ICS2000 Group Assigned Practical Task
Online Museum

David Cachia Enriquez

david.cachia.enriquez.21@um.edu.mt

Jan Formosa

jan.lawrence.formosa.21@um.edu.mt

Matthew Kenely

matthew.kenely.21@um.edu.mt

Abstract

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1 Introduction

Historical and cultural sites are integral to the identity of the Maltese islands, and as such, their preservation is of utmost importance. With the advancement of technology, the methods of monitoring and preserving these sites have changed, an example of how being through the use of digital 3D reconstructions of the sites.

The aim of this project is to create a website proof-of-concept housing multiple 3D reconstructions of Maltese cultural sites. These 3D renders are created via captured photographs and making use of photogrammetry techniques to convert them to models.

2 Background

2.1 Photogrammetry

A crucial part of the project is the creation of the 3D reconstructions from the photographs taken of the sites. This is done via a technique called Photogrammetry. This process can be broken down into a few steps:

1. Capturing of Images: the first step is to gather multiple photographs of the object to be reconstructed. Ideally, these photos are taken from as many different perspectives as possible, so as to gather as much in-

formation about the object as possible, which allows for easier triangulation and an increase in detail on the model.

2. Camera Calibration: after capturing the images, the parameters of the device used to capture them (the camera) must be noted and used in calibration so as to accurately calculate the positions of the 3D points on the model with respect to the position of the camera. Some parameters that are required are focal length, lens distortion and sensor size.

3. Image Matching: the next step is to match the different images together via corresponding points from each image. This is done by making use of feature detection and matching algorithms, which can identify distinctive features between different images, and then match them up together.

4. Triangulation: next, the matched points from the previous step are used to to calculate the position of the camera with respect to the object to be modelled, the process of which being called triangulation. This involves finding the intersection of lines drawn from the camera positions to each matched point.

5. Point Cloud Generation: after finding the camera's position, the matched points are used to create a point cloud, a collection of points within 3D space that represent the surface of the object.

6. 3D Model Creation: the final step of the process is using the generated point cloud and converting it into either a mesh or a series of different surfaces to form the 3D model. The result is then visualised and can be manipulated and altered as seen fit.

Some practical uses of photogrammetry include surveying and mapping, urban planning, forensics and engineering.

3 Methodology

3.1 Meshroom

Meshroom is a free and open-source photogrammetry software that allows users to create 3D models of objects and scenes using photographs. It uses a technique called Structure from Motion, which involves analysing the patterns of motion in a series of 2D images to construct a 3D model.

When you feed Meshroom a set of photographs, it first identifies common features (the descriptors of which can be specified; in this project, we used SIFT features [?]) across the images. Then, it uses these features to compute the camera positions and orientations for each image, as well as the 3D positions of the common features.

Figure 1: Subset of the images fed to Meshroom to construct the British Blomefield Cannon

Figure 2: Features and camera positions of the British Blomefield Cannon images detected by Meshroom

Once the camera and feature positions are estimated, Meshroom applies a technique called dense reconstruction, which involves estimating the 3D geometry of the entire scene based on the camera positions and orientations, and the feature positions.

Figure 3: Mesh of the British Blomefield Cannon generated by Meshroom

Finally, Meshroom creates a textured mesh by projecting the original photos onto the 3D geometry, which creates a 3D model with detailed textures.

Figure 4: Texture maps of the British Blomefield Cannon generated by Meshroom

Figure 4: Texture maps applied to the mesh of the British Blomefield Cannon

We opted to use Meshroom specifically due to it having an easy-to-understand user interface, being able to utilise our GPU (Nvidia GeForce RTX 2060) to generate and process the 3D models relatively quickly, and due to the resulting models it generated being of high quality despite the limitations posed by the museum environment. While further refinement of the 3D models in blender was definitely required, Meshroom served as a solid foundation for the generation of the meshes and textures of the artefacts.

3.2 Blender

Blender is a free and open-source 3D creation software that can be used for a variety of purposes, including 3D modelling, animation, rendering, video editing, and game development. It is a powerful and flexible tool that is used by professionals in the film, animation, and gaming industries, as well as by hobbyists and enthusiasts.

Blender is capable of creating complex 3D models using a variety of modelling tools and techniques, including polygonal modelling, sculpting, and procedural modelling. It also includes a wide range of animation tools, such as keyframe animation, motion tracking, and rigging.

Additionally, Blender has a powerful rendering engine that can produce photorealistic images and animations. It supports a variety of rendering methods, including ray tracing and global illumination, and includes a node-based compositing system that allows for advanced post-processing and special effects.

We used blender to refine the models where necessary.

3.3 Web Application

The culmination of this project is a web application coded from scratch using HTML, CSS and JavaScript, featuring a home page and a page which presents the museum artefacts. We used media queries to make the site responsive, and hence it is usable on both desktop and mobile devices.

The home page provides a brief introduction to the concept of photogrammetry, as well as an explanation of how we populated the online museum.

The museum page contains a grid, displaying a preview of the 3D artefacts and their title. When an item in the grid is clicked, a full screen interface is displayed wherein the user can view the artefacts in 3D, as well as a brief description of each artefact and a link to its corresponding Wikipedia article. The grid, as well as the corresponding fullscreen interface content of each artefact are loaded from a .json file using JavaScript. The .json file contains an array of objects, with each object containing the following keys id Used as a unique identifier for each artefact title Title displayed on the museum grid description Brief description display in the fullscreen interface objpath Path to the .glb file to be loaded into model-viewer imgpath Path to the preview image of the artefact to be displayed on the museum grid wikipedia URL to the wikipedia article of each artefact

There is also a set of instructions on the museum grid on how to operate model-viewer (how to rotate the camera, how to orbit around a specific point, etc.) which changes slightly depending on whether the user is accessing the site from a desktop/laptop or tablet/mobile phone

Since the artefacts are loaded from a .json file, the site is entirely static and can be hosted on GitHub Pages. We are serving the site on https://mkenely.com/ics2000/, so the artefact is publicly accessible at all times.

We opted for the primary use of a monospace font (Ubuntu Mono) throughout the website to emphasise the fact that this is a digital museum.

3.4 model-viewer

To display the 3D models generated on the website, a premade component called ¡model-viewer¿ (found here: https://modelviewer.dev/) is used. This component is used in "museum.html", specifically in the function showObject.

4 Limitations

Glass Encasing One of the most significant challenges faced when taking photos in a museum for photogrammetry is the presence of glass encasing around artefacts. While glass is necessary to protect artefacts from damage and deterioration, it can create reflections and distortions in photographs, which can inhibit the detection of good features within the images, and hence may result in inaccurate meshes (as shown below).

Figure :$Reflectionsvisibleinoneofthephotographsfedto Meshroominattempttocreateaflintlockpistol3D$

The effect reflections have on the detection of features is, however, partially dependent on the lighting within the room. For example, in the case of the Punic Ceramic Vessel, the resulting mesh was, for the most part, accurate and intact (though some touching up was still necessary - see below).

Figure :$ThePunicCeramicVesselwasencasedinglassFi$

Model Refinement While Meshroom did a very good job at generating 3D meshes of the artefacts, in almost all cases some level of refinement of the models was necessary. This mainly consisted of flattening and smoothing faces of the models, deletion of excess vertices, texture painting, and in some cases, mirroring half of a symmetrical object altogether.

Figure :$PunicCeramicVessel - touchingupofthehandleswasnecessarytoobtainanaturalsha$

Figure :$RoyalNavySeaServicePistol - onlyhalfofthe3DmeshgeneratedbyMeshroomwasusableFi$

Spacing angles Another challenge that was encountered when taking photos at the museum was the limited space available for photography. Some artefacts were located in tight spaces, making it challenging/impossible to get the right angles for the photographs.

Figure :$Turretartefact, thebackofwhichisinaccessible$

Figure :$Knights'Shield - photographwithananglefromt$

Lighting The third significant challenge we encountered when taking photos was lighting. The lighting in museums is typically designed to create a specific ambiance and mood, rather than to facilitate photography. This can make it challenging to capture high-quality photos that are well-lit, have a natural colour temperature and are free from shadows, glare and noise. We partially counteracted this by taking the photos in RAW format to capture as much detail as possible, as well as touching up the photos in Adobe Lightroom where necessary.

Figure :$CoatofArms - harshlightingconditions$

Figure :$Aftertouchingup, thecoloursintheimagearemor$

5 Conclusion

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