Automatic reconstruction of 3D geometry from photographs

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Introduction

Photogrammetry is the name given to a range of techniques by which 3D properties of an object are derived from 2D images. It is most often associated with the derivation of topology from aerial photographs, this is now more commonly referred to as a 2.5D reconstruction since the surfaces are generally convex. The automated creation of full 3D models from a series of photographs has been an active area of research for many years in computer science and vision research, often referred to as SfM (Structure from Motion) [1]. The techniques would appear to be maturing, this is reflected in a number of stable software tools being released from research laboratories both as commercial products but also in the public domain.

This poster presents some recent exploration in this area. A number of applications at UWA for automatic 3D reconstruction from photographs have been identified, these include the population of game engines with accurate models (as opposed to manually created models involving artistic interpretation), creation of virtual worlds with realistic models [2] without the need for time consuming manual modeling, and generating databases of 3D models for research and documentation in archaeology [3] and virtual heritage.

Semi-automated 3D surveys have often been performed with "return of fight" methods such as LIDAR (LIght Detection And Ranging). Almost coincident photographic cameras can supply colour for the resulting point cloud or texture for a derived mesh. Structured light scanners, used for example in consumer products such as the Kinect, project a known pattern onto an object and derive surface properties and depth by analysing an image of the result. An early commercial product using just images and developed in Australia was SiroVision [4], which mainly targeted the mining industry as a solution for mapping 3D structures and determining, for example, volumes of rock extracted from mining operations. While the software generally only required two photographs and was aimed at creating a high degree of dimensional accuracy it is limited by the need for some rigour in the image capture process, for example there is often the need for in-scene reference points and a high degree of control and knowledge of the camera optics.

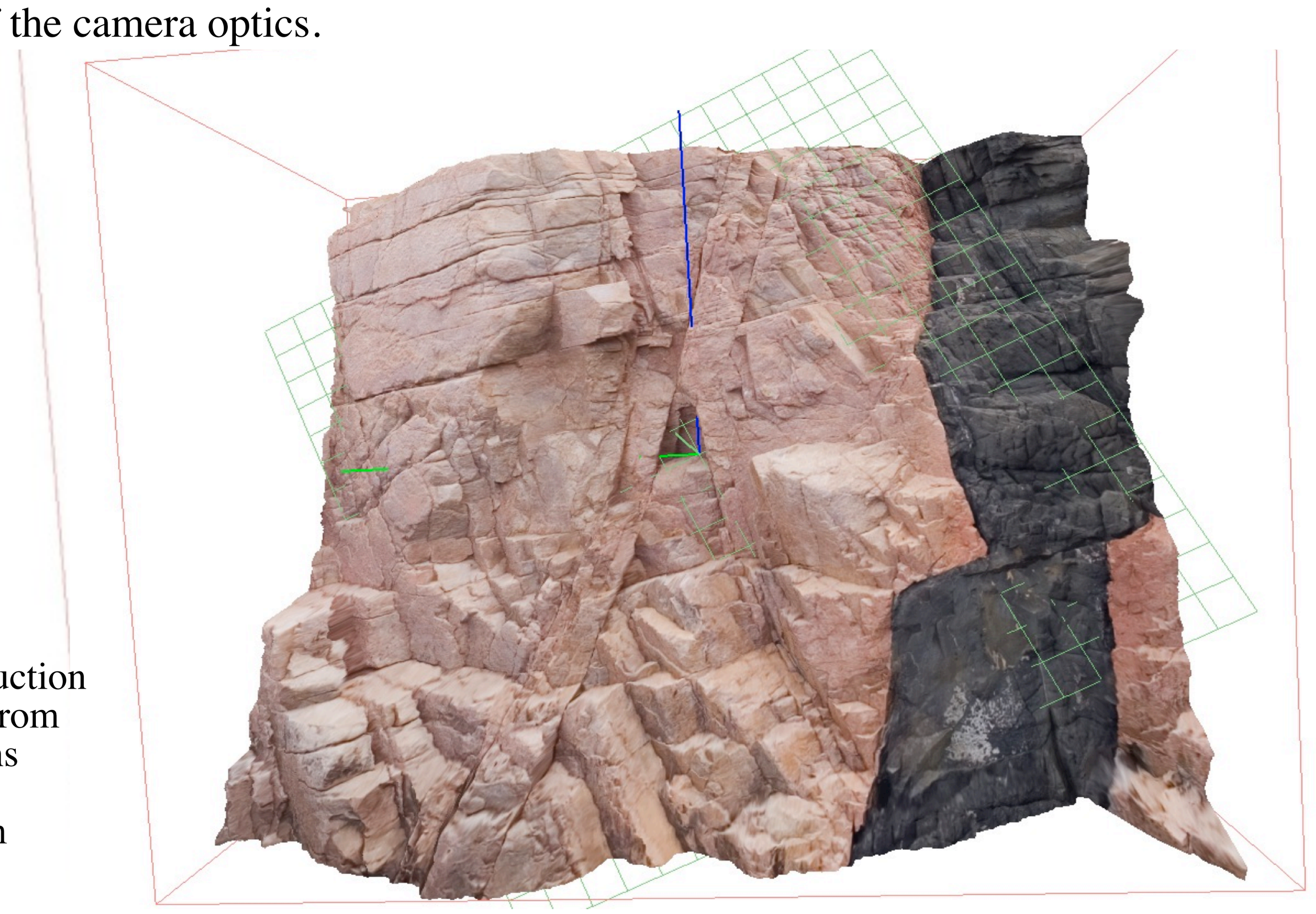

Figure 1: Reconstruction of an outcrop face from just two photographs using SiroVision. Approximately 50m across.

The algorithms discussed here are primarily aimed at "ad hoc" image capture, although there are obviously some guiding principles which can affect the quality of the final reconstruction. For example, one is not going to be able to reconstruct parts of a model not visible to the camera. A number of the current software tools have been evaluated [5], the main ones being 123D Catch from Autodesk, PhotoScan by Agisoft, Photomodeller by Eos Systems, Bundler, Visual SFM, and Photosynth by Microsoft. Note that the last two are based upon the open source tool Bundler. 123D Catch and photosynth are cloud based solutions. The results shown here are from either 123D Catch [6] or PhotoModeller [7].

Example 1: Cultural Heritage (Karnataka, India)

This example is from the Moodabridi temple, also known as the 1000 pillar temple located in the state of Karnataka in India. The intention is to capture the many reliefs carved into the walls and columns of the temple and to subsequently document the associated deities and stories. The great advantage of this technique is the rapid acquisition time, since the reliefs are generally only 2.5D, only between 3 and 6 photographs are required.

Figure 2: Four photographs of a embossed wall at the 1000 column temple, approximately 10cm across.

Figure 3: Reconstructed and textured mesh [8] from the four images in figure 2.

Example 2: Rock Art Archaeology (Pilbara, West Australia)

As the object to be captured becomes more convoluted a higher number of photographs are required. In this example from a rock art archeological survey [9] typically six to a dozen photographs were used. This examples illustrates the ad-hoc nature of the photography, in this case there are a mixture of landscape and portrait images as well as images taken at different times of the day and thus under different lighting conditions. This raises the exciting possibility of reconstructing models from public image collections such as Flicker. This example is also interesting given the rock surface textures are very noisy surfaces without clear distinguishing geometric or colour features.

Figure 4: Seven photographs of a rock art structure, approximately 3m across.

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Figure 5: Two views of the reconstructed model from the seven images in figure 4.

Example 3: HMAS Sydney Memorial (Carnarvon, West Australia)

In this final example a full 3D model is reconstructed. In these cases, due to the image coverage requirements the number of images captured is much higher. In this example 30 photographs are taken from roughly equal positions on a 15m diameter circle around the monument, additonional photographs are taken from elevated positions. Note the shadows burnt into the texture maps.

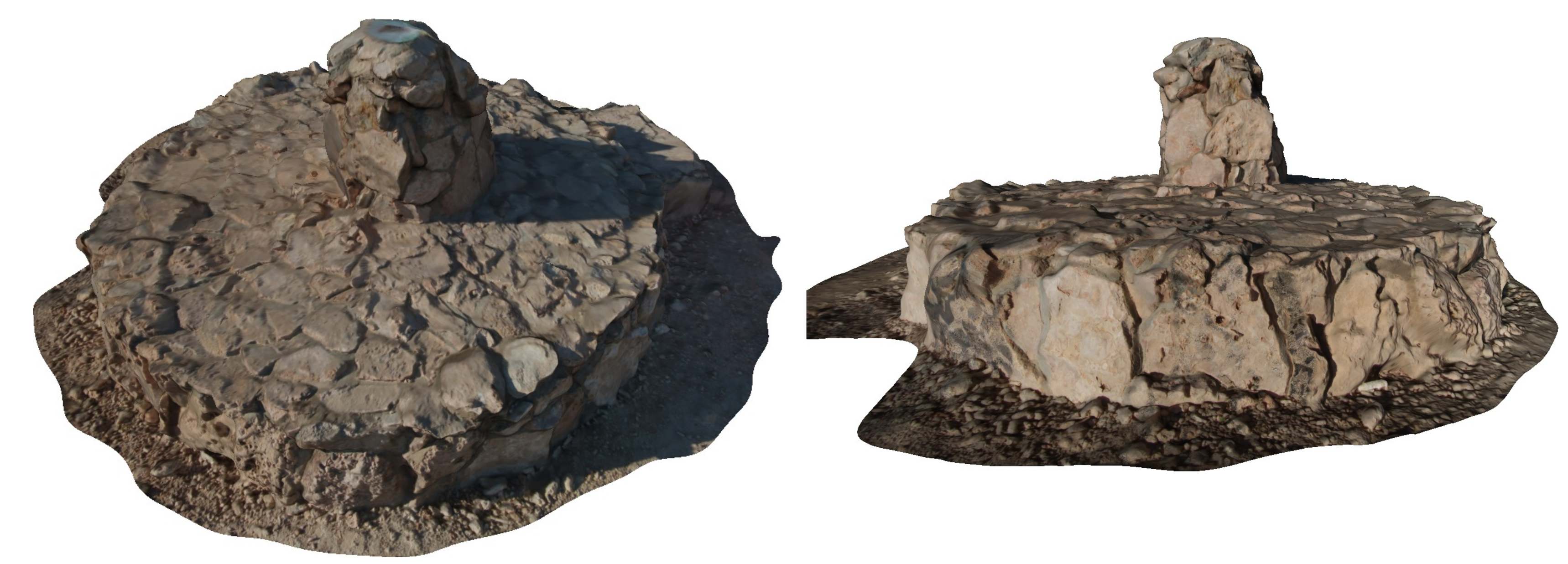

Figure 6: HMAS Sydney memorial reconstruction. Approximately 10m across.

Future work

Future work includes evaluating the accuracy of the models, finding workflows to reduce the mesh density for realtime gaming applications, and exploring the capture/reconstructions of more extended objects rather than the single objects presented in these examples.

References

1. Barazzetti, L., Scaioni, M. and Remondino, F. (2010), Orientation and 3D modelling from markerless terrestrial images: combining accuracy with automation. The Photogrammetric Record, 25: 356–381.

2. Percoco, G. (2011), Digital close range photogrammetry for 3D body scanning for custom- made garments. The Photogrammetric Record, 26: 73–90.

3. Remondino, F., Rizzi, A., Girardi, S., Petti, F. M. and Avanzini, M. (2010), 3D Ichnology: recovering digital 3D models of dinosaur footprints. The Photogrammetric Record, 25: 266–282.

4. SiroVision, http://sirovision.com/

5. Beven, G. A Look at Photogrammetry using Images from the 2008 HMAS Sydney II Survey, iVEC Technical Report iVEC-TR001-2012, 2012.

6. 123D Catch, http://www.123dapp.com/catch

7. PhotoScan, http://www.agisoft.ru/products/photoscan/

8. Meshlab, http://meshlab.sourceforge.net/

9. A. Paterson, J. McDonald. Centre for Rock Art Research and Management, University of Western Australia.

10. Fofi, D., Silwa, T., Voisin, Y.. A comparative Survey on Invisible Structured Light. SPIE Electronic Imaging - Machine Vision Applications in Industrial Inspection XII. San Jose, USA, 2004.