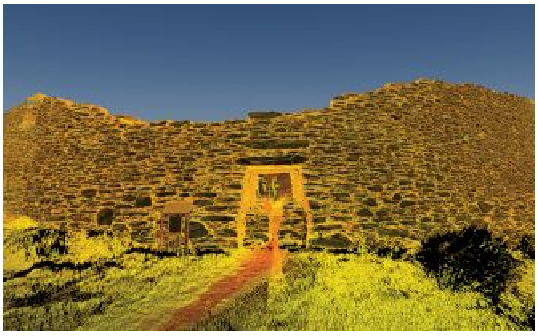
Bringing Heritage to the Public



Throughout the world, many important heritage and archaeological sites are vulnerable and exposed to threats. Natural disasters, such as earthquakes and violent storms, have led to the destruction of countless important sites, and this has been exacerbated in recent times by deliberate acts of aggression - ideologically driven or mindless acts of vandalism. Once destroyed, these important parts of our past are lost forever. In this article, Robert Shaw describes the techniques used by The Discovery Programme to simplify dense point-cloud data for web viewing.

Over the past decade, there has been a growing recognition that 3D surveying methods can play an important role in recording cultural heritage structures and objects through a process of 3D digital documentation. High resolution 3D surveying techniques – such as terrestrial laser scanning – are ideal for recording heritage sites where straight lines and regular geometries are often a rarity. Projects such as Cyark (cyark.org) and the ScottishTen (scottishten.org) have championed this approach and have played a major role in raising the profile of 3D digital documentation.

In light of such projects a three-year collaborative EU co-funded pilot project called 3D-ICONS began in February 2012 with the objective of creating a range of 3D models of the iconic archaeological monuments and architectural buildings of Europe, which would be made available online to the general public. Core to the project was the development of a pipeline for the production of such models including: capture methodologies, 3D modelling and presentation processes, metadata, licensing and 3D data IPR; and finally the potential application of the data in sectors such as education, tourism and conservation.

Diverse sites

The Discovery Programme, an archaeological and innovation research centre, was the partner assigned the task of generating the content for Ireland. Working from the UNESCO world heritage sites list and those proposed on the tentative list for Ireland, twenty-one cultural heritage sites were selected for documentation, ranging from complete ancient landscapes such as Brú na Bóinne, the location of spectacular megalithic tombs, to detailed carved high crosses such as those preserved at the medieval monastery of Clonmacnoise.

The survey methodology depended on the scale of the site. The production of 3D landscape models was achieved through the use of existing airborne laser scanning data (ALS) both from fixed-wing and helicopter-based systems (FLI-MAP 400). Upstanding monuments and architectural buildings were surveyed using a Faro Focus 120 terrestrial laser scanner with georeferencing provided via a Trimble 5800 GPS using VRSnow NRTK corrections. Detailed objects such as carved stones and architectural details were recorded using an Artec EVA handheld optical scanner.

Although these are three very diverse techniques, they all result in high volume, high resolution 3D point cloud data. These are scientific datasets of exceptional value to engineers and architects and they can play a major role in monitoring and conservation of cultural heritage sites.

The data volume problem

Point clouds are an increasingly common survey output and most geomatics professionals are now comfortable viewing and manipulating such data in specialist software. However, to the general public such data can be very difficult to access and understand. Interaction normally requires installing third-party viewers, and then navigating through the point cloud; an unusual environment for the inexperienced, where solid walls can appear transparent. In addition, 3D models have relatively large file sizes, commonly 10-20 GB, which can be difficult to distribute via the web and a challenge to display on a standard PC.

Rather than viewing point clouds, inexperienced users generally find it easier to interpret and interact with surface mesh models, particularly when photo textures or enhanced visualisations are added. However, web access of such mesh models is again not practical. If the model retains an appropriate resolution then the file size is likely to be excessive and not appropriate for accessing via the web.

The researchers at the Discovery Programme – working within the 3D-ICONS project – set about finding a solution to this problem, i.e. to generate 3D models which retain a high level of detail in their appearance whilst also having a suitably small file size to enable online access through the average internet connection.

Retopologise!

The solution came from looking at techniques and software more commonly associated with the gaming industry. In brief, the process enabled us to extract the high-resolution surface model of an object and store this as a normal map which would be subsequently applied to a retopologised low-resolution polygon model recreating the appearance of the higher resolution 3D model. A relatively simple concept but one requiring access to and experience with a diverse range of software.

It is easiest to explain the solution using a case study, St Kevin's Church, a small structure in the monastic settlement at Glendalough, Co. Wicklow. This small eleventh or twelfth century church with a stone roof presented the typical challenge encountered in the project in terms of modelling.

St Kevin's was surveyed using a Faro Focus 120 with the final segmented and geo-referenced point cloud containing 212 million points. The data file in Faro format was 1.48 GB, and when exported as an ASCII xyz file was 7.5 GB.

The following steps, summarized were developed to generate the required model output:-

1. The first processing step was to sample the point data to a uniform spacing of 1cm. This removed unnecessary points where overlap was excessive but retained all the relevant detail. This process also removed noise from the data and created a uniform cloud which would be beneficial to the creation of mesh surfaces. The xyz ASCII file was now 330Mb, down from 7.5 GB and less than 5% of the original.
2. This ASCII file was imported into Geomagic Wrap, a powerful point to mesh modelling software. Here, a high-resolution mesh was generated and a number of functions applied to the mesh model including spikes and outliers removal, and the filling of holes within the data. This cleaned, high-resolution mesh model (17.6 million polygons, file size 1.34 GB) was exported as a .obj file, the industry standard for a mesh. The resulting high-resolution polygon mesh was simplified and re-sampled to form a uniform low-resolution TIN model.
3. The high- and low-resolution models were then imported into Autodesk Mudbox where they appeared in the same model coordinate space. The low-resolution mesh was then retopologised in order to create a mesh suitable for texturing. The result of this process was a low-resolution mesh containing only 200,000 polygons, with a file size of 10.4Mb.
4. The next step was to generate a series of UV maps of the low-resolution mesh. UV mapping is the process of projecting 2D textures onto a 3D model, with U and V denoting the coordinate axes of the 2D texture. Unwrella is a plug-in for Autodesk 3DS max that automatically unwraps a mesh. This UV map was the key component as will become clear as the process continues.
5. A UV normal map was then extracted from the high-resolution mesh model in Autodesk Mudbox. Normal maps store the direction of the normal of the high-resolution 3D model, and when applied back onto a low-resolution model the texture pixels dynamically control how the light interacts with the model surface, creating the illusion of a detailed 3D surface.
6. The second map applied to the low-polygon model was an ambient occlusion map, generated from a programme called xNormal. This process produced a global ambient shading map which enhanced the 3D geometry of the object, such as shading recessed areas on carved stones or the area between stone blocks in built structures.
7. The Faro Focus scanner does not capture suitably high-resolution data for a final model so spherical HDR images were captured using a Canon EOS 5D mkII and a Gigapan Epic Pro camera. Utilising MARI 3D texture painting software, these spherical images were projected onto the model and the photo texture extracted without the evidence of parallax errors.

The results – textured or enhanced shaded models – achieved the objective of the project and could be repeated for models at the other scales, landscapes and detailed stones, using the same processing principles.

Web platform

The final phase of the project was to find a suitable web platform, which provided online access to the models. Sketchfab was chosen, a website that enables users to display and share 3D content online. It provides a 3D model viewer based on WebGL technology that can be embedded on any mobile or desktop webpage. A Discovery Programme sketchfab page was established to host the wider range of 3D content being created, with the resulting models being embedded in a project website (www.3dicons.ie) together with a full range of additional content and media including images, site descriptions, map and videos.

The EU funding of the 3D-ICONS project ended in January, and as such the project was complete. However, the response in Ireland to the project has been overwhelmingly positive and it is intended to continue adding 3D models of new monuments to the website. For the 3D assets already available it is hoped that these will be utilised by a wide range of sectors including: conservation, education and tourism. Over the next year, the Discovery Programme will be working in conjunction with the Irish Office of Public Works (OPW) to generate interactive and immersive visitor experiences for several archaeological monuments using the 3D models.

The 3D-ICONS project has been very much a collaborative team effort. Developing the processing pipeline drew heavily on the experiences of the European partners but it was the team at The Discovery Programme; Anthony Corns, Gary Devlin, Aaron Deevy, Patrick Griffin, Ian McCarthy and Louise Kennedy who developed this solution.

This article was published in Geomatics World November/December 2015