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Creating a Virtual Museum
CCN+ Final Report

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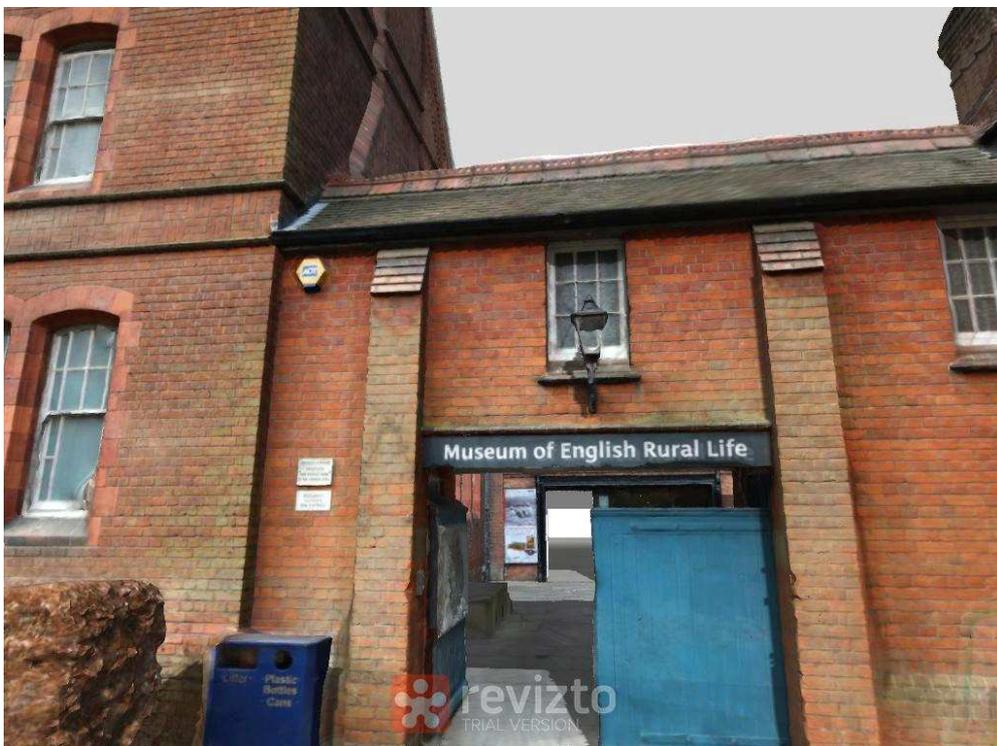
Entrance to MERL in the final model

Executive Summary

The 'Creating a Virtual Museum' project produced a virtual reality (VR) model of the Museum of English Rural Life (MERL), including a number of objects from the museum collections with additional information accessible from within the model. The digital technologies employed were restricted to relatively user-friendly and cost-effective software and hardware to investigate the feasibility of this process for non-experts such as museum staff.

Three key techniques were used to create the shape of the model (known as its mesh): photogrammetry using digital cameras; laser measurement photogrammetry using an iPad and a Structure Sensor; and architectural drawing. The majority of the MERL buildings were modelled along with nine objects. These ranged in size, shape and materials to test the digital scanning technologies, and were chosen for their appeal to school age children. Several compromises had to be made to accommodate the limitations of the software and hardware used, which had the effect of reducing the realism and flexibility of the model, but the final workflow resulted in a good quality, navigable rendering of MERL and nine objects, each with additional text and pictures.

The finished model was demonstrated at two events, one for museum staff and volunteers, and another to groups of children at a local school. At each of these events, three formats of the model were available to experience: iPad, PC monitor, and Oculus Rift headset, alongside four of the objects scanned into the model and brought from MERL. This allowed us to investigate a range of responses to the model from a small screen to fully immersive headset, and a comparison between the experience of VR spaces and objects, and the same spaces and objects in reality. Users were observed during their experience, asked to complete a short questionnaire, and engaged in conversation during their time at the demonstration.

Around 80 people attended the two events, and 56 questionnaires were collected. Preliminary findings from an analysis of the questionnaires and initial thoughts from the qualitative information collected offer four main insights. First, the two main groups (museum workers and school pupils) despite their differences in age, familiarity with the technology and familiarity with the real space, did not produce significantly different responses to the experience. Second, the sensation of being in a different place is ambiguous, with some responses suggesting a separation from reality and others an anchor to it. Third, the experience was compromised by the quality of the model and the demonstration format. The level of realism was good, but not quite good enough to be entirely convincing, and the performance of the hardware was also at its limits, with sometimes distractingly poor responsiveness (iPad) and among the adults a common feeling of motion sickness in the Oculus Rift. Fourth, the idea of aiming to accurately recreate a real place and real objects within it as a proxy for visiting the actual place and objects is flawed. The model will never be real enough, with diminished sensations of social presence, textures, sounds and smells etc. whilst also reproducing the limitations of the real world. Conversely, the same approach does not adequately account for the potential opportunities of the VR world, for example virtual MERL could act as a way of viewing manipulating objects that would not be possible in the real museum. More thought needs to be given to

the role of a virtual model as a complement to the world it represents. One suggestion from the museum staff was the benefit of familiarisation and orientation prior to visiting a complex building, which could result in tailored route planning or help disabled visitors such as autistic children.

The project has had immediate impact: in teaching, as the example for an MSc module in advanced visualisation at the University of Reading; in software development, used by the publisher (Revizto) as a case study for the re-purposing of their editing and viewing software; in gaining research funding, by adding credibility to an AHRC project to create a VR Roman house (IE as PI, starting March 2016, £80k FEC), and in supporting a successful AHRC Doctoral award in collaboration with Historic England, to use 3D models of heritage buildings as a platform for data management (IE as PI, start date October 2016).

1: Background

Efforts to enhance community engagement with local and specialist museums are key to the work of modern museum professionals. Museums, especially specialist or smaller, local museums are evolving their purpose away from the traditional hallowed repository, to becoming a relevant community resource. Archives and collections are becoming more readily available, and the communities the museum seeks to serve are extending beyond the local, to include specialist groups and interested non-locals. Museums such as the Museum of English Rural Life (MERL) as part of the University of Reading, aim to encompass a wider remit than academic research, and have been developing a series of schemes to engage with the community and encourage a more diverse the use of their spaces.

This work is happening against a backdrop of general austerity and a significant squeeze on public funds. Work at local museums is dependent on the dedication and originality of the staff to develop new ways of thinking about their collections without the need for substantial financial resources. Many in the museum sector have been experimenting with the idea of digital archiving, and it has been left to the larger institutions to lead the way in how this might be done. Typically this involves techniques for high quality reproductions of documents and objects, collected together in a digital database, which is then made accessible to the wider public (e.g. the Petrie Museum, which has created a digital archive that allows web-visitors to manipulate 3D virtual objects in abstract space [1]). With collections running into the tens if not hundreds of thousands of objects, such an undertaking is of course prohibitive for all but the upper echelons of the heritage world, and for museums such as MERL, this activity is carried out piecemeal, relying on limited funds and the efforts of volunteers.

Most recently, as well as efforts to digitize their collections, some institutions are experimenting with new ways of experiencing objects in situ, by creating virtual tours that can be explored on line. Examples include the British Museum, which uses themed photographs to form an on-line tour [2], and the Louvre, which has a series of 360° panoramic images linked to form a path of exploration [3]. In 2013, in a first for a UK museum, the Science Museum announced the complete recreation of a display space and its objects, recorded in its entirety before being dismantled as part of a major gallery reorganisation. This is now available as a pre-set guided tour on their website [4]. Unlike these large and national museums, for smaller museums a lack of funding and technical skills prevents them from attempting such projects. However, developments in digital technologies open up the possibility of wide-scale virtual access, enabling museums to increase engagement with communities who might otherwise not be able or inclined to visit.

Creating a Virtual Museum in a way that is practical for smaller museums, and bringing the resulting representations to communities at the fringes of existing

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[1] http://www.ucl.ac.uk/3dpetriemuseum
[2] http://www.britishmuseum.org/explore/online_tours.aspx.
Also see http://www.britishmuseum.org/whats_on/museumcraft.aspx where the BM has very recently instigated a project to recreate the Museum digitally using the on-line virtual building community 'Minecraft'.
[3] http://www.louvre.fr/en/visites-en-ligne
[4] http://www.sciencemuseum.org.uk/about_us/history/shipping.aspx

outreach activities is the basis of this project. We were able to take advantage of a rare opportunity at the University of Reading's 'Museum of English Rural Life' (MERL [5]), which closed temporarily to undergo a major redevelopment, providing unencumbered access to the interior space and key objects in the collection [6]. Using a novel mix of proprietary and emerging digital technologies, we created a prototype virtual museum and explored the possibilities for enhanced interactivity. The prototype was imported into a 3D gaming headset, a PC and an iPad, and used to interrogate the experience of a virtual recreation of a real world, with different potential audiences including the museum staff and school-age children.

2: Aims and Objectives

The 'Creating a Virtual Museum' project had at its core, two primary aims: to produce a model of the Museum of English Rural Life (MERL), using consumer-level digital technology (hardware and software); and to interrogate the experience of the VR model as a substitute for, or an extension of, the real place and objects.

The first package of work involved steps to identify the level of sophistication of hardware and software that might be reasonable for a museum such as MERL, and to use those technologies in the creation of a VR model of MERL. The skill sets and workloads of museum professionals are such that our focus has been on digital technologies that are essentially readily available and straightforward to use. This required some compromise in the quality of the outputs, but as we discovered, the rate of change of the technologies is such that we would expect there to be significant improvements in the next few years to allow this level of digital hardware and software to be able to handle greater complexity with greater precision.

The second package of work has been accomplished with help from members of staff at MERL, and the close involvement of a Reading secondary school. We organised two half day events, one for the staff and volunteers at MERL, and one at the school, at which participants were able to experience the VR models, and provide feedback, thoughts and comments on their experience. This is discussed in more detail below. Each of these two events has allowed us to consider how the VR museum is experienced and how it might be made more useful, interesting and engaging.

3: Model Creation

Architectural Data Capture

Creating the VR museum required the capture of essentially two sets of digital data: one for the buildings and architecture, and the second for a range of objects within the MERL collections.

Beginning with the University of Reading's Faro laser scanner (as used in CCN+ project "3D Cultural Heritage Visualisations"), we were able to produce a point cloud dataset for a series of rooms. While the scanner itself is reasonably

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[5] http://www.reading.ac.uk/merl/
[6] http://www.reading.ac.uk/merl/research/merl-ourcountrylives.aspx

straightforward to use, there are a number of difficulties. Most obviously is the cost to buy or rent this type of equipment (typically several tens of thousands of pounds to buy new). Secondly is the difficulty of handling 'point cloud' data, as produced by the laser scanner. At present there is no simple software that joins the millions of coloured dots (the point cloud) into a mesh of surfaces that can be represented as solid. The resulting effect is a ghostly transparency, rather than a solid surface. Software developers are working on this (e.g. Cloudworx), but these are currently aimed at high end professional users such as building surveyors, and depend on technically challenging software. Autodesk's Memento software, used as our primary means of mesh editing is expected to include this feature quite soon.

However, new consumer-level hardware is bridging the gap, and we have successfully tested one such device – the Structure Sensor. This is a mini laser scanner (around £400), which attaches to an iPad, and combines laser measuring with data from the iPad camera (position, orientation, colour etc.) to produce a laser/photo scan hybrid. Although this is aimed at 3D printing, results appear convincing enough for VR, and formed part of our final model.

The other commonly used method for reconstructing objects and spaces in VR is photogrammetry. This is now a fairly mature technology, but is nonetheless being continually developed in line with new hardware and software. Photogrammetry relies on computer algorithms stitching together multiple photographs of the same object from different angles to create a fully 3D photo-realistic version. Figure 5 shows an object from MERL - a decorated jug used on narrow boats – created using photogrammetry software and around 150 photographs. We have also applied this technique to architectural brickwork, with equally impressive results (figures 1&2). Photogrammetry relies on standard hardware – a reasonable quality camera – and simple to use, low-cost software (more discussion of the role of software is given below when discussing processing). Some practice is required for good results, but this does not need to be particularly technical. A typical modern 'point and shoot' digital camera can achieve good results if lighting conditions are right, and with a mid-range DSLR camera it is possible to achieve very good results especially if lighting can be controlled.

Figure 1: Photogrammetry model of the entrance to MERL

Figure 2: Photogrammetry model of MERL entrance courtyard

There are some issues with photogrammetry, but these will probably largely disappear in the next year or two. As it stands, the software (we used Autodesk ReCap360) depends on significant overlap between photographs, which means a typical small object would need around 50-100 photographs, while a large or complex object, such as a building façade, would require several hundred. Since processing is done remotely, there is a limit on the volume of data and hence number of photographs that can be uploaded. For ReCap360, this stands at 250. To produce the photogrammetry model of the entrance façade to MERL and the inner courtyard (see figs. 1&2 above) we carried out a series of photographic surveys at different heights, resulting in over 600 photos. Reducing the number to 250 to allow processing did not produce a useable model, so it was split into two: 'façade' and 'courtyard', and photos reduced to 250 for each. When processed, these two models could then be manually put together to produce one architectural VR model of the MERL exterior. However, it is worth noting that even since the start of this project the limitation on photos numbers has increased, and Autodesk have stated their intention to remove the limit altogether in the near future. The issue then becomes one of computing hardware being able to support larger and more complex models. As well as the continual development of computer processing power, we would also expect that new forms of less processing hungry hardware, such as the Structure Sensor mentioned above, will continue to be developed, and this may well shift the balance away from computing hardware and back on to software, in line with ambitions for more sophistication and detailed realism.

Whereas the relatively ornate brickwork façades of the entrance and the inner courtyard lent themselves well to being represented though photographic imagery, the interiors are almost universally white and plain, without the complexity required to identify common points in overlapping photographs in photogrammetry software. To create a digital version of the interiors therefore had to be done using more traditional architectural drawing. In keeping with our aim to use proprietary consumer-level software, the package we chose was Trimble 'SketchUp' – a simple

and widely used drawing package that can produce good results very easily, and excellent results with practice and skill. Using drawings produced by the architects for the MERL redevelopment, we produced a basic model of almost the entire interior of the gallery spaces. Most of this work was done with a group of students as a class exercise, developing it into a more sophisticated model, which offers a realistic immersive experience.

Figure 3: SketchUp model of MERL main galleries (exterior)

Figure 4: MERL interior showing 3 objects (Butter Churn, Mantrap and Sheepdip)

One of the project objectives was to attempt to scan a number of different objects to ascertain the best workflow and feasibility for an organisation such as MERL to scan objects into 3D models. Even a small museum such as MERL would typically hold tens of thousands of objects in storage as well as many more documents, photographs and recordings. In keeping with this as a pilot project, our aim was to produce 3D models of 10 objects. These were chosen according to a number of criteria to test the process:

- Different materials – some materials, especially metal and glass are notoriously difficult to model. Variations in reflection causes problems for the software, which is trying to match up visual images.
- Different sizes – larger objects are difficult due to the limitations in image numbers, whilst smaller objects are difficult to photograph with a consistently deep focus. Hence there is a compromise to be made between the quality of the photographs, their detail, and the technical competence of the photographer.
- Complexity of shape – it is more difficult to acquire images of all surfaces if those surfaces are complex with spaces or occlusions. A good example was our failed attempts to image a wooden farm cart, as the complexity of its wheels and suspension created an indistinct blur.
- Availability of additional information - to satisfy our aim to use the objects to test the process for including additional information, in collaboration with curators and archivists at MERL, objects were chosen which were relatively well-known, with interesting stories or easily available additional information.
- Appeal to school-age children – since we also aimed to test the experience for school-age children, we tried to include objects that would appeal to the younger mind, following discussions with teachers at two Reading schools (such as the rather vicious-looking Mantrap, used to capture and disable poachers by breaking their leg).

The 10 objects chosen (with their MERL object number) were:

Mantrap 62/403

Painted metal, 1.5m long, complex shape with many occlusions.

Polehead 55/1180

Unpainted metal, reflective, 1m high, simple shape.

Corn Dolly 86/148

Corn, 1.5m high, high degree of detail.

Sheep Dip 60/134

Wooden, 3m x 1.5m x 1.5m, simple shape, highly detailed.

Decorated Jug 63/474

0.3m high, painted metal, reflective, highly detailed, simple shape.

Butter Churn 78/25/1-5

1.3m x 1m x 1m, painted wood, very complex shape, highly detailed

Milk Churn 97/63

1m high, slightly reflective bronze, very simple shape.

Plough 52/67

1m long, wooden, complex shape, little detail

Glastonbury Wellies (new acquisition)

0.3m high, rubber and mud, simple shape, very little detail.

Clockwork Gun 99/27

0.3m high, galvanised metal, complex shape, highly detailed

We were able to try two methods of scanning: traditional photogrammetry, and laser measurement photogrammetry. The latter uses technology released in 2014 linking a laser measuring device to an iPad and its camera. As discussed below, our first effort was with the decorated jug using photogrammetry, with the assistance of the University's photographer. The result was very successful and highly realistic (see figure 8). This method worked best for the larger and more complex objects. The iPad/laser system was used for 4 objects (wellies, plough, polehead, milkchurn) with a fair degree of success, but failed on the larger and more complex objects (such as the mantrap). Both systems failed on one object - a clockwork gun, probably because the galvanized surface created a complex but repetitive pattern, which is difficult for the software to handle, and the metal walls were thin enough to prevent the software from determining inside/outside distances, creating transparencies. However, the remaining 9 objects were successfully incorporated into the model, along with associated text and an additional picture, which could be accessed through the Revizto 'issue tracker' icon (examples of the additional information provided in the model for each object are given in Appendix A). This was a limitation of the package, as it was intended for comprehensive data management, rather than easy access of simple information. It required several clicks in the right place to see the information and then move on, which caused some problems in our user trials.

Data Processing

Using Autodesk Recap360 for photogrammetry processing returns a file such as that seen in figure 5 below. This is a 3D model defined as a surface 'mesh' and image files that form textures and colours (see figures 6, 7 & 8 below). The initial mesh is edited, for example removing extraneous details such as the table on which the object was standing, using recently released (2015) Autodesk mesh editing software – Autodesk Memento – which takes files direct from Recap360. Memento is being developed in response to the growing demand for consumer 3D modelling, in particular for 3D

printing, and is a powerful but simpler version of other software packages. Perhaps the most commonly used is 'Meshlab' – an open source mesh editing package, which has been developed over the last 10 years or so by academics and enthusiasts, to the point that it includes a wide range of specialist options. The results from Meshlab were in some ways superior to Memento, with more sophisticated mesh simplification options and multiple mesh alignment for example, but require reasonable technical expertise. Memento is intuitive and easy to use for the non-specialist, and still returns very good results. We also expect that, as part of the Autodesk family and currently in development, improvements to some of the issues we discovered will be addressed in the immediate future.
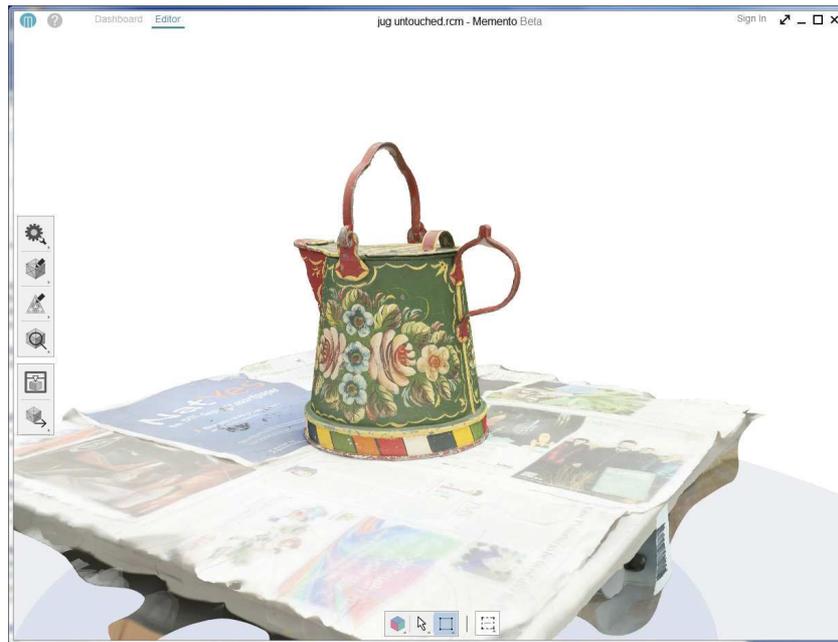

Figure 5: Decorated canal boat jug, untouched photogrammetry file.

Reducing the size and complexity of the model 'mesh' is critical to the useability of the final Virtual Museum. Meshes are made up of triangular faces (usually referred to as polygons, or 'polys') that create an outer surface, closely matching the shape of the original. The jug model created by Recap360 had 1.6 million polys, whilst each of the MERL building meshes (entrance and courtyard) had around 6 million polys. When imported into visualisation packages, a typical number that could be handled would be in the tens to hundreds of thousands. So the complete Virtual Museum, including the photogrammetry facades, the SketchUp interior and nine objects needs to be less than around 1 million polys. Processing the mesh, by combining smaller polys into larger and hence less numerous polys, is known as 'decimation', and can be carried out with varying degrees of sophistication and automation by packages such as Memento and Meshlab. Figure 6 below shows the MERL jug with 1.6M polys, which when decimated by 90% results in the mesh shown in figure 7. This produces a model with around 80K polys. Of course, there is a limit to the degree of decimation that retains the mesh shape, over-simplification of the model in this way can distort the shape or produce a cartoon effect. A simple shape such as this could be reduced to around 20k polys and still look realistic (see figure 8).

Figure 6: Detail of jug with undecimated mesh (1.6 million polys)
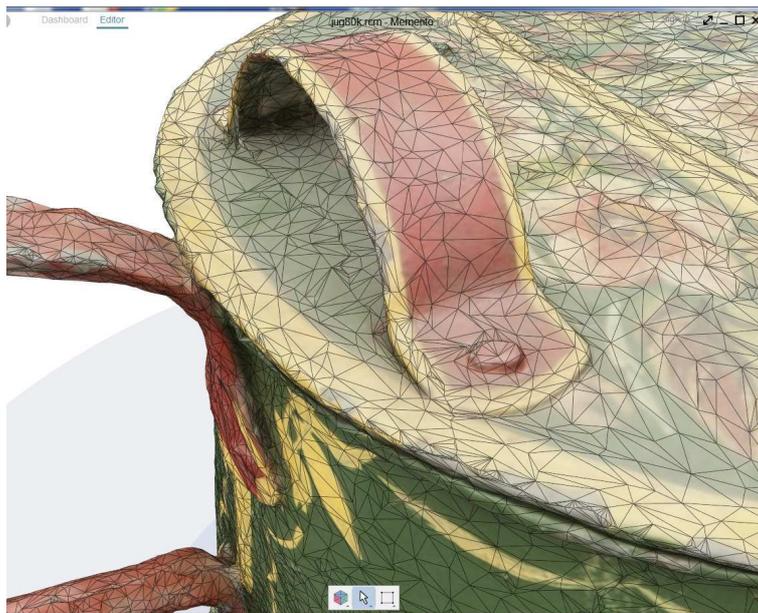
Figure 7: Detail of same jug, decimated by 90% (80K polys)

Decimation algorithms are becoming more advanced, differentiating areas of greater detail (such as the jug handle) and decimating those less, while simple shapes (such as the jug body) can be decimated much more. This is something that can be done manually in Meshlab, but we would expect it to become an automated feature relatively soon. Larger meshes are also likely to be less of a problem as more powerful graphics processing cards are introduced, a trajectory being aggressively pursued by the gaming industry, which will undoubtedly in time trickle down from specialist hardware to everyday PCs. However, these remain current issues, so that there is a balance to be struck between the size and complexity of the meshes, the

resolution of the textures, and the processing capacity of typical PCs and their ability to handle the best models.

Figure 8: Final model of MERL jug, with 20k polys

Visualisation

The dominance of gaming environments in the creation of VR means that the software necessary for visualising models is essentially aimed at satisfying the needs of game developers. We have experience at the University of Reading in using one of the most popular and powerful gaming engines – Unity - that provides a wide range of possibilities for importing and merging meshes, altering the lighting and texturing, and adding physical properties (effects of gravity, colliding or passing through objects etc.). However, Unity and similar software packages are aimed at the professional game production community and do not fit our non-specialist, ease-of-use remit. There difficulties have been recognised by a burgeoning industry that has produced more friendly, albeit limited, user interfaces for engines such as Unity, especially targeted at architectural design, and Building Information Modelling (BIM). The package we identified, Revizto, is aimed at building design and engineering and in particular BIM. It allows us to import meshes (such as the photogrammetry models of the MERL buildings and the jug) and has an import plug-in for SketchUp to give a very simple one-click import option for SketchUp models, such as the model of the MERL main galleries (figs. 3 & 4). It also has a coarse, but acceptable tool for bringing together multiple meshes, allowing us to bring together the drawn and photogrammetry building meshes, and the scanned-in objects, to form a single combined model (see figure 9).

Figure 9: Combined model, incorporating the MERL entrance façade, the inner courtyard (both photogrammetry), and the main galleries (SketchUp)

Revizto also includes first-person navigation and a simple output for the Oculus Rift, and so meets our needs quite closely. Where it falls short is in its limited ability to include additional information for the objects (photographs, documents and audio files). We have been able to overcome to a limited extent using the Revizto 'issue tracker', that allows us to add in other documents and photographs but in a way that could be more user-friendly. However, the balance of functionality to ease of use is heavily in favour of Revizto. As with other points noted in this report, this is a fluid situation. There seems to be a demand for interfaces based on gaming engines that offer selected functionality, but tailored to specific applications. Architectural visualisations are likely to become more important and we would expect there to be developments that would also suit the VR recreation of public spaces such as museums, schools, open areas, hospitals etc.

Having created a combined model of buildings and objects in Revizto, our original aim was to focus on the new Oculus Rift ('OR') VR headsets – the leading brand of a new breed of VR visualization technologies. At present these are available as 'developer kits', with commercially available headsets scheduled for early 2016. Experimentation with the OR headsets again highlighted the balance to be made between model complexity and computing power. Even reasonably powerful laptops struggled with complex models in the OR video driver. Specialist laptops, especially those designed for gaming, with the most powerful graphics controllers are able to cope with this type of model, and as part of the project we have been able to purchase a specialist laptop to run our fairly heavy models on the OR. It is also
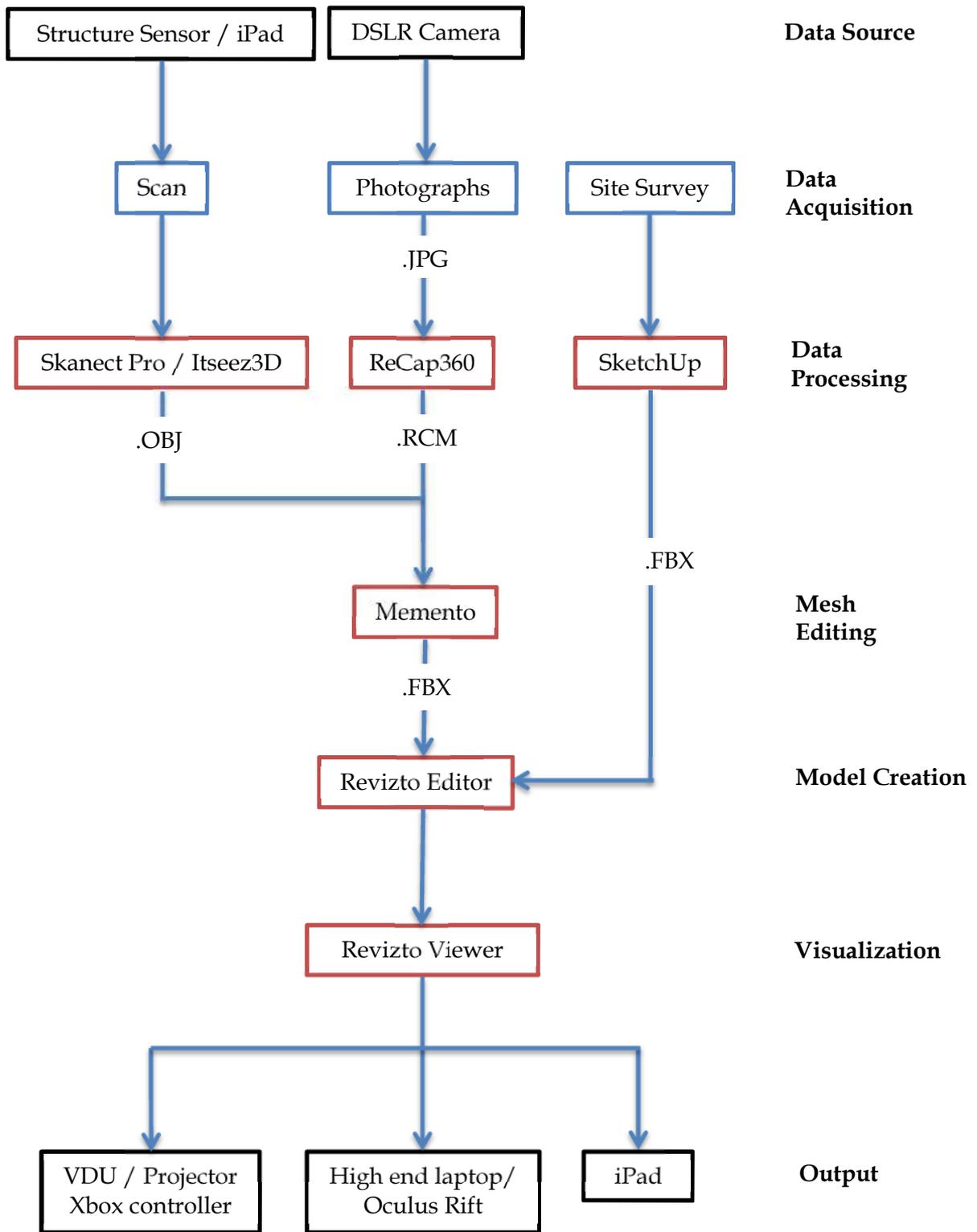
worth noting that although the OR is currently the leading VR headset, purchased by Facebook for \$2bn in 2014, there are a number of other significant new players in this space, including Google/Mattel Viewmaster, Microsoft Hololens, Sony Project Morpheus, HTC, Carl Zeiss/Apple, Razr/Android and others.

Running the model on a standard screen (or high end iPad) is still perfectly feasible without having to resort specialist gaming hardware, although of course this does not give the same immersive experience. Whether that is significant in the experience of a VR world is a moot point, and one that we investigated in the demonstrations. Our other options include iPad, which Revizto supports with a custom navigation control system, and standard PC or large scale projected screens, each of which could be controlled with an Xbox type controller. So despite the current limitations that we see with the OR, it formed an important part of the user experience that allowed us to interrogate some of the basic ideas about VR worlds.

Workflow

Having considered a number of possible solutions to the technical challenges this has required, we have fixed on a workflow that satisfies our objectives of low-cost and non-specialist hardware, and user-friendly software and visual outputs (see diagram below). This is the result of a balancing act between issues of resources (finances and labour) and quality (realism and complexity), in what is undoubtedly a dynamic arena. Even in the course of the few months of this project we have seen several new developments (such as updates to Autodesk Memento and new apps for the Structure Sensor), and more promised (such as Autodesk Recap promising to remove the upper limit of 250 photos for their photogrammetry software). For our purposes, this has led to a relatively conservative approach, attempting to simplify the workflow by using market leading names rather than some of the less well known, even superior products. We expect that in the immediate future there will be further developments in software and hardware, which are likely to become more user-friendly and yet more sophisticated, thus making this type of project easier to carry out.

For the present, we have fixed a point in the Creating a Virtual Museum project where ease-of-use is our key criteria, costly hardware is limited to a high end laptop to run the Oculus Rift headset, and other visual outputs are achieved through essentially standard current PC technology. This part of the project shows that it is becoming easier to produce VR worlds without the need for extensive specialist knowledge, and thus feasible for local institutions such as MERL to incorporate into their community engagement portfolio. The final model was loaded into three output systems: a standard large (27″) PC monitor (which gave a reasonable experience of immersion, especially when seated close to the screen); an Oculus Rift (which was surprisingly tricky and temperamental); and an iPad (the latest, most powerful model, the Air2 was just about able to handle the model). It was an advantage of Revizto that all of these formats were supported, and after some technical teething problems, we were able to get each of them running quite reliably.

Structure Sensor / iPad	DSLR Camera	**Data Source**

Scan	Photographs	Site Survey	**Data Acquisition**

.JPG

Skanect Pro / Itseez3D	ReCap360	SketchUp	**Data Processing**

.OBJ   .RCM

.FBX

Memento	**Mesh Editing**

.FBX

Revizto Editor	**Model Creation**

Revizto Viewer	**Visualization**

VDU / Projector Xbox controller	High end laptop/ Oculus Rift	iPad	**Output**

KEY:

Hardware	DSLR Camera
Data	Photographs
Software	Memento
File Type	.FBX

4: Interrogating the Digital Experience

Demonstrations and Responses

Two events were organized where a number of participants were invited to experience the VR model of MERL. This included three VR formats: iPad; PC screen; Oculus Rift; as well as a selection of some of the objects included in the model, taken from the MERL collection and arranged on tables for close inspection and handling. The participants were invited to complete a questionnaire after their experience (see Appendix B), which was done by around 80% of those attending. The questions were designed to elicit information about the use of the technologies and the experience of virtual space, with a simple 1-5 scale of response. This was supplemented by free form comments at the end of the question sheet, observations carried out by the researcher, and discussions with some of the participants before they left.

The questions, and response scale used, were:

1: Have you been to the museum before? (1 - Never : 5 - Many times)

2: Using the technology was: (1 - Easy : 5 - Difficult)

3: Finding my way around the virtual museum was: (1 - Easy : 5 - Difficult)

4: Did you feel you were actually in the museum or still in this room? (1 - Museum : 5 - Room)

5: Did your other senses (apart from vision) affect your experience (1 - Very Much : 5 - Not at All)

6: Do you think of your experience as images you saw, or somewhere you visited? (1 - I Saw : 5 - I Visited)

7: Were the real life objects the same as the virtual ones? (1 - Same : 5 - Different)

i, MERL

An event was organised with the assistance of the staff at MERL, where the three systems were set up (Monitor, iPad and Oculus Rift), an area of the room was screened off and four of the objects in the model set up on tables (Mantrap, Polehead, Decorated Jug, and Milk Churn). Different users experienced the model in some or all of these formats (including the real objects), while being observed and notes taken. They were then asked to complete the response questionnaire (18 were completed), and many engaged in informal discussions either with the researcher or other users, during which time further notes were taken. The users were a mix of staff members and volunteers, totalling around 30 over the course of an afternoon. This group was chosen for its familiarity with the building, and for some attendees knowledge of the specific objects used in the model. Our objective was to gain greater insights into the relative experiences of a VR encounter with the building and objects and a real-life encounter with the same spaces and things, from users who were familiar with both.

ii, Local School

A second half-day event was organized with a local school, which included a class of children aged 11-12 and various others who stopped by for a short time. The organization was slightly different to the MERL event as we had agreed with the school to include an object-handling session as part of the event, carried out by a member of the MERL staff. The same four of the objects were laid out for the

children to look at and touch. They were asked to describe the objects and to suggest their function, with only limited information from the museum staff. They were then divided into groups to experience the three VR models (iPad, monitor and Oculus Rift) and set the task of finding those objects and noting any others they encountered. As part of the class exercise, the pupils were asked to interview each other, rather than being interviewed by the researcher as in the MERL demonstration. Prior to the exercise they were given guidance about how to interview and the sort of questions to ask. This did result in some differences in the type of responses recorded, but those differences were in themselves enlightening. 38 response forms were completed.

Results

The results are summarized in Table 1 below, and represented graphically in the following sequence of diagrams. Responses were averaged for each question according to both the participant (museum staff or volunteer vs school pupil) and the experience format (iPad, Monitor, Oculus Rift).

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Average	2.26	2.63	2.81	2.82	3.46	2.19	2.44
Avg. Oc. Rift	2.48	2.04	2.52	1.72	3.04	2.84	2.12
Avg. Monitor	2.05	2.58	2.47	3.32	3.47	1.84	2.79
Avg. iPad	2.15	3.85	3.85	4.23	4.23	1.46	2.54
Avg. Museum	4.61	2.33	2.50	3.11	3.33	2.72	2.78
Avg. Pupil	1.18	2.77	2.95	2.69	3.51	1.95	2.28

Table 1 – Response Summary

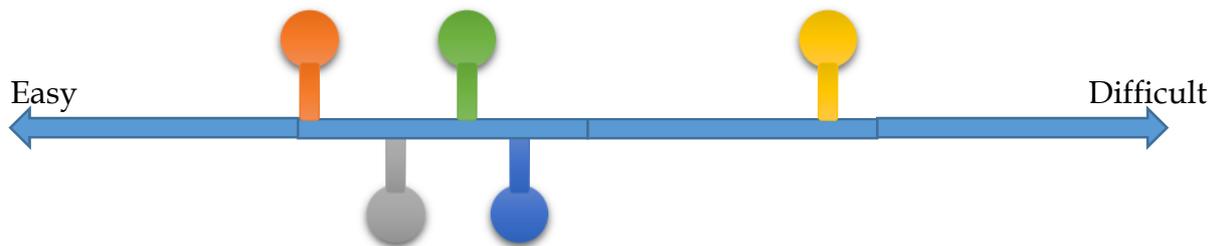Response Summary Graphics Key:

- 🟠 Oculus Rift
- 🟢 Monitor
- 🟡 iPad
- 🔵 School Pupil
- ⚪ Museum Worker

Question 1: Have you been to MERL before?

Never ◄─────────────────────────────────► Many Times

Question 2: Using the technology was…

Easy ◄─────────────────────────────────► Difficult

Question 3: Finding my way around the virtual museum was…

Easy ◄─────────────────────────────────► Difficult
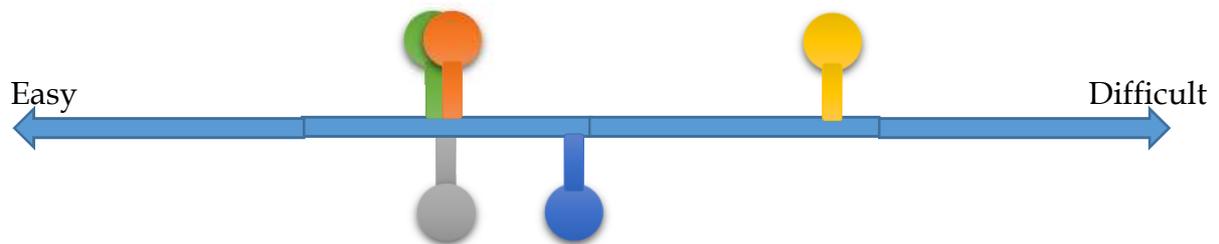
Question 4: Did you feel you were actually in the museum, or still in this room?

Museum   Room
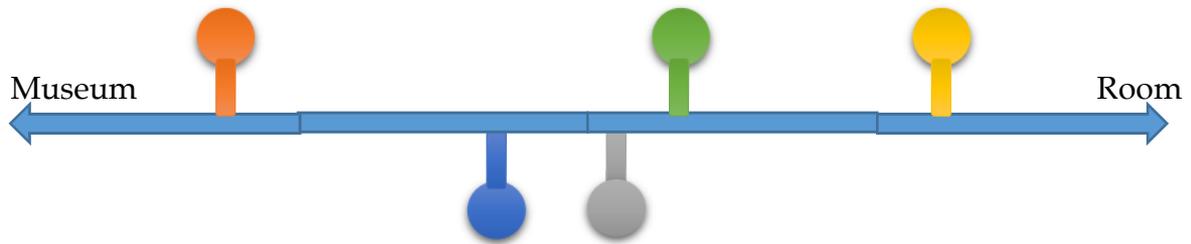
Question 5: Did your other senses (apart from vision) affect your experience?

Very Much   Not at All
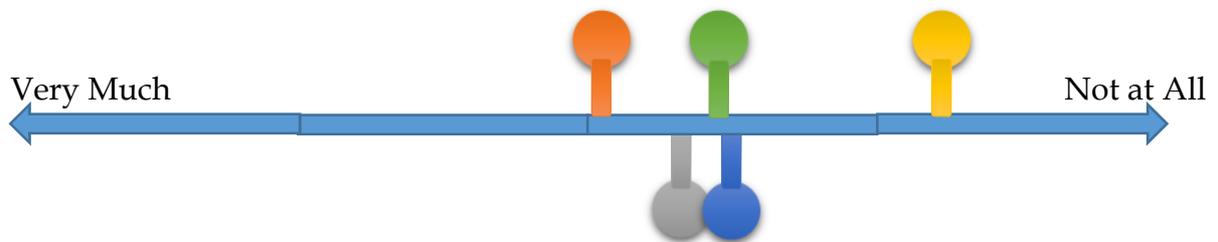
Question 6: Do you think of your experience as images you saw, or somewhere you visited?

I Saw   I Visited
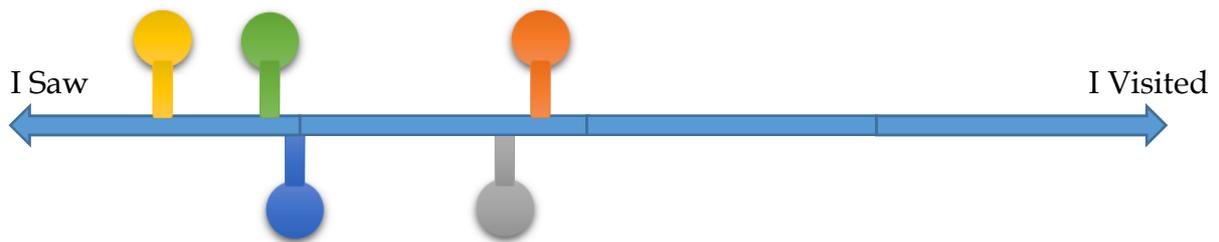
Question 7: Were the real objects the same as the virtual objects?

Same   Different
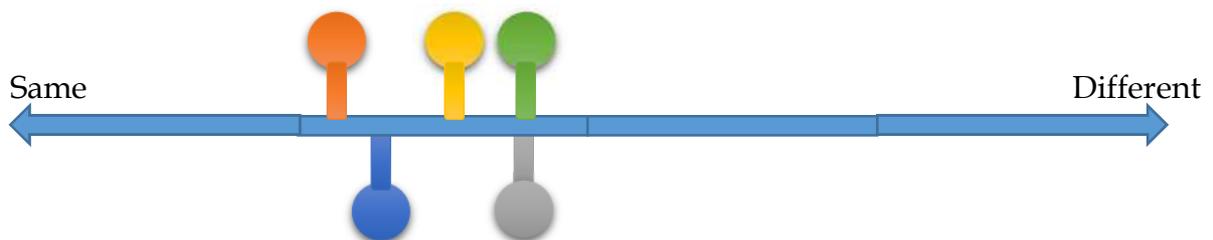
5: Discussion

Familiarity
The two groups were chosen for their relative experience of MERL, with the museum staff and volunteers very familiar with the space and to some extent the physical objects, whereas virtually none of the school children had ever been to MERL (see Q1). Of course, this was not the only difference between the two groups: the age profile was very different; the relative experience with the technology used; and the context in which the experience was happening. The pupils were being taught, whereas there was a sense that the museum workers were advising on a product, and how it could be improved. Despite this, there is remarkably little to separate the average responses by user. Q1 is, not surprisingly, the most significant, but the responses to use of the technology (Q2 and 3) suggest that the museum workers found it easier than the pupils. If there is a trade-off between familiarity with the space and familiarity with the experience format, then it seems to favour the space. A lack of familiarity may also explain the apparent contradiction between the pupils' results of Q6, in which there was a stronger sense of 'viewing an image' as opposed to 'visiting a place' and Q4 where the pupils felt more like they were in a different place (i.e. the museum and not the classroom).

Sense of being there
The three technologies drew very different responses from the users, coloured slightly by the lack of processing power in the iPad creating a slow and sometimes unsatisfactory experience. In general the immersion created by the Oculus Rift seemed to transport the user away from the space they currently inhabited (Q4), although where they were transported to is a matter of debate. In response to Q6 it seems clear that the users did not feel as though they had physically been to a different place, which suggests that this VR experience was not a successful transplantation of MERL into the conference room or classroom. Surprisingly, this was not affected by confusion or interaction with other senses. A working hypothesis before the trials was that the smells and sounds of the VR location would affect and reduce the sensation of leaving the room you were in. However, the responses to Q5 suggest this is not the case. This might be a reflection of the limitations of this study, since there is significant variation between the experience formats, where the Oculus Rift was more likely to have been affected by extraneous sounds and smells, although this was not reported as a strong sensation. A general observation by several users was that visual limits were important, in effect the bigger the screen, the more realistic, which disadvantaged the iPad in particular. An important note to make as a major disadvantage of the Oculus Rift in taking you to a different place, which is that it makes a significant number of users nauseous, especially adults. The majority of the museum users could not spend more than a few minutes using the headsets, and two had to leave work and return home. Interestingly, around half of the pupils admitted to car sickness, but despite being warned that they may feel ill, all of them enthusiastically tried the Oculus Rift, and none of them were affected by nausea.

Quality of the model

One of the aims of this project was to experiment with consumer-level technologies to investigate the possibility for this to be developed and used by non-specialist organisations, such as small museums. As discussed above this has resulted in a number of compromises in hardware and software, such that the detail and possibly 'realism' was reduced, and the flexibility of the model and speed of interaction also had to be balanced against the chosen technologies. The iPad was particularly unsatisfactory, mainly due to the use of photogrammetry for some of the architecture, which represented about 50% of the model size for about 10% of the model (the remainder being the nine objects and the buildings drawn in architectural software). Initial impressions of the model were generally very positive, probably due in part to technological novelty, especially the Oculus Rift. The comparison between the objects in the model and the real objects available to see and touch was also quite positive (Q7), which is slightly surprising bearing in mind some of the other thoughts and responses to the experience (Q6 implies it was imagery rather than a multi-sensory experience; Q4 suggests the experience was not the same as being in the museum). There were comments made about the relative realism of the objects, with the plough and mantrap in particular receiving slightly negative comments. Interestingly, the plough was the longest object we could scan with the iPad system, and was at its limit of size, and the mantrap was the most complex shape with numerous different surfaces, orientations and occlusions. These objects could be defined as at the limits of the consumer technology we used, a fact which became apparent in the quality of the model created. Overall, the virtual museum we produced could be said to be 'not quite real enough' to achieve the experience of visiting the museum, but this does not seem to be simply due to the shortcomings of the model itself.

Future Directions

It seems likely that even if the digital museum could be created with a high degree of visual accuracy, which would be possible with more sophisticated digital reconstructions using commercial technology and gaming engines, it would still offer a very different experience to the real MERL. A fundamental conclusion that has come from this research would be that to use VR as a proxy for reality fails in both directions. First, the virtual will never be the same as the real, however good the technology, even with an enormous expenditure of time and money; the conflicting responses and subsequent discussions consistently raise the ambiguity of the experience, and the lack of emotional engagement (one pupil said "it feels so lonely in here"). Second, it makes no sense to reproduce the limitations of the real world in the virtual whilst ignoring the potential for a different experience. A good example would be interaction with museum objects: the real objects are curated in a particular way (context, storage/display, location, information etc.) and physical contact is limited. The virtual objects can be inspected from any angle, be very quickly put into a different context (with other objects, as a personalized display for example), and be augmented with information, links, activities and so on.

We are hinting here at how the model could be used, but more interesting thoughts came from the museum workers. They recognized this as a means to overcoming a perennial problem – short and conservative visits, where the visitor will not know where to go and tend to head for the 'star attractions', missing the majority of the displays. Many museums try to overcome this by offering fixed routes, suggesting where the visitor should go and what they should look at. A virtual model offers the chance to tailor a route, and prepare the visitor for their experience (length of walk, places to sit, location of interesting objects etc.). This idea of familiarization and orientation would be widely useful but particularly attractive to groups such as autistic children. More work could be done to investigate how well these ideas would work, and further discussions with MERL will hopefully form the basis of future research.

6: Impact

Teaching

The MERL model and the techniques used to create it were used as the main teaching example in a one week module for MSc students from the School of the Built Environment at the University of Reading – 'Advanced visualization and interactive technologies'. Twelve students produced their own 3D models using photogrammetry, and four students have taken this research as the starting point for their individual projects. The feedback was universally positive, especially the new 'hands-on' approach this project allowed.

Software Development

Revizto, the software used to bring together the various parts of the model (architecture, objects and additional information) and make it navigable, heard of the project through Twitter and contacted IE to write a case study and suggest ways the software could be developed to suit this type of application. The context for the case study was the re-purposing of the software from a building information management tool, to a visitor experience. This went live on their website (https://revizto.com/en/blog/entry/university-of-reading-merl) in October 2015.

Further Funding

An AHRC grant was awarded to IE for a new 12 month project: 'Sensations of Roman Life' beginning March 2016. This will build on this project to create a VR Roman house, but including sounds and smells, to be displayed at Chedworth House – a National Trust managed Roman villa complex.

An AHRC PhD studentship was awarded to IE/CH for a project devised in association with Historic England, to start in October 2016. This will use a highly accurate 3D model as the basis for a data management system to allow heritage professionals to document and manage their built assets, and provide visitors with a more informed experience.

The applications for these awards were made more credible and consequently strengthened by the experience we were able to demonstrate through the work carried out in the Creating a Virtual Museum project.

Mantrap

MERL object number: 62/403

This is a man trap, used to deter poachers and trespassers. It has a spring-activated toothed clamp which would snap shut around the victim's leg. Man traps first came into use in England in the second half of the eighteenth century, and were made illegal in England in 1827. Versions without the teeth are known as 'humane man traps' as the injuries they caused were less severe, as you can see in the picture.

©Fourteenacre

MAN-TRAPS AND SPRING-GUNS.

By MILLER CHRISTY.

POACHER CAUGHT IN A "HUMANE" MAN-TRAP.
From an old print.

THAT we have reached, at this dawn of the twentieth century, a very advanced and still rapidly advancing state of civilisation is, of course, a truism which it would be idle to deny. But the thoughtful man may be pardoned for reminding us that we shall be wise not to boast too much of our progress ; for, even now, we have left the days of barbarism but a very short distance in our rear. It is well for us to remember that here in England, scarcely seventy years ago, men were still liable to be hanged for many petty thefts which would now receive no punishment more severe than a few weeks' imprisonment, and that we had entered upon the second quarter of the nineteenth century before it was made illegal to protect game and other private property by the setting of man-traps, spring-guns, and other similar diabolical contrivances deliberately intended to destroy life or limb.

The object of the present article is to give such information as the writer has been able to gather concerning the history and past use of man-traps and spring-guns. Of these contrivances, Mr. H. Addis Price, member of a leading London firm of ironfounders and hardware merchants, and Mr. James Backhouse, of York and Harrogate, have actually formed collections which are certainly unique. Of their specimens, as well as of the ample information each has gathered concerning them, the writer has been allowed to make the fullest use.

These terrible contrivances were never in very general use, but were employed chiefly by persons intent on preserving game in populous neighbourhoods. They first came into use, apparently, during the latter half of the eighteenth century—the period in which the preservation of game on something like the present system commenced. From 1770 to 1825—when they were especially in vogue—was a grievous time in this country among the agricultural and operative classes, and poaching was very prevalent. The man-trap and spring-gun period was precisely that when artisans destroyed machinery because they thought it would take the bread out of the mouths of themselves and their children, and when the labourer, in many parts of the country, received no more than six or seven shillings a week.

In such days these lethal agents proved, no doubt, very effective as deterrents. Thus it is recorded that, in the early days of October, 1814, a vagabond was shot and slightly injured by the discharge of a spring-gun when pilfering a garden at Mitcham, in Surrey. He was let off with a caution, though recognised as an old offender. A few days later, however, the same man was killed on the spot, by the discharge of another spring-gun, whilst robbing an adjacent garden.

There was, however, one especial disadvantage attached to the use of these automatic property-protectors : they did not possess the power to discriminate between a depredator and the owner of the property they were intended to protect. If the latter, walking in his garden or coverts, chanced to do what was necessary to spring a man-trap, spring-gun, or other "engine," set, unknown to himself, by his servants, the instrument

Sheep Dip

MERL object number: 60/134

This is a sheep dipping trough, made of oak with iron fittings and with stocks at one end to hold the sheep by the neck. It was made by Dorset craftsman in the early-nineteenth century or earlier. It was last used by the donor's grandfather around 1890, and was used as a mobile unit within a thirty-mile radius of Gillingham, Kent by a team of four men. The donor's family were famous for sheep dipping for many generations.

Dipping sheep in strong chemicals helped to keep them free of pests, as the picture for 'Robertson's Highland Sheep Dip' chemical dipping compound suggests.
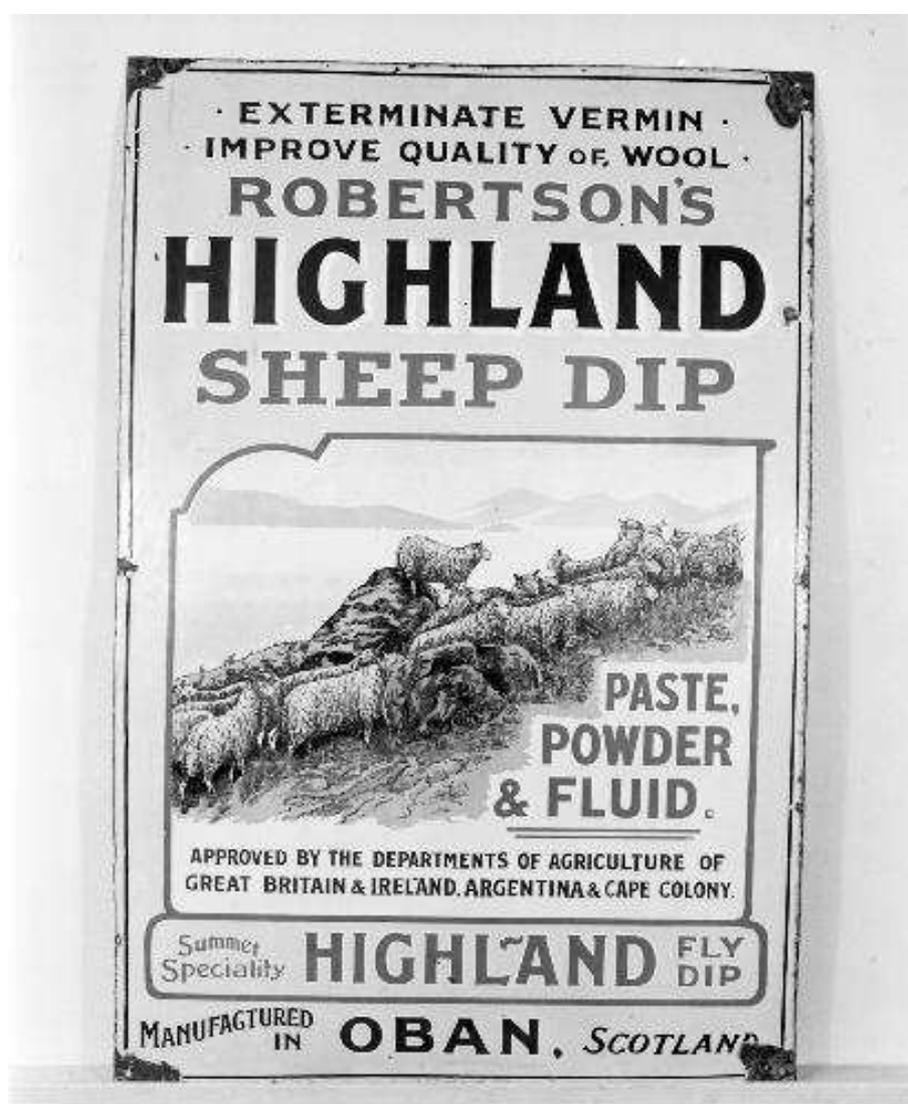
CREATING A VIRTUAL MUSEUM - User Feedback

User: Volunteer / Pupil / Teacher / Museum Staff

Viewing experience: Oculus Rift / Large Screen / iPad

1. Have you been to the museum before?

Never	1	2	3	4	5	Many Times

2. Using the technology was:

Easy	1	2	3	4	5	Difficult

3. Finding my way around the virtual museum was:

Easy	1	2	3	4	5	Difficult

4. Did you feel as if you were actually in the museum or still in this room?

Museum	1	2	3	4	5	Room

5. Did your other senses (apart from vision) affect your experience?

Very Much	1	2	3	4	5	Not at All

6. Do you think of your experience as images you saw, or somewhere you visited?

I Saw	1	2	3	4	5	I Visited

7. Were the real life objects the same as the virtual ones?

Same	1	2	3	4	5	Different

Observations and Comments: