

# Community-driven generation of 3D and augmented web content for archaeology

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## Abstract

*Heritage sites (such as prehistoric burial cairns and standing stones) are prolific in Europe; although there is a wish to scan each of these sites, it would be time-consuming to achieve. Citizen science approaches enable us to involve the public to perform a metric survey by capturing images. In this paper, discussing work-in-progress, we present our automatic process that takes the user's uploaded photographs, converts them into 3D models and displays them in two presentation platforms – in a web gallery application, using X3D/X3DOM, and in mobile augmented reality, using awe.js.*

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Digitizing and Scanning; I.3.6 [Computer Graphics]: Methodology and Techniques—Standards;

## 1. Introduction

Cultural heritage curators and archaeologists are constantly striving to create digital content that describes how our ancestors lived in the past [RMW14]. The use of three-dimensional (3D) graphics, in particular, is a popular way of creating such content, either in the form of stand-alone representations of an archaeological artefact or as elements of larger visualization systems [Rob07]. Archaeologists have been utilising digital techniques for displaying 3D content for more than twenty years, spanning from CAVE-based systems [CAL\*06] to wearable Augmented Reality (AR) systems [RJCC03]. Recent advances revolving around HTML5 and WebGL allow the display of interactive 3D content in a browser, without the need for a dedicated plug-in. In this work, we make use of such technologies, both for desktop-based and hand-held systems.

In this paper, we present a semi-automated process for converting images of artefacts of archaeological significance to 3D representations suitable for displaying on the web, and in handheld AR. Our process (see Figure.1) is an integral part of our community-driven website, that displays photographs of standing stones and burial cairns in North Wales, UK, uploaded by the community. The photographs

are also used to created 3D models, using photogrammetry; these are displayed in our website, using X3D/X3DOM. Finally, we make use of the awe.js AR JavaScript library for displaying *in-situ* simplified versions of these models, using handheld AR. Our web-platform is part of the much larger project *Heritagetogether.org* [MWL\*14], which aims to capture, produce and archive 2D and 3D digital heritage assets in conjunction with local communities.

## 2. Related Work

We briefly describe related work on the technologies we use in our process, namely photogrammetry and standards-based display mechanisms for 3D, suitable for the web. However for an extensive overview of technologies and techniques used in computer-assisted cultural heritage the reader can refer to [KRW\*14].

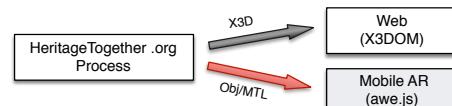


Figure 1: High-level depiction of the Heritagetogether.org work-flow, with web and mobile AR outputs.

Photogrammetry allows the construction of a 3D model of an object from a series of photographs taken from known positions around that object [KRW<sup>\*</sup>14]. Structure-from-Motion (SfM), an elaboration on the original technique of photogrammetry, allows the use of photographs without any prior knowledge of the position at which they were captured [Beh10]. Photogrammetry has been used in various scenarios in archaeology, e.g., for recording data for documenting sites [Kje12], exterior architectural structure [GBS14] and excavations [RSH<sup>\*</sup>14]. The popularity of the technique is down to its non-destructive manner and independence of specialised equipment – one needs only an off-the-shelf digital camera. Although commercial photogrammetry software packages are expensive, Open-source solutions exist, but require some proficiency with software to use [GBS14].

On the other hand, archaeologists and heritage specialists, nowadays have access to various technologies for delivering 3D content on the web, mobile or not. The X3DOM framework [BEJZ09], that allows the integration and manipulation of X3D scenes as HTML5 DOM elements, has been used in various scenarios [JBG11, DBPM<sup>\*</sup>14]. Furthermore, the potential for leveraging web-standards for mobile, handheld AR have been discussed by [AH11] and [SLB11]. Recent efforts include the Argon AR browser [MHR<sup>\*</sup>11] that uses HTML5, CSS3 and JavaScript. A different, and very recent, approach is the open source *Awe.js* JavaScript library, which uses WebRTC, WebGL and sensor APIs (compass, gps etc.) to enable AR content in standards-compliant mobile browsers (e.g., Firefox) for mobile platforms, thus eliminating the need for dedicated AR browsers. *Awe.js* uses the *Three.js* library, to display *in-situ* 3D objects, instead of mere 2D markers.

### 3. 3D Content generation process

Our semi-automated process follows the work flow described in Figure 2. It involves five main stages: image capture performed by community members, image upload, automated mesh and texture generation and output of a 3D model, suitable for display on the web and mobile AR.

The first stage of the process involves the capture of photographs by the community. A list of points of interest, namely prehistoric sites we are interested in surveying, is provided on the *HeritageTogether.org* website. Site visitors may have to obtain permission to access some sites and must ensure they are safely accessible. The contributor can then visit the site and take photographs following simple guidance provided on our website. Importantly, our photogrammetry process needs to have an overlap of about 20% from one image to another; therefore we provide guidelines on how to take appropriate photographs for different types of heritage artefacts. Most of the advice is intuitive, and to take the photographs from a multitude of angles and heights: for instance, standing stone sites need to have several photographs facing into the stone and around the stone, with

some photographs taken around the top and on the top of the stone. Similar guidelines are given by heritage organisations, and we refer the reader to (say) the English Heritage guide to metric surveying for cultural heritage [BBB<sup>\*</sup>09].

Subsequently, once a site has been photographed, contributors are able to upload the images through the website. Users can then browse this collection, add additional photographs, comment on their and other photographs, and add additional site information such as site location and condition. The photographs are associated by the user to the site reference on our list, taken from a unique identification number NPNR (National Public Records Number) which also includes its national grid location.

Once the images and associated textual information have been uploaded into the gallery, the automated photogrammetry process can be initialised. At present our process is semi-automated. A system administrator needs to view the process list for the photogrammetry process to be started. The process is activated by selecting the album containing the images for a site of interest and clicking a button. The button activates a batch script, which generates a list of file locations for each of the photographs to be used, and begins processing those photographs using a Structure-from-Motion (SfM) work flow. This semi-automatic approach was chosen, such that we could monitor the requests, and ascertain the demand and thereby manage the computing resources on our server. We are moving to a model where the process is more automated, and established contributors, who have dedicated time to the project, can initiate the process and monitor and maintain the system.

By extracting and matching features through a series of photographs of an object, SfM can determine the structure of the object and reconstruct a 3D model. First, each image is examined individually with a feature identification process - the VLfeat [VF10] open source implementation of the Scale Invariant Feature Transform (SIFT) method [SGSS08, SSS08] – to identify keypoints which may be present in other images from the series.

Keypoints are identified by rotating and scaling the images, and looking for changes in the illumination conditions and viewpoint of the camera. By comparing the keypoints across the images in which they occur, the position at which each photograph was taken can be estimated, and a sparse point cloud (see Figure 3a) can be generated using a sparse bundle adjustment system [SGSS08, SSS08]. Any features in the area of interest that are only present in a limited number of overlapping images are automatically filtered from the final 3D scene [LFP07] and will not be included in the final 3D reconstruction. The Clustering View for Multi-view Stereo (CMVS) algorithm [LFP07, FCSS10] is used to decompose the sparse cloud into a set of manageable image clusters, then the Patch-based Multi-view Stereo (PMVS2) algorithm [LFP07] is used to create a dense point cloud with

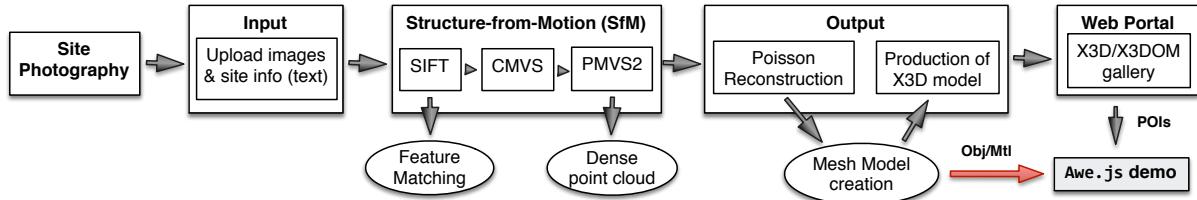


Figure 2: 3D content generation process for the HeritageTogether platform. It includes the stages: image capture, image upload, mesh and texture generation and output of a 3D model, suitable for display on the web and handheld AR.

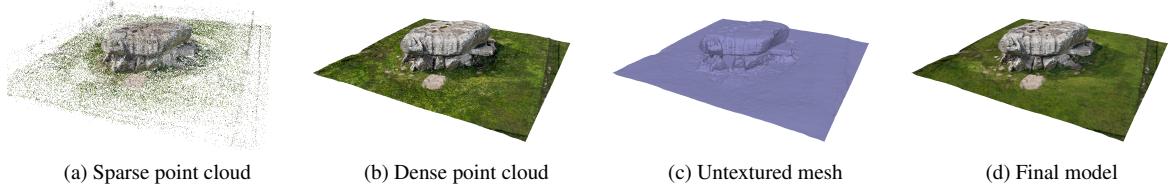


Figure 3: An example 3D model, produced from our process, is the Lligwy Burial Chamber on Anglesey, UK. The images correspond to each stage of our process, following the image uploading by the community, with the final X3D model in (d).

points of estimated position and surface normal, which estimates the 3D structure of the object.

Once the dense point cloud has been created from the photogrammetry process, a 3D mesh is generated by method of triangulation of the areas between each of the dense points. The Poisson surface reconstruction model is used [KBH06] because it is known to be reliable, stable and usually [BTS\*14] effective in producing clean mesh surfaces from noisy data, such as that encountered in point-cloud dataset produced using photogrammetry (see Figure 3c).

After the high resolution mesh has been created, a texture is produced from an averaged mosaic of the images used in the photogrammetry process. Thereafter, a low resolution version of the mesh is also created, that is suitable for displaying on the website, saved in the X3D format. The high resolution mesh is decimated using Quadric Edge Collapse Decimation, optimising the mesh generation by determining the most important edges and reducing the polygons between them (see Figure 3d). The X3D file is then uploaded to the gallery and can be viewed using X3DOM [BEJZ09].

#### 4. Display Mechanisms

Image contributions from our community are uploaded to a Coppermine Photo Gallery, an open source PHP web gallery managed by a MySQL backend. The gallery is displayed on the HeritageTogether.org web site through a WordPress-plugin. The produced 3D models are displayed using X3DOM [BEJZ09], eliminating the need for specialised browser plug-ins. Basic zoom and rotation, using the mouse, allows inspection of the models. A separate gallery, with static images of the models provides an alternative for iOS and Safari.

Complementary to our website, we have created a series

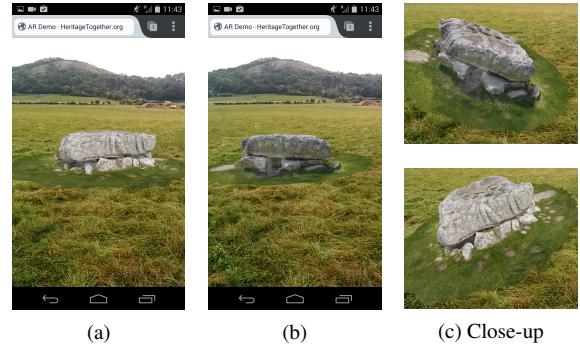


Figure 4: AR views of the Lligwy Burial Chamber. The model can be rotated by touching it. Figure (c) depicts angled close-ups. In this view the model is not render in the actual site, for demonstration purposes.

of handheld AR demonstrations for various sites in North Wales, using the `awe.js` library. Our current demo displays models from our collection, anchored in hard-coded geo-locations in the HTML/JavaScript pages for testing purposes, using the information in our database (Figure 4). The models used with `awe.js` are `obj/mtl` files and are derived from those depicted in our main 3D gallery. However they are significantly simplified at about  $10^4$  polygons, with our initial goal to have models and textures under 2MB. Unfortunately, with `obj/mtl` files there is no progressive loading as with X3D/X3DOM. We are currently working on a web application that will pull all the location and orientation information from our database, and will allow the dynamic creation of the handheld AR contents.

As our handheld AR delivery mechanism is still a work-in-progress we provide a plain points-of-interest (POI) in-

formational AR layer, through the Wikitude browser and the Maps Marker WordPress plug-in. Our AR world, *Heritage-Together Sites of Interest*, uses a collection of POIs corresponding to the locations of the sites in our database - thus modified in real-time by user's contributions.

## 5. Conclusions and Future Work

We present an online semi-automated photogrammetry work flow that enables the general public and members of our research team to create 3D representations of archaeological artefacts. Our process makes use of Structure-from-Motion for model creation and X3D/X3DOM for web display. In addition, we make use of the *Awe.js* JavaScript library in a browser-independent, standards-based AR demonstration that displays *in-situ* 3D models, derived from our main gallery, with location and orientation information from our database. As our work on AR is very much in progress, but our website public, we have incorporated mechanisms for the creation of 2D ARML content, suitable for display in the Wikitude AR browser.

Our future plans include: a) the expansion of our artefact collection which at the moment holds over 5000 photographs, allowing the creation of over 40 models of different megalithic monuments b) further development towards the integration of our model repository, POI database and AR webpages, and c) exploration of complementary, alternative view mechanisms [Rob07] for the visualization of the cultural heritage artefacts.

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