Photography based 3D reconstruction for archaeology and heritage recordings

Introduction

Three dimensional models as a way of recording objects in heritage and archaeology are obviously more valuable research assets than the more traditional data recordings such as photographs, sketches, selected measurements, bearings, verbal and written descriptions. Indeed most of the above, and other metrics, can be derived if one had an accurate 3D model. There are various approaches to the capture of 3D models, including but not limited to, structured light scanners, depth cameras, laser scanning, various 3D volumetric scanners and photogrammetry. 3D reconstruction from photographs has been an area of active research over the last 4-5 years, the improvement in the algorithms has resulted in a corresponding improvement in the quality of the resulting models. For many types of model, especially those requiring capture in the field [1], a skilled practitioner can photograph and reconstruct models with an accuracy that challenges the more traditional view that laser scanning is the gold standard. In what follows a number of examples of 3D reconstructed models in heritage and archaeology by the author will be presented. Reference will be made to the simplicity of capture, compared to many other techniques and comments around the question of accuracy [2][3]. Finally, some of the challenges will be presented arising from the storage of large textured meshes in databases, their intelligent searchability and online delivery.

Examples

Figure 1. Indigineous rock shelter in the Weld range of Western Australia. Typically 1000 photographs and 5-10 million triangle meshes textured with eight 4Kx4K image maps.

Figure 2. Door of a 8th cententury cathedral door in Magdeburg, Germany. 100 photographs. Note the concave structures such as the coiled snake and limited side access, limiting many scanning technologies.

Figure 3. Underlying mesh data of the Diotima statue to be found at The University of Western Australia. 60 photographs were acquired for a full 360 object representation with a measured error of at most ±1mm over the 1.5m object.

Figure 4. 3D model of an exposed skeleton on Beacon Island, a victim of the Batavia shipwreck in 1629 on the Morning Reef near Beacon Island in the Wallabi Group, part of the Houtman Abrolhos Islands. Five grave sites were reconstructed at multiple times during the excavations, typically 200 photographs per recording.

Technology choice

When choosing a capture technology in fields such as archaeology and heritage there are a number of considerations, some of which are unique to these disciplines, specifically:

1. Can the technology be deployed in the field [4] or is it limited by environmental conditions. For example most of the structured light scanners do not operate in direct sunlight. Figure 7 shows a particularly constrained capture environment where the object under question is surrounded by a glass container.
2. Cost of the underlying hardware. A high end SLR camera costs considerable less than the alternatives.
3. The effort, time and staff required to perform the capture. This is particularly important for field work that is often in remote areas, possibly in adverse weather and with limited time budgets.
4. The visual richness of the result and the required format as a research asset. Is a point cloud sufficient, a mesh, are there aligned textures?
5. The accuracy of both the textures and the underlying mesh. What does the research require?

By almost all these metrics it is increasingly becoming accepted that photographically derived 3D models, if performed by an experienced operator and with optimal hardware/software, is the prefered choice. It can be performed in the widest range of conditions of any other technology, the hardware/software costs are minimal, it only requires a single operator and results in both 3D geometry and rich co-aligned texture data. The traditional argument for laser scanning, the main contender, is accuracy. This is not as clear cut as many imagine [5] and laser scanning has significant disadvantages in the field, including the effort and time involved. It is not the purpose of this discussion to hail photographically derived models as the solution to all 3D capture. On the other hand the accuracy argument in favour of laser scanning is not as obvious as often suggested. The technology chosen needs to weigh up all factors, the intended use of the data as well as the accuracy required.

One example why the accuracy "gold standard" for laser scanning is not straightforward is to consider highly convoluted structures such as the rock shelter in figure 1 and figure 5, or concave features for which a laser station can not be positioned to achieve line of sight, such as features on the door in figure 2. In the later case there is more scope for camera positions to capture concave structure, indeed photographing for reconstuction works best when every photograph is taken from a different position.

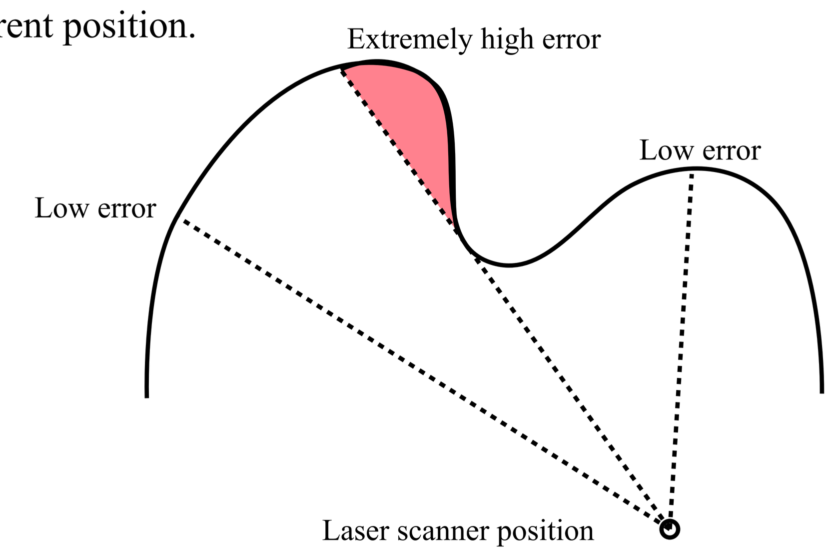

Figure 5. Illustration of what could be considered infinite error in laser scannings when parts are not visible from laser station position. This is equivalent to a data loss and even data misrepresentation. Noting that in this example one could choose multiple laser station positions but as the complexity of the scene increases this becomes an increasingly time consuming process and impractical for structures that may require hundreds of positions. Shadow zones such as this greatly complicate the comparison of accuracy [3] between models.

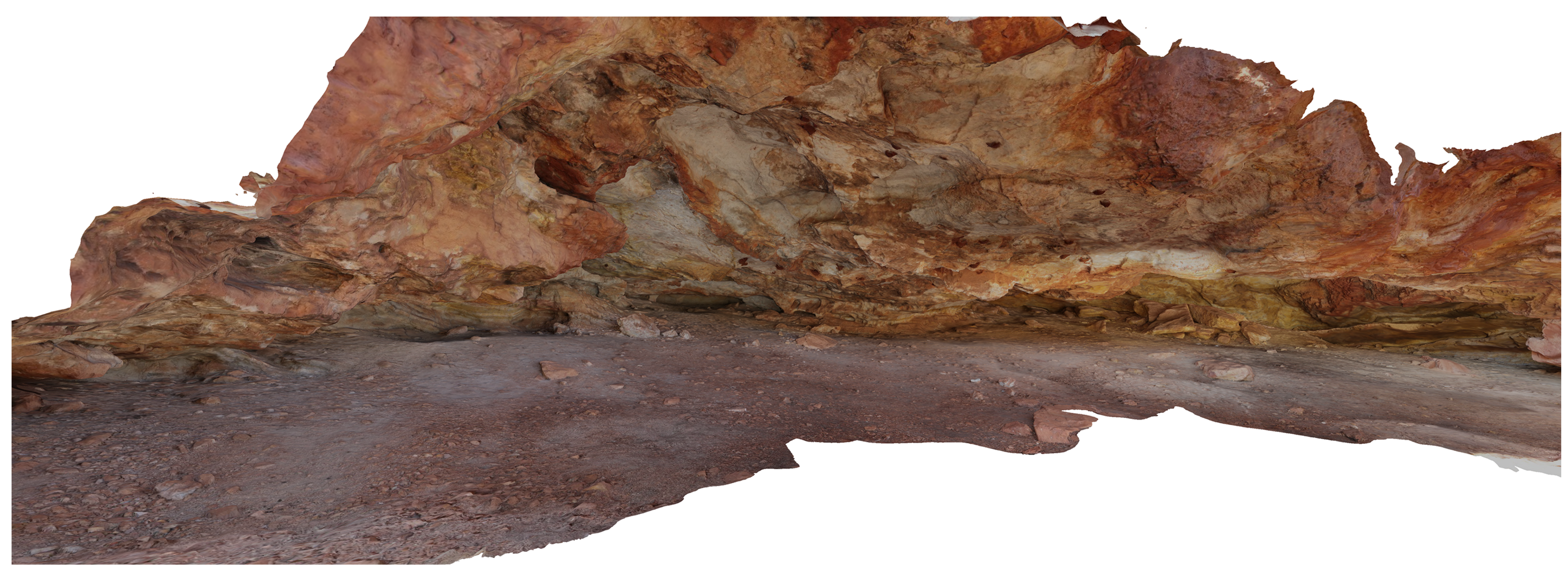

Figure 6. Example from a cave in West Angeles, Western Austraia. The highly convoluted rock structure at different levels (for example upper left hand side) and piles of rocks (for example right rear) would mean that a very large number of laser station positions would be required to achieve the coverage achieved in this photographic reconstruction.

Data storage, searching and delivery

A number of challenges remain for the storage, interrogation and delivery of textured 3D models. It is not uncommon for a model mesh to contain 5 million triangles and for there to be a number of 16MPixel texture files. As such 1GB per 3D model representation is not uncommon. These full resolution models are of high research value and while subsampled versions may be useful for some purposes, the full resolution are equally important, particularly for many analysis processes.

These geometric forms can have questions asked of them above what might be baked into a database record through meta data, even questions relating to research questions unanticipated at the time of capture. For example, measures of roughness, dimensions, major/minor axes, colour metrics, area of surface with a particular facing and so on. These are geometric properties that can be computed from the data and as such would ideally be capabilities of the database query language.

Lastly, how are these potentially large objects delivered to an end user, client or researcher on a network connection of unknown bandwidth? Standard techniques exist for incremental delivery of large images, for example gigapixel images are partitioned into tiles where only those tiles are delivered that are visible within the viewer window and progressively revealed to the appropriate resolution. While there are attempts at progressive textured mesh delivery [6] and it is an active area of computer graphics research, there are as yet no standards for the delivery of multiresolution textured meshes. Noting that storing multiple copies at different resolutions is not ideal nor efficient, one expects a means that provides progressive refinement rather than simply one of a number of level of detail models.

Figure 7. Photographically derived models can be acquired in situations where other technologies would fail, in this case pathology objects located within glass containers. One photograph from 20 is shown in top left, one view of the reconstructed model top right.

Author references

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