Brief Communication

Reflectance Transformation Imaging and the Cuneiform in Australia and New Zealand Collections Project

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Abstract: The paper assesses the suitability of Reflectance Transformation Imaging (RTI) for the Cuneiform in Australia and New Zealand Collections (CANZ) project. This project will produce a series of monographs, develop an interactive web-site for educational purposes and use various media to publicise the collection. While RTI is a well-established technique, its suitability for the CANZ project has not been assessed. The report discusses examples of images of cuneiform tablets captured using RTI fitters and processing tools.

Introduction

The Cuneiform of Australia and New Zealand (CANZ) project was commenced in early 2013. Phase one of the project is complete (Siddall 2015). It identified the locations and numbers of cuneiform tablets in Australia and New Zealand institutions, established, where possible, the provenance of the tablets and identified the content of their texts. A few hundred tablets were identified. The next phase of the CANZ project will involve cataloguing, imaging and publishing.

Reflectance Transformation Imaging (RTI) is proposed to be one of the imaging methods that will be used. RTI is:

> *a digital [image] acquisition process that captures sets of images of a subject from a single view [point] under varying lighting conditions... reflectance functions are modelled from the captured data, making it possible for the user to interactively relight the subject,* (Palma et al. 2010).

The Australian Institute of Archaeology (AIA) will be the principal place for RTI imaging because of the availability of a large multi-light dome. During 2016 a number of trial images was captured and processed using Cultural Heritage Imaging, (CHI) © software.

The imaging results using the AIA multi-light dome for the smaller cuneiform tablets are presented in this paper, however the larger cuneiform tablets have yet to be imaged using either the dome methodology or Highlight-RTI (H-RTI), which uses a fixed camera position and about 40 flash illuminations at fixed radial positions from the centre of the artefact. Light directions are obtained from specular highlights from a black sphere positioned in the camera's view (Mudge et al. 2006).

RTI technology at the AIA

The RTI technology proposed for the CANZ project will largely use a fully-enclosed dome with a single string of 35 white light emitting diodes, (LEDs), positioned around the dome and fired sequentially. With each illumination the camera is triggered. With appropriate camera settings, sufficient illumination time is allowed for automatic focus, however a pre-set manual focus also appeared to function effectively. The dome was developed by eAustralis Pty. Ltd (Figure 1).

The camera used for the imaging trials was a Canon EOS T4i/650D with an EFS 18-135mm macro-zoom lens. Prime macro-lenses at 100mm, 50mm and 18mm will also be used for the capture of images for the CANZ project.

The space under the dome has been modified to include an internal table, which is movable in the vertical direction. This accommodates some of the thicker cuneiform objects by ensuring that the low angle lights provide the same illumination angles for every object.

The images were processed using one of two 'fitters' or tools that model reflectance from captured image pixel data; viz. the Polynomial Texture Map (PTM) developed by Malzbender et al. (2001) of Hewlett Packard Laboratories and the Hemispherical Harmonics (HSH) developed by Wang et al. (2009) of U. California, Santa Cruz. The advantages and disadvantages of the fitters within the RTI Builder of CHI need not be discussed here but we note that some researchers prefer one methodology over

Figure 1: The multi-light illuminations dome for capturing RTI images at the AIA.

Figure 2: *Images of IA5.074 a tablet from Nimrud, inverted to highlight the seal, dim. 52x35x23. A an original capture; and PTMs, B using AR unsharp masking, and C a composite image rendered using specular enhancement.*

the other for specific imaging tasks. Further trials using both methodologies are planned for the different types of cuneiform tablets in the CANZ collections.

The matte nature of the surfaces of the cuneiform tablets meant that both fitters were applicable. The PTM fitter was developed specifically for matte surfaces while the HSH fitter was developed for the modelling surfaces with significant texture and with glossiness and specularity. The images presented in this paper were those developed using the HP PTM fitter.

Currently the JPEG files produced by the Canon camera were used for the imaging presented in this paper. The processing of camera-RAW to JPEG will be adopted to produce better quality JPEG images for texture mapping (Schroer 2013) and to be consistent with recommended CHI work-flow.

Preliminary imaging

Three artefacts, two cuneiform tablets and the fragment of a clay brick, IA5.074, IA8.505, and IA7.873, were imaged using the current RTI dome system. All 'texture maps' were generated from the CHI RTI Builder Version 2.02 ©.

Both the PTM and HSH fitters were used. The PTM fitter was preferred in this initial work mainly because of the experience gained using the comprehensive rendering tools implemented in the CHI RTI Viewer Version 1.1.0.

Results

Imaging IA5.074

Tablet IA5.074 (Figure 2) was excavated in 1953 from a private house in ancient Kalhu (Nimrud). The tablet documents a loan on security provided by a person who appeared to be a high official in the city in the time of King Ashurbanipal (668-627 BCE). The text was published by D.J. Wiseman (1953: 135-6, 142).

Of particular interest was the imprints of two seals, placed side by side on the obverse of the tablet. These were below three lines of text and a further four lines of text follow below and around the tablet. The text continues on the reverse and includes statements of witness of the loan. These seals were algorithmically rendered using a number of the CHI tools.

Where there is not significant raking light, single images of IA5.074 appear 'flat' with very little detail apparent in the seals themselves Figure 2A. Figure 2B, however, shows un-sharp masking Algorithmic Rendering (AR) applied to IA5.074. This methodology provided a clearer perception of detail, possibly suitable for publication, but colour rendition was not preserved.

Specular enhancement AR is shown in Figure 2C. The Phong-Bling-Torrence reflectance model, (Malzbender et al. 2001), implemented as an AR tool, provided significant improvement in detail of the seals, although colour rendition was not preserved.

The trials have also shown that higher magnification RTI imaging of the seal imprint region is feasible and has the potential to provide significant detail for specific instances in CANZ publications. In the case of the seal on IA5.074, small regions of text distortion were apparent, thus it would appear that the seal was imprinted after the text. Macro-RTI has been demonstrated in published work and will be trialed in future.

Imaging IA8.505

Tablet IA8.505 (Figure 3) was excavated by Leonard Woolley in 1936-39 from ancient Alalakh Level IV (Tell Açana). The tablet lists soldiers and other persons who entered the city on one occasion during the Late Bronze Age *c.* 1,400BC. The text has been published and translated by Wiseman (1953).

The cuneiform signs on this tablet are clear in the photograph. The aim of the RTI trial with this tablet was to achieve detailed and readable text across the obverse and reverse faces.

IA8.505 is a 'flatter' tablet than IA5.074, thus the over-all surface lighting appeared more uniform for the higher angle lighting. Un-sharp masking, Figure 3B, provided clear imaging of the text and detail could be examined using raking lighting.

Specular AR, Figure 3D, provided significant improvement in the perception of detail over un-sharp masking, Figure 3C.

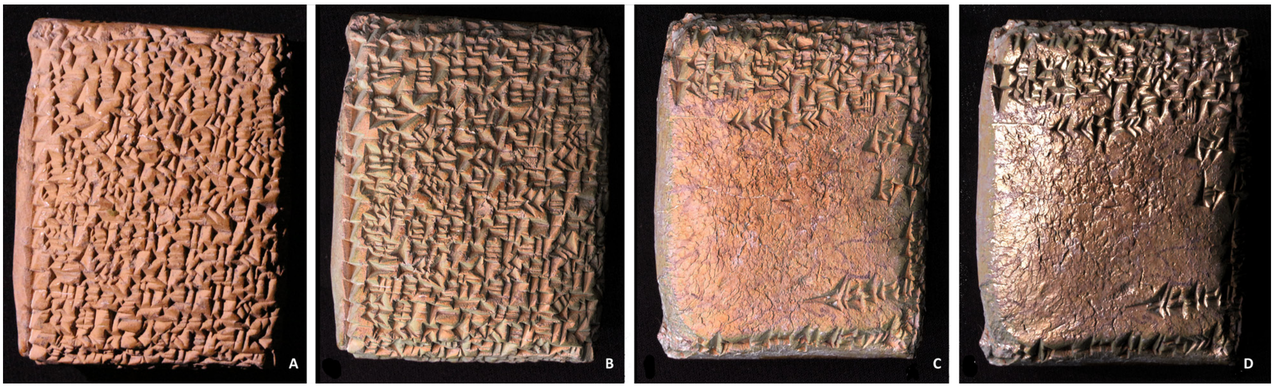

Figure 3: *Images of IA8.505 a tablet from Alalakh dim. 65x50x25. A (Obv) natural light, PTMs with B. (Obv) luminance un-sharp masking rendering C (Rev.) luminance un-sharp masking rendering, and D (Rev.) specular enhancement rendering.*

Imaging IA7.873

Clay brick fragment, IA7.873 (Figure 4), was excavated from the site of ancient Kalhu (Nimrud). The brick has a centrally located 'stamp' that depicts a lion.

This was the largest artefact imaged using the AIA RTI dome. Similar raking light angles to those used for IA5.074 and IA8.505 were achieved by adjusting the z position -50mm.

Figure 4A is one of the original captures of the clay brick and the image appears 'flat'. It is noted that, as with IA5.074 and IA8.505, the use of raking light in the RTI Viewer provided greater perception of detail. This perceptual effect can be seen by comparing Figure 4B, default rendering, and Figure 4C, specular enhancement, with the original capture. AR more acutely renders the details of markings on the brick and clearer 'resolution' of the embossed animal images

Conclusions

Suitability of Images for CANZ publications

The Hewlett Packard PTM and CHI HSH 'fitters' currently available process image files in JPEG format. This file format was chosen in the early development of RTI for cost expediency and for software licencing reasons. A fully 16 bit work-flow may be a future development. This necessitates the preservation of either the camera-RAW or the PNG files, consistent with the CHI work-flow.

The CHI work flow requires that all images be captured in camera-RAW format and, using the proprietary camera manufacturer's software, produce the best quality .JPG renditions of the original images. Colour cards will, therefore, be included in CANZ original image captures (RAW).

The PTM AR tools provided a range of mathematical tools that have been used to 'enhance' the perception of detail in clay tablets with cuneiform texts. Further work is planned using texture maps generated using HSH.

The selection of images for publication will be subject to the editorial decisions of the CANZ project staff. Assuming relevance, acceptable sharpness and representativeness of the cuneiform tablets, the published images will render colour as accurately as possible, based on the accompanying colour cards. AR images, as demonstrated in this work, may also be used for illustrative purposes within the publications and will be supported by sufficient metadata to allow those referring to AR images to know the process used to obtain the AR image.

Figure 4: *Images of a brick fragment IA7.873 dim 165x125x75. A original capture, PTMs with B default rendering and C specular enhancement*

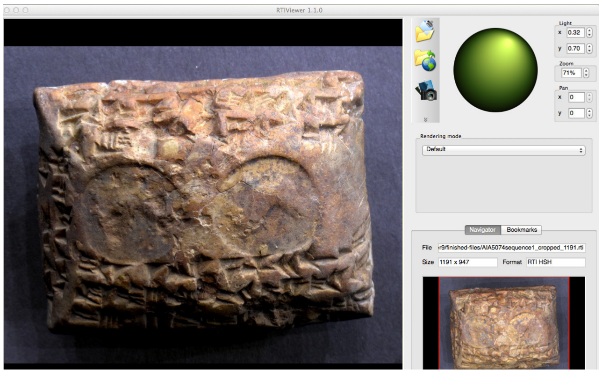

Figure 5: *The RTI Viewer © CHI for interactive relighting of IA5.074, also know as algorithmic rendering.*

The development of the recommended CHI work-flow and archiving system within the AIA imaging capability will be the priority activity for the early stages of the CANZ imaging project in 2017. Imaging for publications will be commenced as soon as the work-flow has been finalised.

Purveying the CANZ Project AR Images

The publication of the CANZ AR images will be those relevant to particular points of discussion as well as more general 'sets' to provide context and comparative images.

The project will also provide the full set of images for each artefact to enable others to study the texts and details of the artefacts themselves, therefore it is proposed that the 'texture maps' developed from AIA imaging will be made available as files that can be Algorithmically Rendered using the CHI Viewer ©. Additionally the AIA's work-flow associated with the image set for each artefact will be made available to those researchers who require such information for their work. A screen capture of the RTI Viewer © CHI is shown in Figure 5.

The advantage of the CHI methodology is that the user may examine captured data from the artefacts as Polynomial Texture Maps (.ptm files) or generated using Hemispherical Harmonics (.rti files) and view using the CHI RTI Viewer. Detailed explanation of the Algorithmic Rendering tools may be found in Malzbender et al. (2001) and Palma et al. (2010).

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