A New Digital Dimension

pursuing a holistic digitisation approach to the Miegunyah Collection

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Abstract

Digitisation of cultural materials, predominantly undertaken through digital photography, has become standard practice in the 21st century, furthering public access, research data sharing, digital conservation and record keeping. Recent developments in more advanced imaging techniques allow for a new wave of digitisation, creating much more detailed, sophisticated, and representative digital surrogates. This project combines the cutting edge techniques of structure-from-motion photogrammetric modelling and photometric stereo imaging to create opportunities for distant and remotely accessed cultural objects to become more present and powerful than ever before.

Introduction

Digitisation is today the most important means by which collecting institutions can bid to retain cultural relevance in the modern world. From fictile ivories to gift-shop postcards, collectors have always sought to broaden engagement through reproduction, but it is only with the advent of the Digital Age that infinite reproducibility can truly be achieved, broadening reach and democratising collection access through enriched surrogation of artefacts in the virtual world.

Digitisation of cultural material collections is today common practice in museums, galleries, and educational or cultural institutions. Two-dimensional (2D) imaging has been broadly adopted at an institutional level and, with the recognition that many objects are defined by their geometry, three-dimensional (3D) imaging has begun to be explored within the heritage sector. In pursuit of more representative, evocative and accurate digital representations there emerges a case for '2.5D' imaging, suitable for capturing the texture and surface characteristics of geometrically flat objects. The aim of this research was to explore methods for combining 2D, 2.5D and 3D imaging processes for a variety of media and object-types to improve documentation workflows in a field with many possibilities and little standardisation. Details of the objects digitised and research aims are provided in Table 1.

Discussion of techniques and methodology

Photography

Many institutional digitisation projects generate 2D assets through the use of digital photography. Photography provides a stable and highly detailed mode of record keeping, suitable for the generation of public facing access files, which are indexed and made available online. Modern, high-resolution digital cameras are capable of capturing remarkable detail, however a photograph is static, limited to representing a single perspective captured under controlled conditions. While an immensely valuable resource in terms of access and equity, the possibilities viewers have to engage with these assets is fundamentally different from the experience of viewing these objects in a gallery setting, where objects are brought to life by their dynamic interaction with light, perspective and the viewer. The methods explored in this research seek to capture the high detail and low access barriers of digital photography, while emulating some of the interactivity of environmental ambience.

Photogrammetry

Photogrammetry provides a means of generating 3D assets from many 2D photographs. It works by generating 'structure from motion', whereby software tracks and calculates triangulation for common points in divergent perspectives, similar to the way the human eye exploits the parallax effect to generate stereo depth perception. When properly executed, photogrammetry is capable of generating submillimetre accuracy and resolution using images taken with any digital camera.[1] For this reason, it is considered to be one of the best and most accessible methods of 3D asset generation, and has been widely adopted across many industries, including terrestrial mapping, videogame asset creation, and archaeological documentation, to name only a few. It is becoming common practice in the digitisation of museum collections.[2]

Figure 1: Photogrammetry model of wood block, with textured (left) and untextured mesh (right). Note the detail in the textured mesh is not consistent with simulated lighting, and the lack of fine detail in planar surfaces of the untextured mesh.

[1] Bornstein 2022.
[2] Stojićević 2020, 14; Keep 2021; Keep 2022.

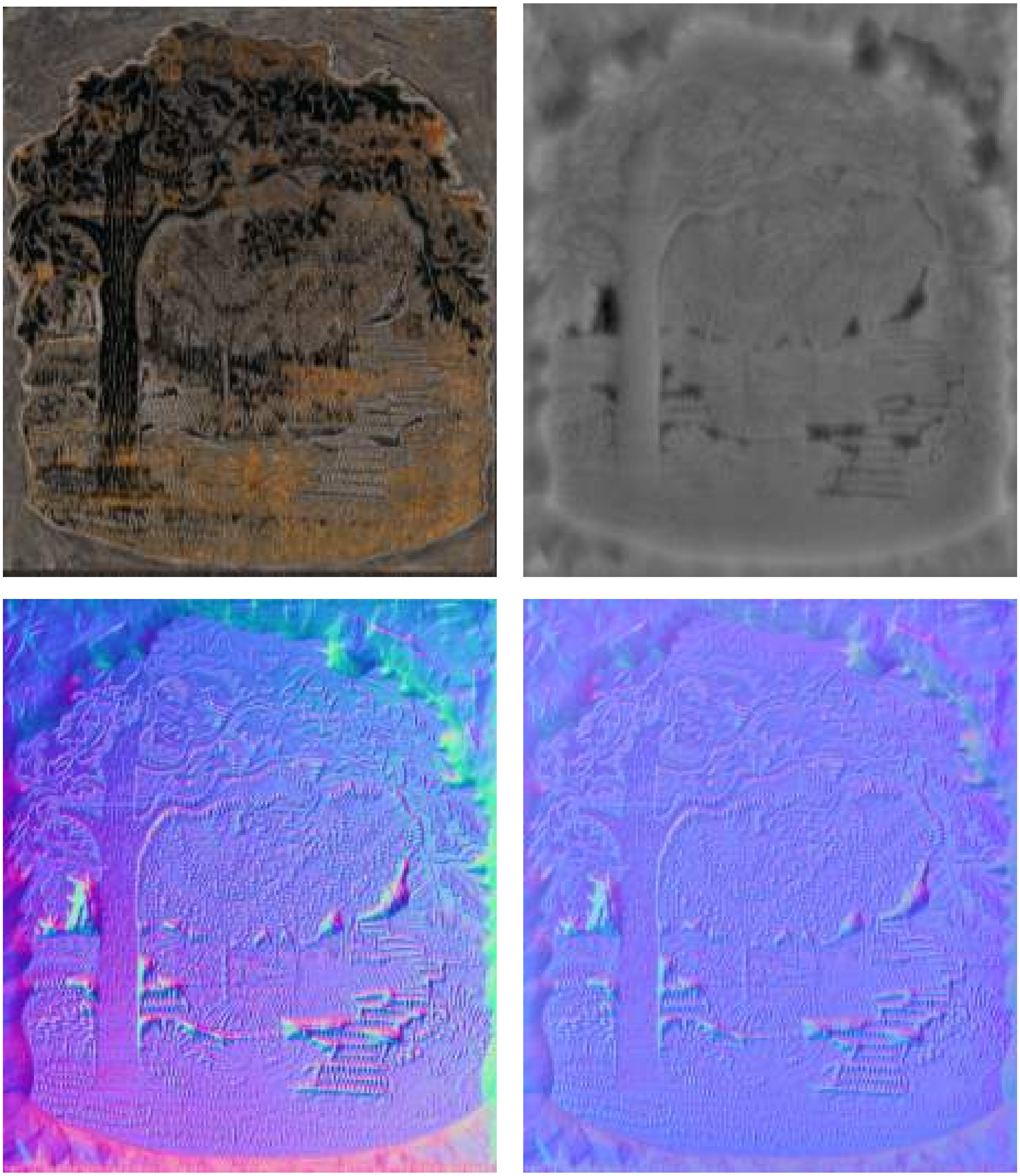


Figure 2: Photometric stereo imaging renders of Helen Ogilvie wood block. Clockwise from top left: albedo, height map, normal map (flat), normal map (original). Notice the fine surface detail, as compared with the photogrammetry model. Images: Thomas Keep and Daniel Bornstein, 2022.

Photometric Stereo

Photometric stereo imaging reconstructs the surface variation of an object by measuring changes in illumination as a light source is moved around a fixed object at a raking angle.[3] Photometric stereo imaging excels at recording fine surface details, but does not produce true three-dimensional meshes, instead generating a series of texture maps capable of procedurally imitating the impact of fine surface details on light sources. It is a good complementary technique to photogrammetry, which is ideal for capturing spatial qualities of real world objects but not well suited to recording micro-details of planar surfaces, such as painted canvas.

Photometric stereo has been found to record much finer low-frequency surface data than photogrammetry, able to pick up micro details of painted surfaces such as brush stroke impasto, craquelure, woodgrain, or the individual fibres of canvas.[4] Each method has notable advantages and shortcomings, and research is only beginning to explore the potential of combining the two methods.[5]

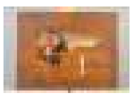
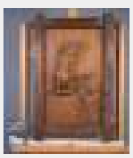
Discussion of selected pieces

The applicability of digitisation methodologies was explored for a variety of media types and geometries, comparing suitability of techniques (or combinations thereof) for different surfaces. In particular, the potential for texture maps derived from photometric stereo imaging to be converted into highly detailed surface displacement models was explored, in view of conversion into 3D mesh files which would allow for fine surface details to be replicated using 3D printing.

Accordingly, eight artefacts were selected from the Miegunyah Collection for imaging and 3D modelling, including: two oil paintings on different substrates (canvas and board); one wooden carving; and five woodcut printing blocks. These artefacts are listed in *Table 1*, overleaf.

[3] Karami, Menna & Remondino 2021, 520.
[4] Hasegawa et al. 2011.
[5] Karami, Menna & Remondino 2021.

Table 1: Selected works digitised and summary of research interests

Work		*Accession #*	*Medium*	*Research interests*
	Melbourne from the Botanical Gardens 1865	2018.0098.000.000	Oil on canvas in gilt frame	Combining photogrammetric modelling of the frame with photometric stereo imaging of the painted canvas Contrasting photometric stereo and photogrammetry model detail of a painted surface
	Clerk of the Course	1996.0022.000.000	Oil on wood panel	Assessing photometric stereo's capacity to image partially painted surfaces
	Cockatoo	1973.0699.000.000	Carved wood	Demonstrating the use of photogrammetric modelling to represent the three dimensionality of cultural materials
	Wood blocks	1973.0402:0406	Carved wood	Contrasting photometric stereo and photogrammetry model detail of a carved surface Generating high resolution 3D print files for the creation of replicas

Results

All works with the exception of *Clerk of the Course* were modelled successfully using structure from motion photogrammetry. *Clerk of the Course,* being oil media on board, was excluded from photogrammetric modelling since only its fine surface details (and not its geometry) were of concern for this research.[6] Similarly, photometric stereo imaging was excepted for the Prenzel cockatoo woodcarving, on account of its geometry (rather than texture on planar surfaces) being of principal interest. Both methods were employed and combined for the oil on canvas (*Melbourne from the Botanical Gardens*) and for the five Helen Ogilvie woodcut printing blocks.

[6] See Figure 4.

Figure 3: Comparison of photogrammetry (above) and photogrammetry with photometric stereo texture maps applied (below). Notice that the lower model responds to simulated light, displaying craquelure and impasto. Images: Thomas Keep and Daniel Bornstein, 2022.

The combination of photogrammetry and photometric stereo used for the *Melbourne from the Botanical Gardens* painting proved to be particularly successful, producing a much higher resolution and more representative digital model than either method alone. The photogrammetric modelling captured the geometry of the frame, but displayed very few of the surface details of the canvas which give the oil painted surface its distinctive character. These surface details were added in Blender 3D modelling software using the normal map texture derived from photometric stereo imaging, producing a notably more textured surface than the photogrammetry model alone. This combination allows for procedural rendering of light interacting with the surface, producing a highly accurate appearance of a real life painting complete with the subtle shadowing caused by the craquelure and canvas fibres.[7] The final asset could be viewed in a contextually emulated setting with indexical accuracy.

The woodcut printing block models demonstrated the capacity of photogrammetric modelling to create 3D digital models which replicate the overall geometry and proportions of an object and achieve a high degree of visual similitude to the physical original, while also demonstrating the inability of photogrammetry to record and represent fine variations in surface detail.[8]

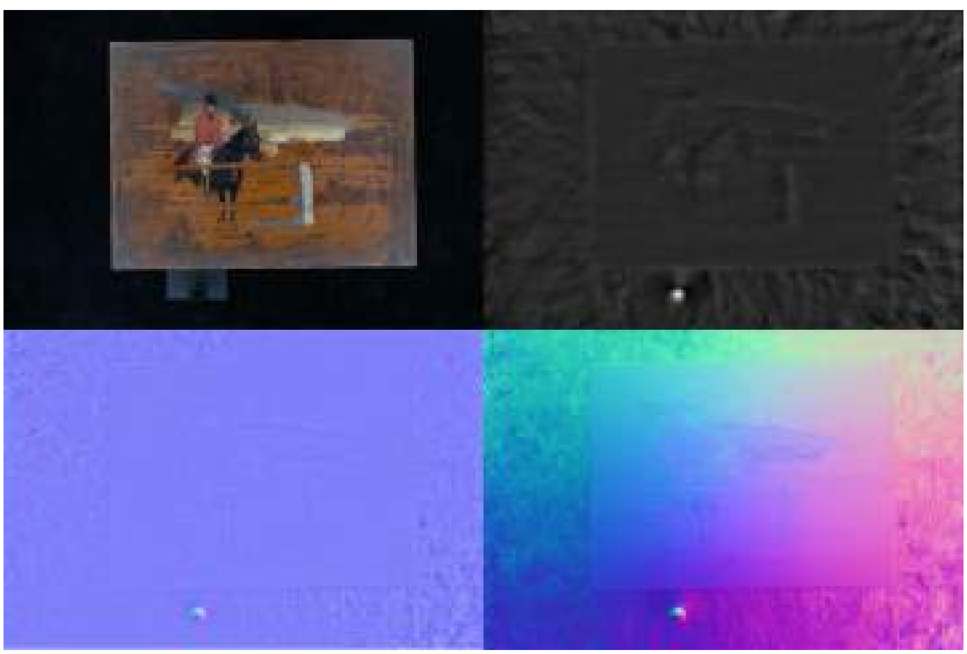


Figure 4: Lambert Clerk of the Course photometric stereo imaging. Clockwise from top left: albedo, height map, normal map (flat), normal map (original)

[7] See Figure 3.
[8] See Figures 1 & 2.

Conclusions and Future potential

While high-resolution imaging has reached maturity in the field of 2D digitisation, 3D imaging techniques remain niche and accessibility of assets remains limited. The workflow explored in this research generates 3D assets with broader applications, bringing standardisation and widespread implementation of 3D imaging closer to reality in an institutional context.

Geometric and textural information was included in the textured mesh assets generated from the combined imaging methodology which would not have been possible to capture using other techniques, considerably improving their documentary value. These assets respond dynamically and accurately to changes in their virtual environment, improving their utility in extended reality applications and enriching possibilities for audience engagement. These techniques also generated assets with sufficient accuracy for facsimile reproduction through computer aided design and manufacturing (CAD/CAM).

References

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