.2312/VAST/VAST12/081-088

itage organisations may attempt when deploying technologies. One of the advantages is that most knowledge is embedded within the organisation. However, this model also requires continual investment in the staff to improve their skills in what is a fast-paced moving field. Success measures of insourcing solutions involve indications of cost savings and service excellence [HL00]. Moreover, the risk is always latent that once staff have developed their skills they could leave the organisation taking their knowledge with them. In addition, the innovative nature of 3D technologies imposes further challenges on heritage organisations as equipment is also expensive and might require an extra set of skills to operate.

Outsourcing was popularised as an alternative business model when Eastman Kodak started outsourcing its information systems functions in 1989 to IBM, DEC and Businessland. Thereafter, both large and small organisations have found it acceptable to delegate technology functions to independent organisations. This business model is commonly chosen by those organisations who do not consider the use of 3D technologies as part of their competitive advantage. Hence, outsourcing offers an opportunity to remain competitive by accessing the latest technologies along with external expertise [AJ94]. In return, this frees up personnel to work on specific value-added functions [DGHJ04], [SvdMKL10].

Moreover, one of the earliest applications of crowdsourcing was for the open source software movement, where volunteers participate in the development of software for the benefit of the community. In cultural heritage, early adopters of crowdsourcing included the museums behind Flickr Commons, but it was not until 2010 that crowdsourcing began to see wider use in the sector. Existing crowdsourcing initiatives applicable to cultural heritage have been classified according to different criteria, including the model of participation used [BBJ*09] and their tangible outcomes [OA11]. The latter presents projects classified under six different categories: correction and transcription (e.g. Digitalkoot [Nat12]), contextualisation (e.g. Civil War Faces [Lib12]), complementing collections (e.g. The Great War Archive [Uni08]), classification (e.g. Flickr Commons [Yah12]), and crowdfunding (e.g. We Did This [WeD12]). Crowds participating in these projects contribute to generate different types of output data. The simplest being text and images followed by multimedia and finally 3D outputs.

While technology transfer is widely studied in industry, it is apparent that there is far less information available for 3D digitisation in the heritage environment. A number of important aspects of the three business models have been explored in the following descriptive case studies.

2. Case study 1: In-house mass acquisition at the Victoria and Albert museum

The Victoria and Albert (V&A) museum photographic studio undertook a trial project with the objective to understand what effort is required to develop a 3D collection of a variety of cultural heritage objects in a working studio environment. As the national museum of art and design for the UK, the collection is varied and the opportunities to test 3D technologies are extensive. Hence, in order to make some reasonable judgements, the objects acquired in this trial represent this variety and contain a large range of material types and surfaces.

The V&A photographic studio is well equipped and appointed for imaging in a CH institution. It is wholly funded by the museum and it operates with full-time employed staff in purpose-built studios within the museum buildings. Its staff are experienced in all forms of object photography and well practised work-flows have been developed for the successful completion of digitisation projects. It has good equipment with lighting and general photographic accessories so background equipment is substantial.

During this trial, the 3D acquisition was conducted using the Breuckmann smartscan device [Bre12] as shown in figure 1. In order to become proficient in the process, staff had to undertake several training sessions to acquire knowledge in the scanning process as well as the complexities of acquiring different types of objects (e.g. artefacts, painting, textiles) as well as their details, including fine and rough surfaces, shiny edges and large objects with areas of fine detail. Other knowledge related to the device was also relevant, such as working with multiple lenses in the most efficient and accurate way, using align and pre-align functions and handling very large files. It was recognised that the order of training undertaken was sound; basic training followed by a period of familiarisation followed by further training.

Figure 1: *3D scanning setup in the photographic studio of the V&A museum*

Artefacts in the collection were classified according to the different features they exhibit which affect the efficiency of the scan. These included texture (roughness), reflectance /diffusion, occlusion, rigidity, transparency/translucency, noisiness (a function of texture but a characteristic in its own way), size (physical dimension of the object) and colour.

The trial, including training, was conducted from March to September 2011 and involved two members of staff generating 28 scanned artefacts (see example in figure 2). During the trial, the V&A realised that there are similarities between 2D and 3D workflow. For instance, initial response to an imaging request, assessment of the object, access and movement and imaging setup are elements of the workflow which are comparable in both instances. With this in mind the V&A Photographic Studio has taken advantage of its experience of photographing cultural objects in a public service museum environment and applied it to 3D.

Nevertheless, scanning in 3D is a lengthier process than 2D imaging. To fully complete a task requires space to be available for between 24 and 48 hours. In contrast, for 2D acquisition the turn-round time for a studio can be 1 or 2 hours. This has implications for the use of work-space. With this is mind to undertake a substantial 3D digitisation campaign would require its own dedicated work-space.

Figure 2: *Example of 3D model of the Meissen Fountain produced during acquisition trial in the V&A.*

At the V&A it took at least six months to become proficient with the digitisation process. Besides training, it took experience and observation of the effects of actually doing the work to develop full in-house expertise. During the trial, the workflow timeframe for scanning improved from 11 to 6 hours after a few months. Projecting this result for a year, it would be reasonable to expect the digitisation of 150 models per year. In addition, it is necessary to consider start-up costs for acquisition of equipment. Scanners vary greatly in price but an approximate cost for a scanner is €80,000. This is assumed to depreciate to zero over four years. Other institutions may, or may not, already have support equipment such as lights and backgrounds in place. If not these would cost in the range of €20,000.

Finally, the resulting 3D models were presented to staff in the museum, which created considerable interest. This has allowed them to consider how 3D can assist them in their work or be able to present the collections in novel ways. Therefore the trial project fed back into the wider strategy of the museum.

3. Case study 2: Expert mass acquisition and presentation of the coin collection of the National Museum of San Matteo

When the curators of the National Museum of San Matteo in Pisa wanted to present their collection of ancient coins in an innovative way they turned to outside experts in order to achieve their goal [PSP*12]. A coin is a very small artwork, which, in a standard museum, is presented to the public at a distance displayed behind a glass case. This does not allow visitors to appreciate small and interesting details on the legend or on the coin bas-relief. Moreover, the coin is usually visible only from one side. Therefore, CNR proposed to digitise the collection as well as design and implement an interactive kiosk that would allow the virtual manipulation of the coins. This would allow visitors to inspect them in detail, and to reveal some of the hidden meaning of the coins.

The management of the virtual inspection of the coins was one of the most important aspects in the design of the kiosk. RTI (Reflectance Transformation Imaging) images were chosen because they have several advantages with respect to the acquisition of a complete 3D model (3D geometry and appearance). Starting from a set of images taken from a single viewpoint under varying lighting conditions, RTI techniques [MGW01, GWS*09] encode the surface normal and the appearance of the coin in a single image to enable the interactive re-lighting from any direction. The interactive re-lighting allows to reproduce the illumination-dependent effects of the surface with a higher quality and a higher resolution than with 3D scanned models. The acquisition and processing steps are cheaper than 3D scanning and the final representation can simplify the interaction because the user is more used to interacting with images rather than 3D models.

Figure 3: *The nine layers with the coefficients of a HSH image.*

The first step of the trial project was the acquisition and the generation of the RTI images; 41 coins were selected by the museum curator for the first acquisition session, following numismatic value and storytelling criteria. The coins cover different epochs, from the Roman Empire to the Grand Duchy of Tuscany (XVI - XIX centuries). For the digitalization a minidome designed by the University of Leuven

Figure 4: *Acqusition setup in the National Museum of San Matteo in Pisa.*

was used [WVM*05]. The acquisition of the photos was carried out in October 2011 in a single working day on site in the museum (see figure 4). This was possible because the minidome can be dismantled and transported easily. The acquisition phase was undertaken by staff from the University of Leuven, but it is quite easy to do even for people without specific expertise in this field. The hardware setup requires only the shell and the camera to be mounted and for the coins to be placed in the middle of the dome. For each coin the acquisition only required about 10 minutes which was necessary to shoot and store 520 photos (260 photos for each side).

The generation of the final image involved the computation of the RTI encoding for each coin side and the construction of a multi-resolution format. For the generation of the RTI images the HSH (Hemispherical Harmonics Map) format [GWS*09] was chosen because it guarantees better reproduction of the specular reflection with results that are more photorealistic compared to the more common PTM (Polynomial Texture Map) format [MGW01], as shown in [MMC*08]. For the construction of the multi-resolution format, the RTI image was subdivided into nine layers, one layer for each HSH coefficient (figure 3). The *i-th* layer contains the *i-th* coefficient of the three RGB colour channels. For each layer a multi-resolution tree was created and each level of the tree was cut in tiles using a quad-tree structure. Finally each tile was saved in a different PNG image. The advantage of this format is that it allows an out-of-core loading of the data, which makes at least some low resolution data immediately available, progressively refining the coin as soon as the higher resolution data are loaded. The loading of the tiles at the different resolutions is guided by the zoom and pan operation of the user. The generation of the RTI images took about 24 hours of completely automatic processing, without user intervention.

Part of the project involved investigating the possibility of using photometric stereo with respect to non-lambertian surfaces [WVM*05] to extract BRDF information. Although real BRDF data cannot be extracted from a one-camera setup, actual 3D surface descriptions and reflectance information can be deduced from RTI recording. The trial shows that this way of recording allows much more basic information to be extracted on the shape and material characteristics of the observed surfaces, although it was not included in the final kiosk application, because for realistic viewing for the public the HSH approach is much more suitable.

The interactive kiosk was implemented by using the Community Presenter, a tool designed for managing 3D data and 2D media such as the RTI images. It is composed of two integrated sections. The first section introduces and presents the different categories of coins to the user. The second section leads to the interactive RTI visualization. The kiosk starts with a presentation of the project (figure 5). On the left there is a menu that allows the user to navigate among the different categories of coins and to directly access the RTI viewer. In the RTI viewer the user can change the light direction, pan the image, zoom in and zoom out, flip the coin to see the other side, enable the visualization of the hot-spots. By clicking on a hot-spot the user can display the relevant multimedia content on the left side of the page.

The installation setup is composed of a 24-inch multitouch screen, for user input and visualization, paired by a bigger screen which will be set above showing the same content as the touch screen to a larger audience. This will allow visitors not interacting directly with the kiosk to see what is happening.

Figure 5: *Presentation page of the kiosk.*

The trial project was successful, as it solved the problem of how to digitise a subset of a collection of coins with an enhanced 2D approach whilst also producing an interactive tool for visualisation. Estimating the overall cost of digitization and development of the interactive kiosk is not easy: time is negligible (two working days), but the cost of the acquisition equipment is unclear since it is a research prototype. A rough estimation for the cost of the commercial device would be in the range of €10,000-15,000.

4. Case study 3: Crowd sourced mass acquisition of public monuments and sculptures in Brighton and Hove

The aim of this trial project was to test a crowdsourcing approach in order to produce a 3D collection of public monuments and sculptures in the city of Brighton and Hove in the United Kingdom (UK). This approach aims to guarantee the quality of the output while being completely open to anybody for participation. Quality is ensured by combining contributions, embedding provenance information and directing the contributions of the crowd over an entire selection of heritage artefacts in order to create a 3D collection of those artefacts. The trial aimed to understand how small organisations (e.g. trusts, charities), such as the Public Monument and Sculpture Association (PMSA), who oversee and promote these entities in the UK, could develop their 3D collection.

During the trial, a selection was made of specific objects dispersed in several areas of the city to best direct the efforts of the crowd. Eight areas were chosen in total (see figure 6), with a selection of between two to nine objects for a person to photograph. Each area was no larger than 1 km^2. The selection included a variety of objects ranging from sculptures, monuments, memorials, fountains, facades and clocks with a great variety of shapes and sizes, from a one meter high sculpture in a park to a six meter high memorial on an avenue. Different motivational mechanisms were used in order to involve the crowd, such as promotional material distributed by press and web based social media sites, presence at local events across the city and prizes from local organisations.

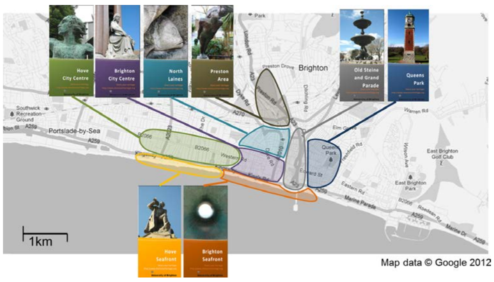

Figure 6: *Map with distribution of objects for acquisition in the city of Brighton and Hove, UK.*

The main tasks people were requested to do was to select an object to digitise from a website or promotional material, take photographs at their location and upload the photographs to a website. The photographic technique involved walking in a circle around the object, framing it and taking a photograph of the object for each step made (see figure 7). The photographs contributed were protected by the Attribution Share Alike 3.0 Creative Commons license [Cre12]. Through several cycles of different people performing this process, data was gathered of the same object photographed from different angles. The resulting 3D collection included the 3D models and their provenance metadata, which was then uploaded to a repository infrastructure and made available via a website and the European digital library Europeana.

Figure 7: *Member of the public photographing the Spring and Summer sculpture for digitisation and resulting 3D model.*

The crowdsourcing trial, which was run from July to October 2011, generated a series of photographs with 70% coverage of the sculptures and monuments selected for the trial. These photographs were used to produce photogrammetric 3D models of 18 objects (50% coverage). In addition a few more committed volunteers, spent more time learning and supporting the process to build the 3D models.

The trial showed that this type of project needs to be considered as a long-term initiative, with a time span of years rather than months. This is because a preparation period is required to design and deploy the required mechanisms to support public involvement. This leads to a high initial overhead.

In addition, motivating users is also time consuming. For instance, it is important to select the type of volunteers most suitable to the objectives of the initiative. Loosely associated individuals might be harder to motivate than people already associated with the organisation. In contrast, associated groups might be easier to contact and motivate. However, there are potentially fewer of them. Looking at the profile of contributors to the trial, it is possible to see a trend of people with strong motivations to contribute to a cause, with time available and the necessary equipment. The most committed contributors contributed on average 3 hours taking photographs and up to 3 hours in processing them to upload them to the site.

Looking into the economic considerations, this type of project might only be viable for a large number of objects over a long period of time as this will minimize and distribute the commitment both from volunteers and the organisations which undertake the projects. Nevertheless, an initial budget will be required to set up the project.

Finally, organisations will require support with setting up an infrastructure for the 3D collection. For this it could be possible to use existing partnerships from charities with universities or pay yearly fees to access a common infrastructure and expertise.

5. Analysis and discussion of case studies

In the three case studies a total of 87 CH objects were captured in 3D using the three different business models for acquisition and visualisation of the data (in-house, outsourcing, crowdsourcing). The evaluation of these studies has elucidated a number of broad insights that are applicable to CH organisations wishing to undertake a 3D mass-digitisation campaign.

5.1. Strategy

An organisation's strategy is a key driver for why a mass digitisation campaign might be conducted. The reason and motivation for 3D acquisition is a key determinant of the resources that the organisation will devote to the acquisition ([MKS06] and [KMS10]). As highlighted by previous research [HL00], investing in an in-house solution with all its associated costs it is more likely to be done by those organisations which see a competitive advantage in regularly using 3D technology for digitising their collections. This was demonstrated in the V&A interest in investing effort on learning about the technology as opposed to smaller organisations, such as the National Museum of San Matteo and the PMSA who were more interested in the final resulting 3D collection.

5.2. Size of organisation

The organisation's size (staff numbers) is an important variable. Larger organisations usually have better capacity and funding to support initiatives which are deemed of importance to the overall strategy of the organisation. In addition, the greater the number of departments with different expertise, the more likely it will be that there are staff with the appropriate skills to learn additional related skills. This was observed in the case of the V&A, which has the capacity in terms of staff to experiment with new technologies. In smaller organisations it is more likely that there is not funding available and that staff will be devoted to core activities and simply could not be spared. For instance, the PMSA staff is very small and so can only focus on core activities.

5.3. Skills

The skills available in the organisation have a profound influence on the capacity of the organisation to undertake a mass scanning campaign in 3D. Few museum and heritage sites are likely to have the skill sets available to undertake a mass digitisation campaign. At the beginning of the acquisition trial the V&A had no experience with a high end scanner, such as the Breuckmann scanner. However, the photographic department had a body of transferable skills in 3D acquisition. Similarly larger organisations have the potential for the internal transfer of skills to a greater extent than small and medium size organisations.

Moreover, analysis of the volume trial conducted at the V&A highlights that there is a learning curve associated with training staff to undertake 3D acquisitions. In this case it took around 6 months for the trainees to become maximally efficient at 3D scanning. This needs to be factored into any assessment of potential number of models acquired. With outsourcing, the number of 3D models generated is relatively constant and the learning curve is much less pronounced. Furthermore, if more objects need to be digitised in a short period (e.g. for an exhibition) then it is possible to devote more personnel to the job (which will incur a cost to the CH organisation) and so acquire more objects in less time. However, with an insourced model it is far more difficult to increase production levels. Training additional staff members is slow and, in the short term, will potentially reduce the efficiency of the scanning operations as the trainee undertakes 'on the job' training.

Efficiencies of scale and volume can be achieved by mass digitisation of objects of the same size and type. For example, 41 coins from the San Matteo Museum were digitised in a single day. This was in part because of the minidome device which did not require significant modifications to settings between captures, and also because this device is highly efficient at mass acquisitions.

5.4. Equipment

Few heritage sites have their own scanning equipment, and that equipment can incur a high cost (either through outright purchase or rental). There is continuing downward pressure on the price of acquisition hardware with the cheapest devices (e.g. NextEngine scanner) now in the €4,000 range, higher-end products are in the €20,000-150,000 range. However, at the low end of the market, digital cameras for photogrammetric capture are now in the sub-€1000 price bracket for semi-professional devices. Nevertheless, equipment affects the quality of the end result. Hence, it is important to carefully consider the best solution if the organisation's overall strategy is to insource the development of the 3D collection. This is because the equipment implies a large investment which will depreciate and become obsolete within a period of time. On the contrary, the case study of the National Museum of San Matteo exemplifies how an organisation which outsources the development is more agile in accessing state of the art equipment which might be suitable for specific objects in the collection.

5.5. Accessibility

The 3D digitisation of CH objects has a number of characteristics. The objects are for all intents and purposes fixed to a location (e.g. the museum, city or archaeological site). Moreover, access to objects in a museum environment is essentially controlled. This limits the potential for techniques such as crowdsourcing, because the public cannot access the objects for photography. Moreover, the fundamental reliance on access to the object for digitisation means that the internet cannot be used to outsource the operations 'offshore'. Digitisation is essentially limited to insourcing and domestic outsourcing.

Accessibility has implications for cost. In two cases (the V&A and the National Museum of San Matteo) the objects were available within the museum environment. While clearly there are some costs in curatorial time associated with choosing and locating the objects in store, and transporting them to the site of scanning, these are relatively low. However, these costs cannot be mitigated; they remain fairly constant for all objects. In contrast the crowdsourcing trial considered the acquisition of widely dispersed, publically accessible objects. Here, the time required for in-house staff to travel to the statues and monuments to digitally acquire them represents an important cost centre, which is reduced by volunteer labour undertaking the task. The greater the number of objects to be acquired the greater the cost saving would be, compared to the use of in-house staff.

5.6. Complexity

Object complexity covers a number of issues, ranging from the optical surface characteristics (e.g. reflectance, transparency), to the rigidity, number and type of occlusions and size. The greater the complexity of the objects the longer the acquisition time is likely to be as demonstrated both by objects acquired in the V&A and the PMSA case study.

5.7. Quality/Cost/time

The three case studies used different types of equipment (structured light scanner, minidome and cameras for photogrammetry) and so generated models of three different forms. The V&A scanning generated digital models with sub-millimetre accuracy, the National Museum of San Matteo acquisition generated high quality 2D digital representations of the coins although not all of these were full digital 3D models per se, and the crowdsourcing trial generated low quality 3D models of variable appearance depending on the skills of the photographers and the attributes of the monuments. Clearly there is a correlation in these trials between the cost of acquisition and the quality of the resulting model. However, if the variable of time is also included then the proposition becomes more complex. Crowdsourcing 3D potentially requires the longest time to acquire objects, followed by in-house capture (taking into account the training required and the learning curve for acquisition), finally outsourcing is the quickest method of acquisition because it incurs none of these overheads. However, the in-house capture becomes comparable if not faster than outsourcing once the learning curve has been achieved. Obviously, the museum professional seeking mass acquisition of artefacts through outsourcing can choose the level of quality of the model (the higher the quality, usually a higher cost). The crowdsourcing acquisition is currently at the lower end of the quality scale because of current limitations of photogrammetry and the quality of the photographs taken by the, in many cases, amateur photographers. There is a clear correlation between the investment and the potential quality output achievable.

6. Conclusions

The different case studies described in the paper have demonstrated that the proposed business models can work under certain conditions to produce a 3D collection. The results clearly show that each business model is appropriate to different situations; and as illustrated in figure 8, issues such as cost, risk, control, quality and output will vary.

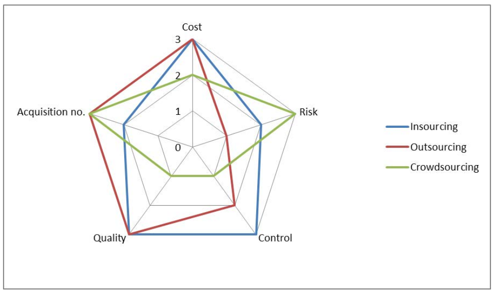

Figure 8: *A comparison between business models for 3D collection formation*

Outsourcing and in-house training is most appropriate for organisations such as museums where the collections are easily accessible to staff but generally inaccessible to the public. Museum collections are of course accessible for the public to view but not usually for 360 degree photography, moreover most museum objects are in fact not on view to the public but held in store. Crowd sourcing is reliant on the accessibility of objects and monuments to the general public. As such this is more appropriate to the acquisition of sculptures, monuments and buildings rather than collections of objects.

In terms of costs, in-house training of staff has the highest start-up costs and incurs the biggest risks if staff move on, however, it has a huge strategic value in terms of flexibility and long-term cost reduction for large numbers of objects. In all probability this is an approach that is more likely to be undertaken by larger organisations.

Outsourcing a mass digitisation is probably the approach most widely used by the professional CH community. This generally incurs a low risk to the organisation, guaranteed results (assuming a properly negotiated contract and service levels), but at a higher cost.

Crowdsourcing incurs moderate to high start-up costs but the long-term acquisition costs are low. However, there are risks. Crowdsourcing is at the mercy of the whims of the public so it is possible that not all the objects will be acquired, and their quality may be variable. Crowdsourcing is therefore, more appropriate for mass digitisations of large numbers of objects which are accessible to the public.

This emphasises that control of the process is a key variable that differs between the acquisition business models. It is highest with insourcing, and lowest with crowdsourcing. Related to control is the issue of risk. This is highest with crowdsourcing and lowest with outsourcing. Risk manifests itself in different ways in the various acquisition models. In insourcing, the biggest risk is that staff are trained and then move on, in crowdsourcing the biggest risk is that the project is not completed because of the lack of interest from the general public.

These trials have shown that any size of CH organisation can undertake a mass 3D digitisation campaign and acquire objects. However, understanding the business processes that underpin mass-digitisation is crucial for making 3D commonplace in the cultural heritage realm.

7. Acknowledgements

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007 2013) under grant agreement No. 231809. The authors would like to thank the National Museum of San Matteo and the PMSA for working together to digitise collections for these experiments.

References

[AJ94] Arnett K. P., Jones M. C.: Firms that choose outsourcing: A profile. *Information & Management 26*, 4 (1994), 179 – 188. doi:10.1016/0378-7206(94)90091-4. 2

[BBJ*09] Bonney R., Ballard H., Jordan R., McCallie E., Phillips T., Shirk J., Wilderman C.: Public participation in scientific research: Defining the field and assessing its potential for informal science education: A caise inquiry group report, 2009. 2

[Bre12] Breuckmann: SmartSCAN3D Series, 2012. http://www.breuckmann.com/1. 2

[Cre12] Creative Commons: Attribution share alike creative common license, 2012. http://creativecommons.org/licenses/by-sa/3.0/. 5

[DGHJ04] Dibbern J., Goles T., Hirschheim R., Jayatilaka B.: Information systems outsourcing: a survey and analysis of the literature. *SIGMIS Database 35*, 4 (Nov. 2004), 6–102. URL: http://doi.acm.org/10.1145/1035233.1035236, doi:10.1145/1035233.1035236. 2

[GWS*09] Gunawardane P., Wang O., Scher S., Rickard I., Davis J., Malzbender T.: Optimized Image Sampling for View and Light Interpolation. In *VAST 2009* (2009), pp. 93–100. 3, 4

[HL00] Hirschheim R., Lacity M.: The myths and realities of information technology insourcing. *Commun. ACM 43*, 2 (Feb. 2000), 99–107. URL: http://doi.acm.org/10.1145/328236.328112, doi:10.1145/328236.328112. 2, 6

[KMS10] Kaminski J., McLoughlin J., Sodagar B.: čD-ISF: An impact measurement tool for business and strategic planning in ICT and 3D heritage applications. In *In Proc. of the 11th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage* (2010), pp. 139–45. 6

[Lib12] Library of Congress: Civil war faces (library of congress flickr pilot project), 2012. http://www.flickr.com/photos/library_of_congress/sets/72157625520211184. 2

[MGW01] Malzbender T., Gelb D., Wolters H.: Polynomial Texture Maps. In *SIGGRAPH 2001, Computer Graphics Proceedings* (2001), pp. 519–528. 3, 4

[MKS06] McLoughlin J., Kaminski J., Sodagar B.: ICT investment considerations and their influence on the socio-economic impact of heritage sites. In *In Proc. of the 7th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage* (2006), pp. 109–17. 6

[MMC*08] Mudge M., Malzbender T., Chalmers A., Scopigno R., Davis J., Wang O., Gunawardane P., Ashley M., Doerr M., Proenca A., Barbosa J. a.: Image-Based Empirical Information Acquisition, Scientific Reliability, and Long-Term Digital Preservation for the Natural Sciences and Cultural Heritage. In *Tutorial Eurographics* (2008). 4

[Nat12] National Library of Finland and Microtask: Digitalkoot, 2012. http://www.digitalkoot.fi/en/splash. 2

[OA11] Oomen J., Aroyo L.: Crowdsourcing in the cultural heritage domain: Opportunities and challenges. In *5th International Conference on Communities and Technologies* (2011). 2

[PSP*12] Palma G., Siotto E., Proesmans M., Baldassarri M., Baracchini C., Batino S., Scopigno R.: Telling the Story of Ancient Coins by means of Interactive RTI Images Visualization. In *CAA 2012: Computer Applications and Quantitative Methods in Archaeology* (Southampon, UK, 2012). 3

[SvdMKL10] Smuts H., van der Merwe A., Kotzé P., Loock M.: Critical success factors for information systems outsourcing management: a software development lifecycle view. In *Proceedings of the 2010 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists* (New York, NY, USA, 2010), SAICSIT '10, ACM, pp. 304–313. URL: http://doi.acm.org/10.1145/1899503.1899537, doi:10.1145/1899503.1899537. 2

[Uni08] University of Oxford: The great war archive, 2008. http://www.oucs.ox.ac.uk/ww1lit/gwa. 2

[WeD12] WeDidThis: We did this, 2012. http://wedidthis.org.uk. 2

[WVM*05] Willems G., Verbiest F., Moreau W., Hameeuw H., Van Lerberghe K., Van Gool L.: Easy and Cost-Effective Cuneiform Digitizing. *VAST 2005* (2005), 73–80. 4

[Yah12] Yahoo: Flickr, the commons, 2012. http://www.flickr.com/commons. 2