Level 3

Volume 18 | Issue 1 | Article 1

1-2023

Community Engagement in Cultural Heritage A Digital Context

Maurice Murphy, et al.

Community Engagement in Cultural Heritage

A Digital Context

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Keywords:

Digital Tools; Cultural Heritage; Cultural Entrepreneur; Community Engagement; Virtual Heritage; Laser Scanning; Photogrammetry; Historic BIM; Game Engine Platforms; Heritage Education Learning.

Abstract

A series of case studies outlining the application of virtual reality and digital technologies for cultural heritage is presented in this article with an aim to examine the role for community engagement and SMEs in cultural heritage within a digital context. Digital technologies can be a repository and tool for telling local stories in relation to place and time on site and virtually off-site. In a series of case studies, tools and technologies for virtual reality experiences are outlined to identify the appropriate tools which can best facilitate this community engagement. In addition, community-based digital heritage initiatives will be discussed with reference to the Faro Convention. These technologies include applying BIM or GIS for historic structures involves initially data capture of the geometry and texture using laser scanning or digital photogrammetry, and then converting the digital survey data to solid Building Information Models (BIM). The process is described as Historic BIM or Historic GIS and, in this paper, several virtual reconstruction case studies of Irish Megalithic and Romanesque structures are presented.

1 Introduction

The Faro Convention is a Framework Convention on the Value of Cultural Heritage for Society; a multilateral Council of Europe treaty whereby states agree to protect cultural heritage and the rights of citizens to access and participate in that heritage. In this paper a series of case studies outlining the application of virtual reality and digital technologies for cultural heritage are presented. These case studies focus on community-based digital heritage initiatives and are discussed with reference to the Faro Convention.

Our aim is to examine the role for community engagement in cultural heritage within a digital context. Digital technologies can be both a repository and a tool for telling local stories in relation to place and time on-site and virtually off-site. The series of case studies present tools and technologies for virtual reality experiences and identify appropriate digital tools which can best facilitate this community engagement. The application of these digital tools relates to how communities across different cultures and societies can be assisted in terms of levels of involvement and support. This may involve bringing together communities and local SMEs who specialise in these technologies for collaboration in design and building of digital heritage initiatives. Information sources that support the value of heritage is usually expressed and presented in traditional formats, on the other hand, innovations in technology can enhance information sharing, representation on heritage sites and within virtual worlds.

Digital recording and modelling techniques and the application of virtual reality (VR) technology allow digital representation of a historical site or cultural artifact off or on site. Digital recording and modelling are non-invasive tools for the preservation of cultural heritage. Laser scanning and photogrammetry can provide highly accurate digital heritage without any physical intervention or damage to historic objects or buildings. VR as dissemination tool for digital heritage can allow access to sites or objects remotely or as part of on-site presentation. The VR experience can range from visualisation to interaction and knowledge extraction to conservation simulation tools for preservation or reconstruction scenarios. Digital recording and modelling techniques, combined with VR technology, offer a powerful tool for the preservation and accessibility to cultural heritage and to explore and learn about the past.

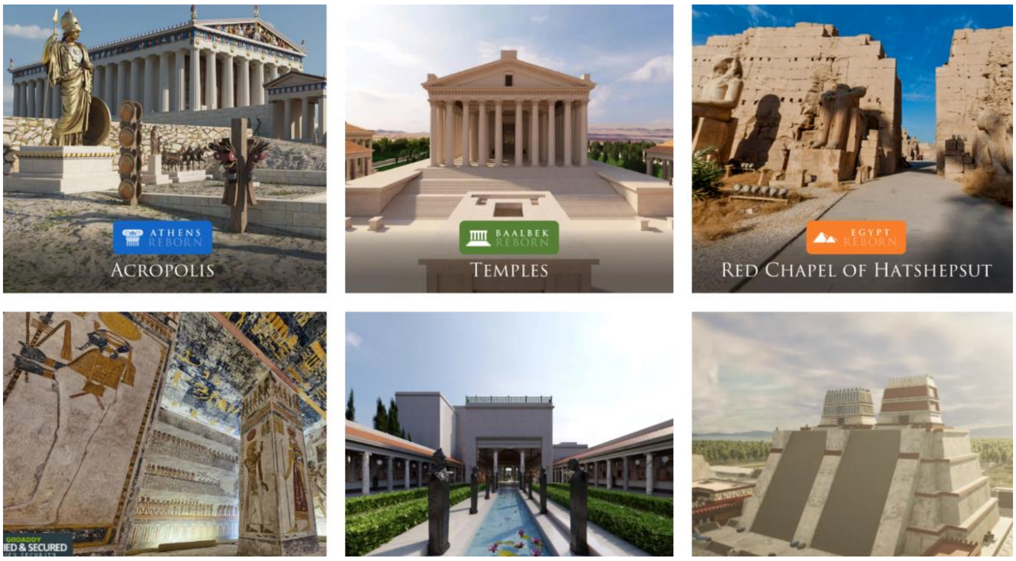

Figure 1: Virtual Tours – Flyover Zone

The above figure illustrates Virtual Tours which is led by Bernard Frischer who is a virtual archaeologist working in this area since it began in the 1990s. His labs at UCLA, the University of Virginia, and Indiana University created projects such as Rome Reborn, the Digital Hadrian's Villa Project, and The Uffizi-Indiana University 3D Digitization Project.

2 Data Capture

2.1 Laser Scanning Kilmalkeader Romanesque Church

Aerial and terrestrial laser scanning has been used extensively to record and document archaeology and architectural heritage for more than twenty years and at this point the instruments are less expensive and much more efficient. The terrestrial laser scanner is a device that automatically measures the three-dimensional co-ordinates of a given region of an object's surface, in a systematic pattern at a high capture rate in near real time. The laser ranger is directed towards an object by reflective surfaces that are encoded so that their angular orientation can be determined for each range. The entire instrument and/or the recorded object are rotated to achieve, where possible, complete 3D point coverage. Time-of-flight scanners calculate range, or distance, from the time taken for a laser pulse to travel from its source to an object and be reflected to a receiving detector.

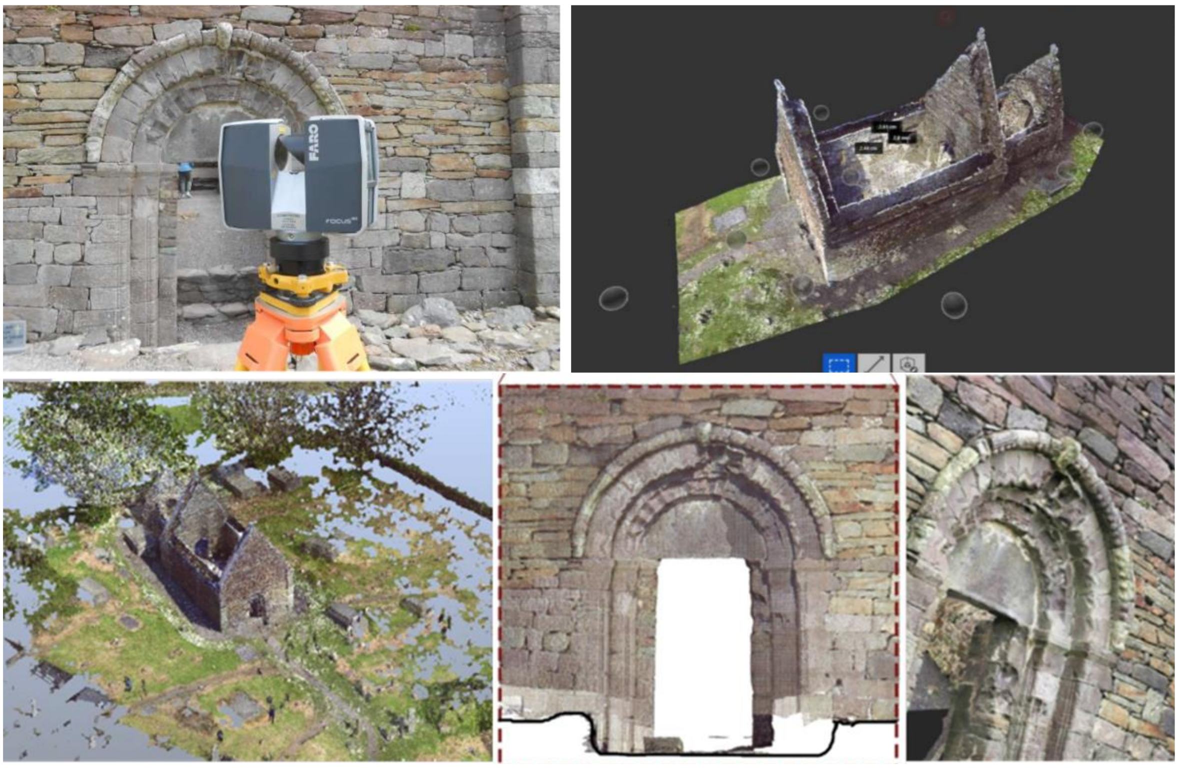

Figure 2. Faro Terrestrial Scan of Kilmalkeader Romanesque Church (Discovery Programme), the top left image shows the Faro scanner used the top left image illustrates the processed point cloud and the bottom images illustrate the unprocessed and registered scan on the left and in contrast the use of photogrammetry to capture the doorcase.

2.2 Structured Light Scanners

The process of structured light scanning involves projecting a known light pattern onto the subject. The light patterns will deform in relation to the surface of the object. These deformations in light will then be picked up by two cameras placed each side of the light projector. The images from the camera will then be sent onto a computer where software will process these deformations and create a 3D model.

Figure 3. Case Study 2-Dowth Hall Structured Light Scan. Top left of image showing A photo-textured 3D mesh model generated using structured light data. A generated radiance scaling visualisation of the section of the HD model

2.3 Digital Photogrammetry

Digital photogrammetry is based on hardware for data capture such as SLR digital cameras and thermal imagers or in some cases off-the-shelf cameras. The acquired data is then processed, fused and integrated using state-of-the-art photogrammetric and computer vision algorithms which are readily available with software platforms Reality Capture, Autodesk Re-Cap, Agisoft Photoscan, Micmac, Pix4D, etc. (Remondino et al. 2011).

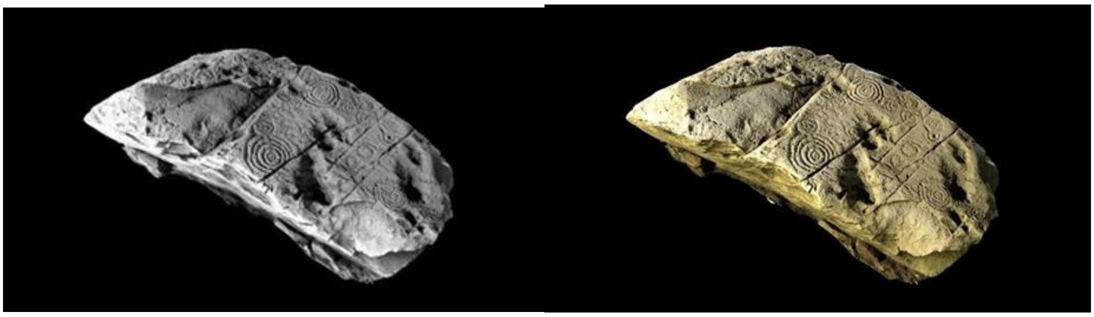

Figure 4. Case Study Dowth Hall Photogrammetry, A rendered image of the K2 model generated in RealityCapture with procedurally generated texture.

2.4 Low-Cost Sensors

In addition to low-cost solutions for photogrammetry using smart phones and applications such as the iPad Pro which has introduced LiDAR Survey Apps in association with applications developers. The data collected are then processed using 3D scanner application (Laan Lab). There is an associated editing tool with the app whereby segmentation and cleaning of the mesh is generated and standard Euclidian transformations, scale, rotate etc. Like other software applications there is a wide variety of file output formats which are ideal for further processing in BIM environments.

Figure 5. A textured mesh of K2 created using the iPad Pro, in conjunction with the 3D Scanner App recorded with IPad Pro Lidar

3 Historic Building Information Modelling HBIM

3.1 Digital Reconstruction of Megalithic and Romanesque Archaeology

The more recent development of Building Information Modelling (BIM) makes it the most likely tool for digital reconstruction of Archaeology. BIM incorporates the main developments in 3D modelling including parametric and feature-based modelling combined with a dynamic 3D database for storing information relating to buildings. The addition of a dynamic relational database for building elements (like a Geographic Information System) enables many new applications for managing and analysing buildings and elements. Historic Building Information Modelling (HBIM) was developed for historic structures and archaeology and involves data collection using laser scanning/structure from motion and modelling historic architectural elements graphically using BIM software platforms followed by mapping 3D objects in the point cloud data [1, 2, 3, 4, 5, 6, 7]. In addition to the first two stages in HBIM of data capture of the geometry and texture for the structure, and secondly, converting the digital survey data to solid Building Information Models (BIM). A third stage consists of tools for dissemination of these data to allow for various end users exploring education, conservation, engineering and virtual reconstruction.

3.2 HBIM Case Studies

Kilmalkeader **-** Romanesque Church

While archaeological survey data exist for this site [8] historic material collections are sparse and the complex geometries and shapes within the composition of the building make this modelling task difficult. The virtual replication of the structure is mainly achieved by mapping objects onto the laser scan and photogrammetric data to create solid 3D models. The replication of complex geometries and shapes require authenticity and accuracy for digital reconstruction. In the case of this site, authenticity and accuracy for digital reconstruction can be an evolved process as more information comes to light. Initially the structural elements of walls, floors, roof, beams and columns are mapped as separate objects and positioned onto the point cloud within the HBIM platform. These objects can be built from the existing BIM libraries, or in objects where deformations or irregular geometry exists. meshes from the digital survey data can be employed. In the case of the roof its construction is an interpretation of what may have existed in the 12th century construction. Below are screen images of part of the mapping process and illustrations of the some of the objects built on the left side of the figure.

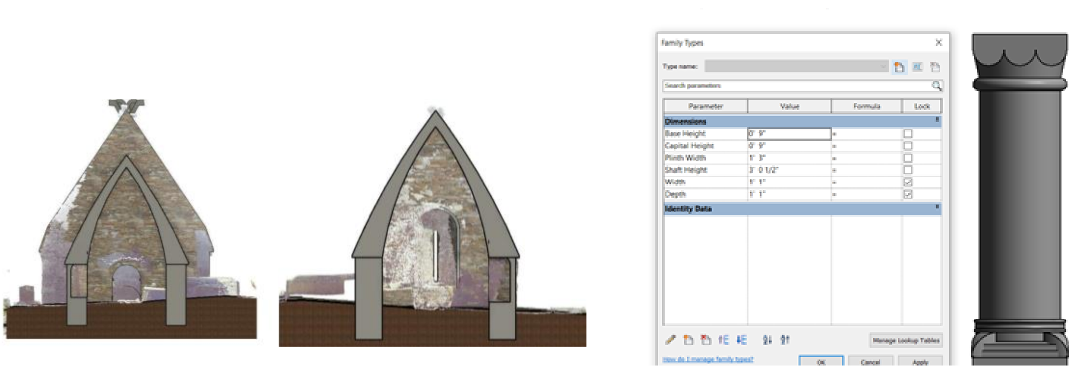

Figure 6. Wall construction and mapping process and illustrations of the some of the parametric objects built in HBIM

The variety of complex and irregular objects found in historic buildings are not available in existing BIM libraries. Therefore, parametric library objects need to be rebuilt and coded for Historic Structures. In Figure 7 below a shape grammar is developed for reconstructing the door-case based on the remaining elements of the door-case from the point cloud digital surveys and existing documents. The grammar initially develops the primitives for the opening of the archway and columns. The Romanesque carving and the complexity of the stones making up the arch are initiated from simple geometric shapes representing the arch and its stones. The procedure for forming the primitive is based on a Boolean operation production rule based on the non- terminal shape on the bottom left through to the terminal block shape on the right of the figure below.

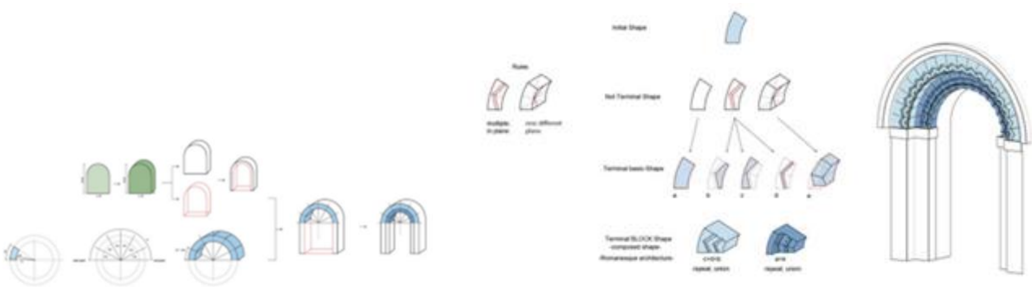

Figure 7. Construction of Romanesque Doorcase based on shape grammar ontologies

For the more complex geometry a shape grammar is developed for reconstructing the doorcase. The grammar initially develops a set of primitives for the opening of the archway and columns. The Romanesque carving and the complexity of the stones making up the arch (Keystone, Voussoir, Extrados, Impost, Intrados, Rise, Clear span and Abutment) are based on parametric primitives combined to make the full object.

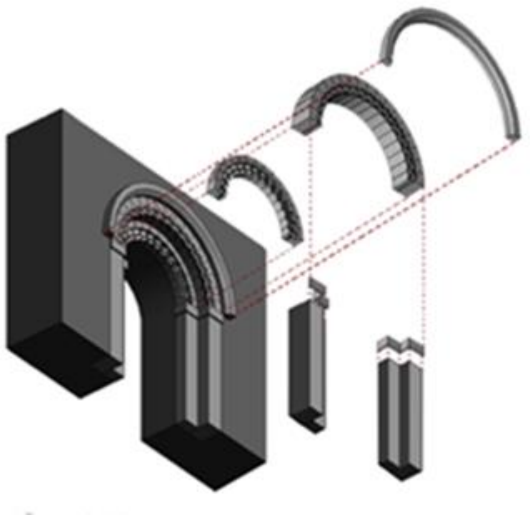

Figure 8. Shape Grammar for Romanesque Door-case, Exploded Model of Door-Case and Scan Survey

Visual Programming – Parametric Modelling

In our previous work we have built parametric library objects using coding or scripting for these objects which then can be reused within the context of their architectural rules. Here we introduce visual programming which is based on procedures, operations and commands and are executed through a graphical (or 'visual') user interface as opposed to using text bound by syntax, and is less complex. Dynamo is a visual programming tool that provides one such interface within Revit, thus allowing for access to the Revit API. Figure 9, shows parametric wall opening built in Revit, using Dynamo, allowing for the modification of any constraints relating to its geometry. Points in 3D space can be parameterized using variable values of x, y, and z based on Cartesian coordinates. Such points can be connected to form lines, while the lines can be closed to form surfaces, and the surfaces can be extruded to form entities. In this way, any geometric shape can be parameterized by using the point coordinate value parameters and combining them with certain geometric rules.

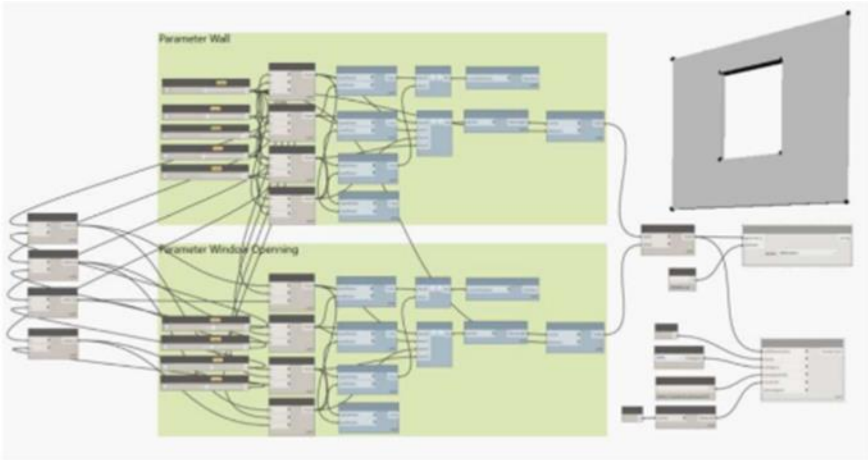

Figure 9. Dynamo Script for a Standard Parametric Opening

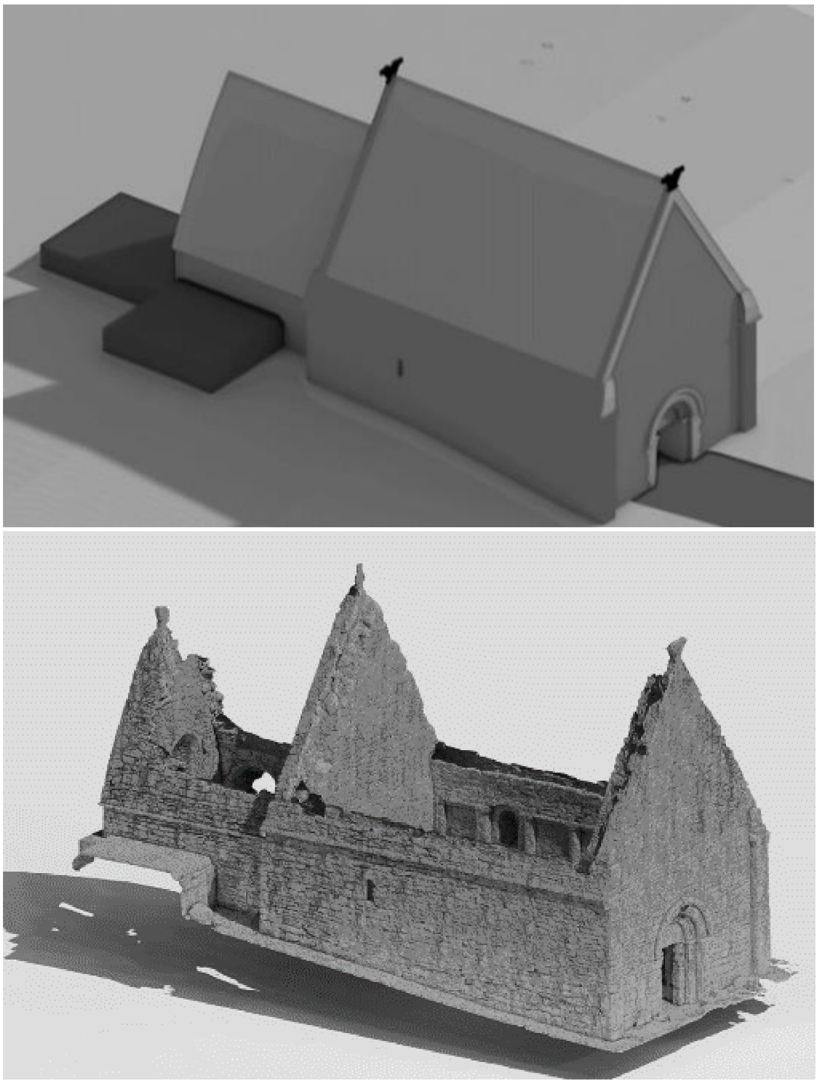

Figure 10. Untextured HBIM top and 3D Photogrammetric survey bottom of figure

4 Dissemination - Documentation and Virtual Reality

4.1 Documentation

One of the advantages of applying HBIM is that automatic documentation can be produced from raw scan or photogrammetric data, and this can be illustrated with orthographic projections for megalithic construction which are difficult to represent digitally. The visualisation of objects is achieved through walkthroughs, viewing 2D and 3D features, plans, sections, elevations and 3D views. BIM can automatically create cut-sections, elevations, details and schedules in addition to orthographic projections and 3D models (wireframe or textured and animated). All these views are linked to the 3D model and automatically update in real time, so if a change is made in one view, all other views are also updated. This enables fast generation of detailed documentation required in the AEC/FM and heritage industries. By converting the mesh models in BIM, the virtual models can automatically generate not only standard drawings and schedules but also provides automatically cut-sections, elevations, details and schedules in addition to orthographic projections and 3D models (wireframe or textured and animated. All these views are linked to the 3D model and automatically update in real time so if a change is made in one view, all other views are also updated. This enables fast generation of detailed documentation required for conservation and reconstruction. (See Figure below).

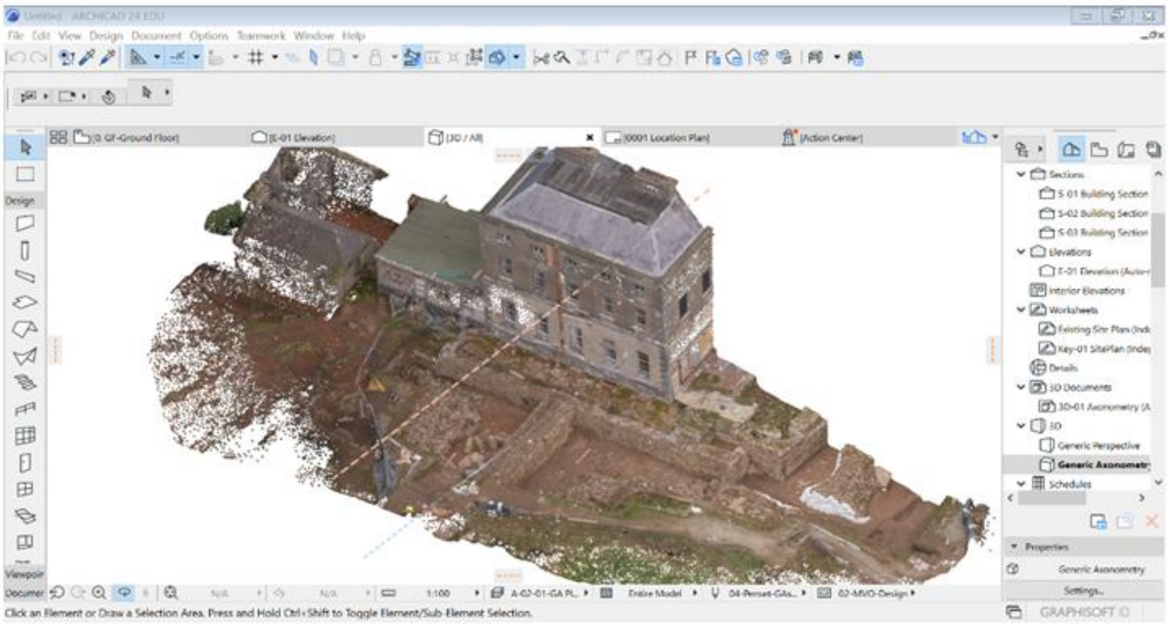

Figure 11. Aerial Photogrammetric Survey Doth Hall in ArchiCAD-HBIM as point cloud for further analysis in HBIM

4.2 Dowth Hall

Sited c.665m east-northeast of the renowned 'mega-mound' at Dowth, the Dowth Hall tomb lies buried beneath an artificially shaped terrace on top of which stands the mid-18th century villa. With two smaller, previously recorded tombs located c. 41 m to the west and c. 48m to the southwest, it appears to have been the focal mound of what was an unknown passage tomb cemetery in the area [9, 10].

Figure 12: Images from 3D Survey of Dowth Hall

Click on Link below to view 3D model

[Dowth Hall — A 3D model collection by maurice.m.murphy (@maurice.m.murphy) – Sketchfab]

Documentation

The initial step in using photogrammetric or Lidar survey data in HBIM is in developing and the creation of Ortho projections which allows for analysis –geometry, texture, alignment position and other relationships. One of the advantages of applying HBIM is that automatic documentation can be produced from raw scan or photogrammetric data, and this can be illustrated with orthographic projections for megalithic construction which are difficult to represent digitally. The visualisation of objects is achieved through viewing 2D and 3D features, plans, sections, elevations, and 3D views. BIM can automatically create cut-sections, elevations, details, and schedules in addition to orthographic projections and 3D models (wireframe or textured and animated). All these views are linked to the 3D model and automatically update in real time so if a change is made in one view, all other views are also updated. This enables fast generation of detailed documentation required in the AEC/FM and heritage industries. By converting the mesh models in BIM, the virtual models can automatically generate not only standard drawings and schedules but also provides automatically cut-sections, elevations, details and schedules in addition to orthographic projections and 3D models (wireframe or textured and animated. All these views are linked to the 3D model and automatically update in real time so if a change is made in one view, all other views are also updated. This enables fast generation of detailed documentation required for conservation and reconstruction. (See Figure below).

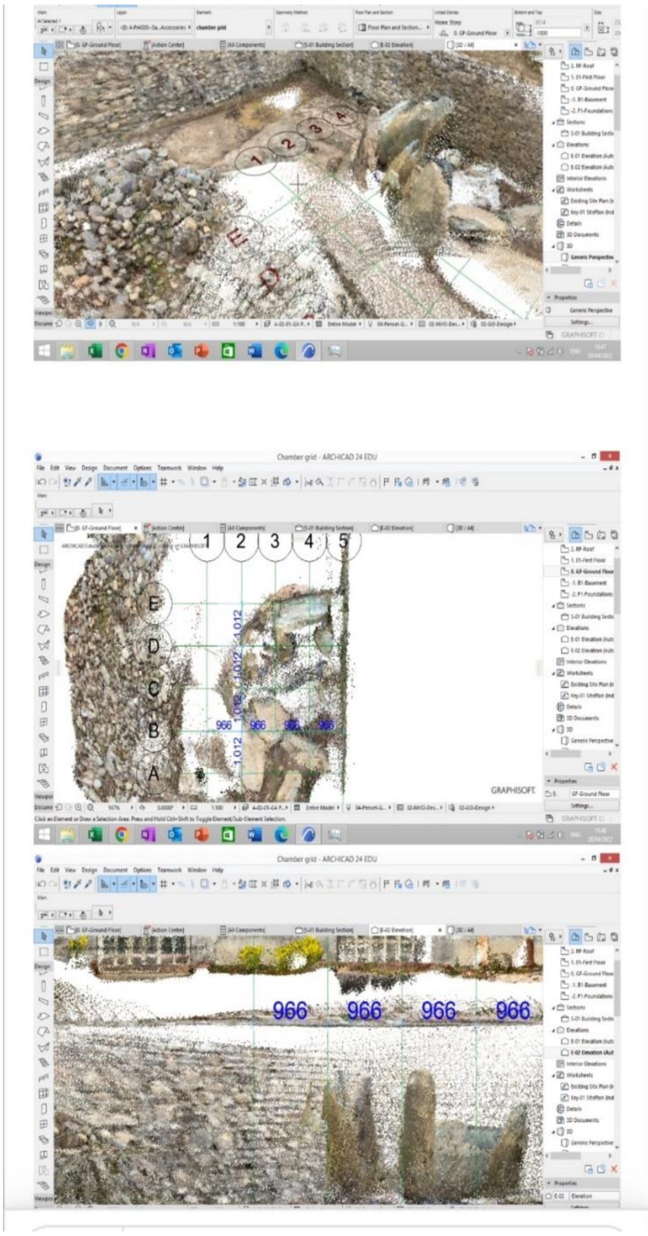

Figure 13: The traditional formats of plan, elevation, section, details in 2D and 3D and schedules can be automatically produced in HBIM environments. Secondly semantic attributes can be added to identify the architectural or building elements which make up structures or objects. Ortho Projections and 3D Sections from Aerial Scan, HBIM Documentation

5 Virtual and Augmented Reality

Virtual Reality (VR) digitally recreates a real-world scenario using a range of software and hardware platforms, Augmented Reality (AR) on the other hand superimposes some of these VR experiences as digital elements in the real world. They are used interchangeably and share some of the same software and hardware technology, but the interactive experience is noticeably different. VR offers the user degrees of freedom, that is it is confined in a computer-generated world view while AR provides degrees of freedom in that it uses visual and auditory senses to provide you with sensory information overlaid on the world that you are surrounded in. Virtual Reality utilizes software and hardware platforms to simulate and re-create numerous and complex behaviours that exist in the real world. VR virtual worlds are constructed in 3D space using computer graphics. This is enhanced by a virtual human presence as an immersive experience with user interaction, navigation and sensory experience with the virtual world and its objects. The continuing evolution of VR computer simulation software has generated lower cost, accessible and more intuitive tools. These tools are now used for the development of AR/VR learning environments.

5.1 Virtual Reconstruction - Dowth Hall

A sample of the stones from Dowth Hall passage were reconstructed digitally filling in missing parts and constructing solid geometry from the Lidar and Photogrammetric models. The occluded gaps were filled in blender as MeshLab can't deal with large gaps. The objects are imported into HBIM and other modelling platforms to begin the reconstruction process.

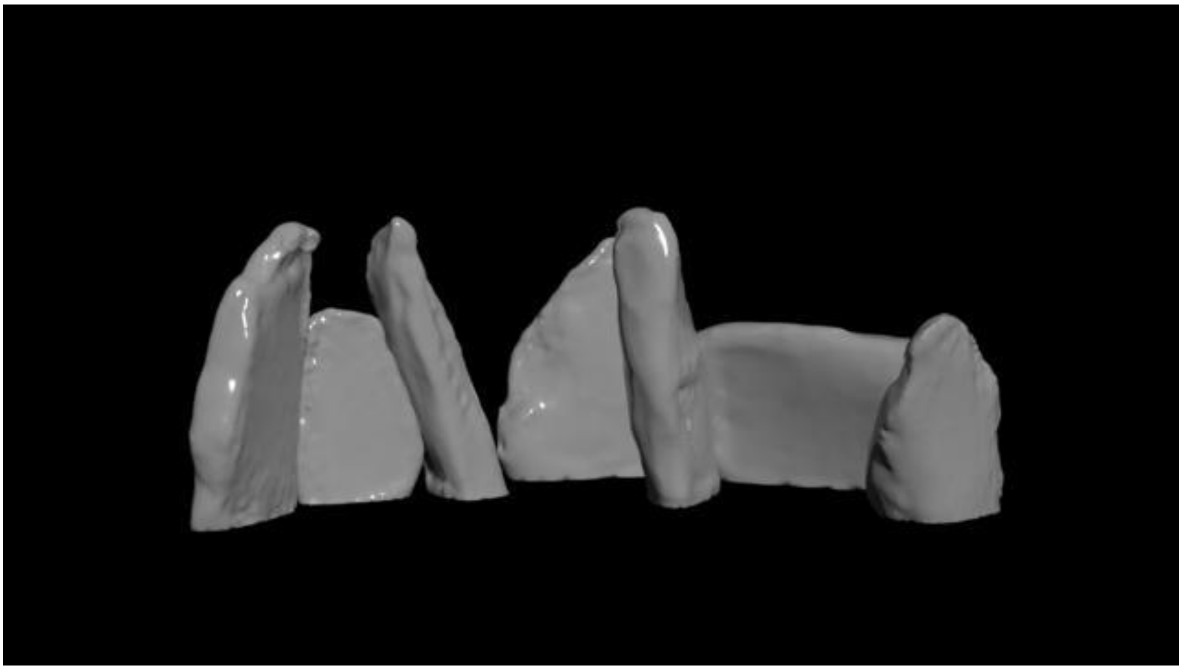

Figure 14: Stage 1; Reconstructed Chamber Stones in 3D Studios which can be rendered in Lumion or other platforms for an initial VR experience.

Click on link for 3D: https://youtu.be/tKLRysLNkEU

5.2 Case Study Kilmalkeader

The digital reconstruction of the Early Irish Christian and Medieval ecclesiastical complex at Kilmalkedar (CillMaolcethair), detailed in section 3, has been an-going project directed by the Virtual Lab in collaboration with Carleton University in Canada and Polytechnic of Milan and the Discovery Programme. The HBIM model was textured and the landscape model added in the software platform Lumion as VR experience of the site.

Click on link below for 3D model

https://view.mylumion.com/?p=y6hqxwwwreaiqmbx

(3) 2022 08 16 Kilmalkeadar Church Video – YouTube

Figure 15: The HBIM model of Kilmalkeader textured and the landscape model added in the software platform Lumion as VR experience of the site

5.3 Athgreany stone circle

Athgreany stone circle, is a Bronze Age stone circle in County Wicklow known as the Piper's Stones. Traditional folklore refers to dancers who were transformed into stone and one larger stone representing the piper. There are sixteen stones around the site while some have been displaced. The larger stone representing the piper is 40m further to the Northeast and may represent the entrance.

Figure 16: Images from VR reconstruction of Athgreany stone circle in Lumion, the original model was developed from a Lidar survey of the site.

Follow the link to view 3D scene: https://view.mylumion.com/?p=p5q7t4lg9jj8ctpl

The digital reconstruction of Athgreaney and Kilmalkeader were developed by Virtual Lab Dublin and Carleton Immersive Studio (Carleston University) using a range of digital recording, modelling and visualisation software by PhD and master's research students supervised by the Virtual Lab Dublin. Site survey workshops were incorporated as part of this project for data collection.

6 Emerging Projects

6.1 Lidar Scan of Historic Centre of Dublin

The Lidar and 3D mapping surveys were carried by the School of Engineering UCD in 2008 and 2015 funded by Science Foundation of Ireland and European Research Council. The survey data includes most of Dublin City's medieval and classical historic areas. The high density, aerial remote sensing data for a 2km² area of Dublin, Ireland obtained at an average flying altitude of 300m. The data include aerial laser scanning (ALS) from 41 flight paths in the form of a 3D point-cloud (LAZ) and 3D full waveform ALS (LAS and Pulsewave). Imagery data includes ortho-rectified 2D rasters (RGBi) and oblique images. The ALS data consist of over 1.4 billion points. The ALS and imagery data are structured both by flight paths and by 500 × 500 m rectangular tiles [11]. In addition to solid 3D CAD or BIM models meshing of point clouds can either create whole or part models or used to enhance the HBIM models and achieve real world geometry. Polygonal surface meshing creates a surface on a point cloud; the created surface is made up of triangles connecting the data points into a consistent polygonal model. The point cloud a a series of random points, which can be developed as a solid model using a meshing algorithm.

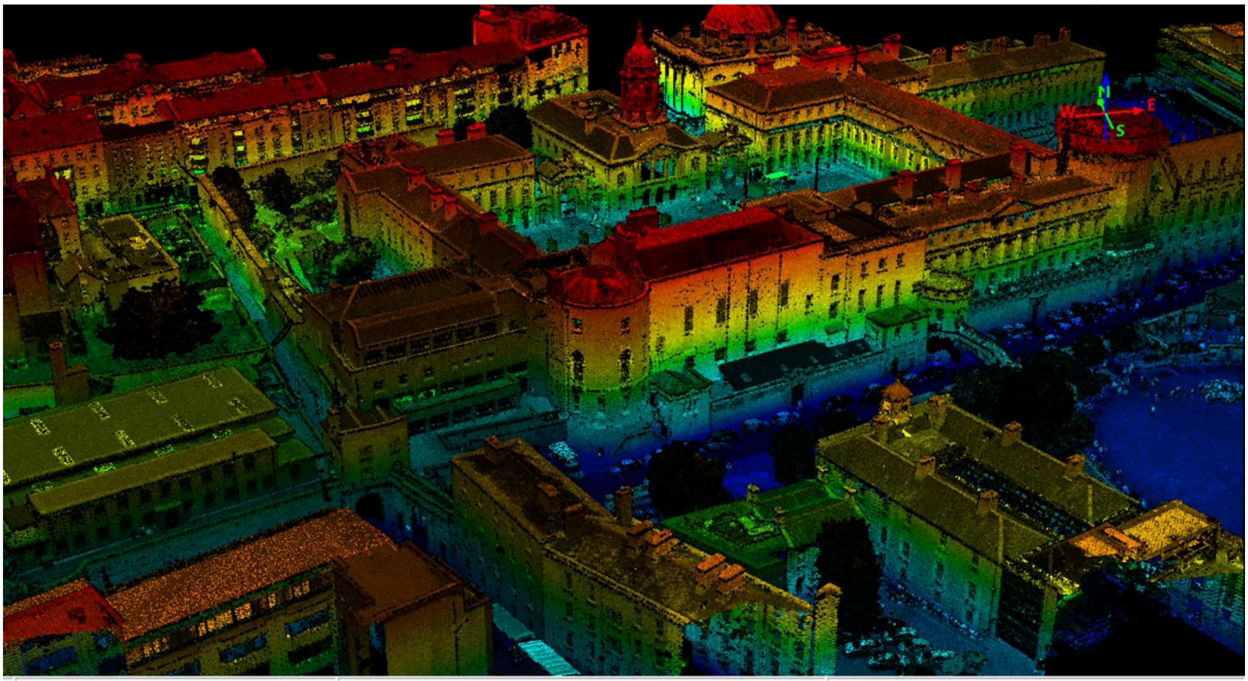

Figure 17: Part of the LIDAR scan of Dublin City

6.2 Dunsink Observatory

Research now underway by Aideen Herron PhD Candidate University College Dublin and funded by the Irish Research Council PhD Enterprise Partnership Scholarship 2019-2023 with the Office of Public Works has two main topics of concern. The first is architectural and designed landscape- research into connected historically significant scientific sites, focusing on Dunsink Observatory, Co. Dublin. The second is the recording and potential creation of a digital model to inform state decision-making regarding such heritage sites which will follow international best research and practice. In pursuing the second aspect of the PhD, pilot surveys were carried out to establish the best method of recording (whether laser scanning, digital photogrammetry, GIS or combinations of these digital surveying and other manual techniques). The main pilot survey carried out to date is a terrestrial laser scan of the buildings resulting in a 3D point cloud illustrated in the top of the figure following below. The South dome, which is a separate domed observatory, dating to 1868, is made of stone and a cladded dome was carried out as a second pilot survey using photogrammetry and processed in Autodesk ReCAP. The resultant mesh model was further process in MeshLab and further tested in a BIM environment exploring the possibilities of creating an information (see bottom of figure below). The use of these surveys (point cloud and mesh) in HBIM rather than building a model is now being considered. This can facilitate the building of a repository linking the 3D building to the historic research. A methodology and workflow are now being developed to combine the historic and archival data collected, and the laser scan data. The parameters of the scan need to be defined and decisions made on how best to convey the value and significance of the Dunsink site through a model and will determine the most effective workflows.

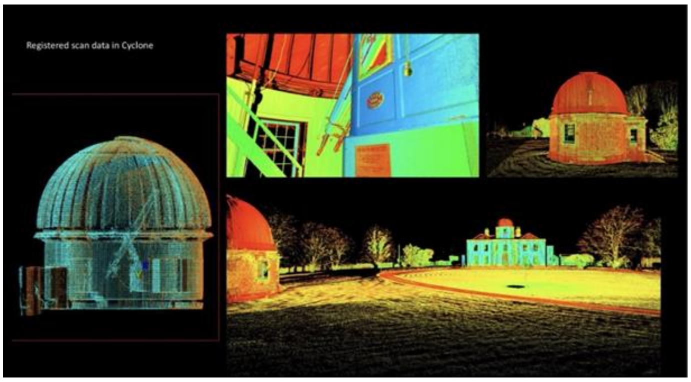

Figure 18: Laser scan survey of Dunsink Observatory

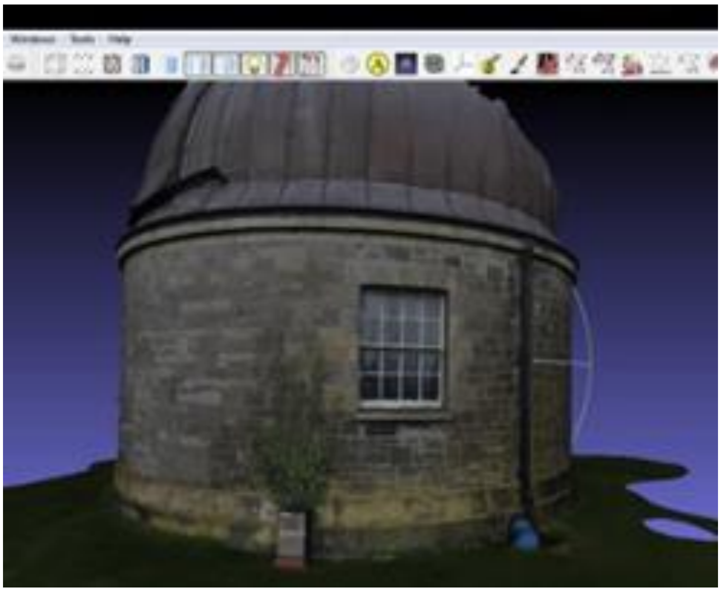

Figure 19: Research Plan and laser scan survey of Dunsink

Case Study - Community access and involvement

The Annals of Athy 2021, developed as a local government 'Heritage Week' initiative is a repository of industrial, agricultural, sporting and more of the area's heritage. Over 50 named authors, editors and artists are credited in the Annals, which has been published just three months after a Heritage Week exhibition. The youngest contributor was a five-year-old artist while their most senior supporter is 98 years of age. Topics covered between the pages include forges and foundries, sporting food and agriculture. The original 1931 *Annals of Athy* was compiled by Michael Malone, Chairman of Athy District Council; in a nice touch, the 2021 edition was designed and printed by Malone's grand-niece and great-grand-niece. It is now intended to develop part of this project as a prototype Community Digital Heritage Initiative.

Figure 20: Traditional Publication *Annals of Athy 2021*

https://www.researchgate.net/project/Digital-Heritage-Local-and-Community

7 Conclusion

We are experiencing the early evolution of community engagement in digital cultural heritage because the technologies and skills are not always fully available and in a development phase. There is no doubt on the other hand that these tools and skills will assist communities in telling their local stories in relation to time and place and reaching a global audience outside of their location. In presenting the series of case studies in this article we have attempted to identify the appropriate tools and technologies. These digital tools are complex and require the expertise of specialist SMEs who work in the area. A cooperation between the state education and heritage bodies and specialist SMEs will facilitate this community engagement. This may involve bringing together communities and local SMEs for collaboration in design and building of digital heritage initiatives with the direction, support, and expertise of state bodies.

Secondly, the way forward for this project in TU Dublin in collaboration with Discovery and OPW will require funding. Three strands of funding are proposed as follows:

1. An IRC funded PhD like the Dunsink project to develop a framework for use and analysis of large data sets in the Lidar Scan of Dublin City, Dowth Hall and possibly smaller projects like Kilmalkeader.

2. Erasmus Plus application, a training initiative bringing together communities and local SMEs for collaboration in design and building of digital heritage initiatives with the direction, support, and expertise of state bodies.

3. A manual for Heritage experts and specialists for Digital Heritage Surveying, Recording and Modelling.

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