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Retrieving the ancient colours: artistic practice as a tool for heritage reconstruction

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Abstract

The frieze of the Palace of the stuccoes, dated between the 5th and 6th century BC, was a polychrome Maya relief discovered in the 1907 in Yucatán, Mexico. It was documented in watercolours and hand tinted photographs by Adela Breton. After years of exposure to the harsh environmental conditions of the Maya area, the colours and the stucco relief disappeared. The aim of the project is to develop a hybrid digital-analogue printing method for reconstructing the appearance of the original polychrome relief based on digitised hand-made records.

A description of the process to produce full colour images combining digital and photomechanical printing is provided. Using photopolymer plates, an intaglio printing process has been used to produce colour images, whilst inverse relief plates have been created based on height maps to transfer a positive embossing on paper when applying pressure on a printing press. The influence of physical parameters related to the appearance is studied. Reflectance Transformation Imaging was carried out to record the colour and surface shape of the prints. Measurements of gloss were made on relief inkjet prints and intaglio prints on paper to compare the outcomes of commercial 2.5D print and the method proposed here.

By modifying an analogue process with digital technology, it is possible to incorporate ancient materials to the printmaking process and therefore approach naturally the appearance of the original. On the other hand, incorporating imaging techniques and quality measurements enables to improve the quality in analogue printing techniques.

Introduction

The processes and materials for recording and reproducing archaeological findings have evolved since the early 20th century. At that time, hand-made copies and analogue photography were the only ways to reproduce an image. Other processes involved tracing copies over the reliefs or casting moulds from the originals. Even though these recording practices were more invasive that non-contact methods today, based mostly on scanning, photographing and digital processing, the graphic documents left by explorers and artists are valuable sources of information for heritage reconstruction.

Mesoamerica is the name given to the territories occupied by the autonomous native cultures that developed in Mexico, Guatemala, Honduras, and Belize. The landscape of this area is a range of environments from lowland tropics and highland forests to arid plains, where each ancient cultural region developed its own identity and artistic traditions, with colours playing an important role in the worldviews and aesthetics of the ancient inhabitants [1].The cultural tradition of stuccoes and polychromatic murals in central Mexico dates back to Early Classic Teotihuacan (100- 600AD) and continued into the subsequent Epiclassic period in Xochicalco and Cacaxtla (ca. AD. 650–1000) [2]. In the Mayan area, encompassing the territories of southern lands of Mesoamerica, examples of mural painting have been found in Mexico and Guatemala, with dates that range from the late Preclassic to the Postclassic period. Most significant are those from Uaxactun (250 bc–ad 550), Tikal (250 bc–ad 900), Holmul (250 bc–

ad 600), Yaxchilan (ad 300–900), Bonampak (ad 300–900), Dzibilchaltun (300 bc–ad 900), Coba (ad 300–900), and Chichen Itza (ad 900–1000) [3].

In terms of conservation, the Mayan area is specially challenging due to the humid and hot tropical climate. Degradation of excavated archaeological stone structures is caused mainly by wind and water and the rapid wet dry cycles. Damage to the limestone and stucco is accelerated by the chemical and mechanical effects of lichens, mosses, algae, fungi, and bacteria that are endemic to the region [4]. This has often represented a critical hazard for the wall paintings that are not transferred to a protected environment immediately upon their excavation [5].

Chemical characterization of materials via different analytical techniques has allowed a better understanding of the technology and practices involved in the making of polychrome relieves in the Maya lowlands [6]. There are few examples of original polychrome murals that have been partially preserved and that are a priceless source of information such as the Bonampak murals. Some ancient relieves have been reconstructed using modern cements such as the case of the full colour reconstruction of the Rosalila Temple exhibited at the Copan Sculpture Museum [1]. The strategy of the reburial of modelled and painted lime plaster facades, in conjunction with the construction of exposed replica facades overlying the reburied originals, has been or is being considered as a preservation strategy at a number of sites in the Mayan region [7].

At present, buildings in the Maya region are recorded using 3D scanning and photography. These methods are useful tools for the collection of information for future reference or reconstruction projects. Virtual reconstructions offer the possibility to disseminate an overview of the heritage worldwide. The mesh and colour information collected via 3D scanning [5], photogrammetry and reflectance transformation imaging (RTI) can be presented in a virtual format or processed into printed replicas.

In the beginning of the 20th century, American and European archaeologists started to focus their attention towards Mesoamerican ruins [3]. With the technology available at the time, they captured what they saw in the ancient temples and buildings before these were dismantled or naturally erased. Even though the technology for recording colour and surface structure was limited to analogue photography, tracing and painting, today's tools for image rendering allow to digitally or materially reconstruct the appearance of the ancient images based on the records made by the earliest explorers. One

example is the 360° render of the 'Temple of the Warriors' of Chichen Itza, generated by the Bristol City Museum based on the drawings by Adela Breton in 1907 [9]. Another approach for disseminating the visual heritage, that might be situated in the middle of the replication and the virtual display, consists in replicating the appearance in terms of colour, texture, relief and all relevant aspects that provide a haptic view similar to viewing an original.

In 1906 residents of Acancéh, Yucatan, a town 25 km southeast of Merida, were dismantling an ancient structure for building material when they uncovered a 2 m high wall decorated with brightly painted stucco reliefs that later was called the Palace of Stuccoes. It was a 13 m long surface, protected by a coat of whitewash and the rubble of later buildings, displayed two rows of animal, bird, and human figures modelled in relief and contained within twenty-one overlapping cartouches. The scene was framed at either end by large stucco birds and above and below by decorative mouldings [10].

For a substantial time, the pre-colonial buildings of that site had been purposed as a quarry to erect the modern town of Acancéh and because of the ongoing activity the stucco frieze became exposed in 1906. In 1907 Adela Breton was already in Yucatán, when the news of the discovery of mural paintings on the stucco façade at Acancéh reached her [11]. Adela Breton travelled to the newly discovered site and spent 5 weeks in 1907 copying the frieze of the Palace of the Stucco [12]. She traced it on drafting linen, also known as drafting cloth. This material was used for technical drawings from the end of the 19th century until the middle of the 20th century and is highly starched and calendared cotton or linen fiber. In 1908 Adela Breton published a short article in which she presented the watercolour reproductions she had made of the building wall paintings. Adela proceeded to identify each of the motifs and characters that make up the frieze, but she did not venture to propose any interpretation, hoping that subsequent excavations would reveal other portions of the frieze on the remaining facades of the building. Her watercolours remained unpublished in the City of Bristol Museum, England until 1991, the year in which Virginia

E. Miller published them in their entirety together with his iconographic interpretation of both the frieze and of the wall paintings [10]. In 1907, Edouard Seler visited Acancéh too and documented the frieze in the state it was found in, using an ink drawing and photographs by Wilhelm von den Steinen. In 2000, Wolfgang Voss N et al presented a comprehensive report to the "Proyecto Arqueológico Acancéh" directed by the National Institute of Anthropology and History where they explain what is known so far about the symbolism linked to the characters depicted in the frieze [13].

Figure 1. *a) watercolour by Adela Breton, panels 6 to 11 of the Acancéh frieze. b) surviving part of the frieze, photo taken by Sue Giles in 2019.*

Image a) shown in Figure 1 is part of her 2.76 x 1.19 m watercolour of a section of the Acancéh frieze showing panels 6 to 11. Shortly after its creation the stucco relief was covered by cut stone mosaic and its brilliant colours were therefore preserved until its discovery. Unfortunately, the fragile stucco did not survive its discovery for long. From the twenty-four figures depicted, only remains of four still exist [11]. The colour has gone completely. Image b) in Figure 1 shows one of the 4 remaining figures in its present state of preservation. According to [13] the characters in the image are the mythic bath Camazotz' (cfr. Popol Vuh), a howler monkey, a macaw, and a rattlesnake.

It is said that Breton was interested in reproducing the images and colours accurately and that she accomplished this goal as much as possible. She understood the influence of surface structure on the appearance of the relief and was therefore unhappy with photographic recordings [11] The real size watercolours are a unique example of how observation and artistic skill can support scientific documentation practices.

The goal of this project is to implement intaglio and relief printing methods, aided by digital technologies, in the reconstruction of the appearance of an original ancient Maya relief. The images and colour references are graphic registers made by Adela Breton when the polychrome relief still existed.

The hues chosen for the prints are based on Breton's work but the overall target is to approach the appearance of other ancient reliefs in Mesoamerica outside of the Maya area that have been better preserved, such as stucco murals from Teotihuacan, considering that the Acanceh artistic style was influenced by this culture from the centre of Mexico.

Printing methods

The first set of experiments consisted in using hybrid analogue-digital intaglio and relief printing methods for generating embossed prints on paper. High resolution image files of Adela Breton's watercolours from the Palace of Stuccoes were provided by Bristol City Museum. Colour separated positives were made for photogravure and negatives for relief printing. A height map of the surface structure was designed to create printing plates for transferring an embossing onto the paper by applying pressure.

Polymer Photogravure is the intaglio printing process whereby a UV curable printing plate is grained, via exposure to UV light under a stochastic screen, and then re-exposed under a positive film carrying image information in a grayscale. The screen provides the halftone dot by generating dimples in the plate which are close under the transparent parts of the positives and stay open under their opaque parts. The colour separation was made by halftoning in CMY process and by spot colour separation in Photoshop software. Both sets of colour separations were printed in grayscale on transparent film via inkjet and these were used to mask the photopolymer flexographic plate, thus controlling the intensity of the light reaching the surface. In photogravure printing, when the photopolymer plate is exposed to UV light under the screen, part of the surface is hardened and stochastic dimples remain uncured. These are the cavities that will hold the ink and realise it onto the printing medium when pressure is applied. In the second exposure made under the positive film, the darker areas which correspond to more saturation, will prevent the light to cure the dimples. On the other hand, under the more transparent areas, which correspond to a lower saturation in the film, the

light will cure the dimples according to the grayscale values. After the second exposure the photopolymer plate is washed off and dried. The result will be a printing plate with a distribution of craters with variable depth. The depth will determine the amount of ink transferred to the paper when printing and, therefore, will be related to the saturation of a certain hue in the halftone print.

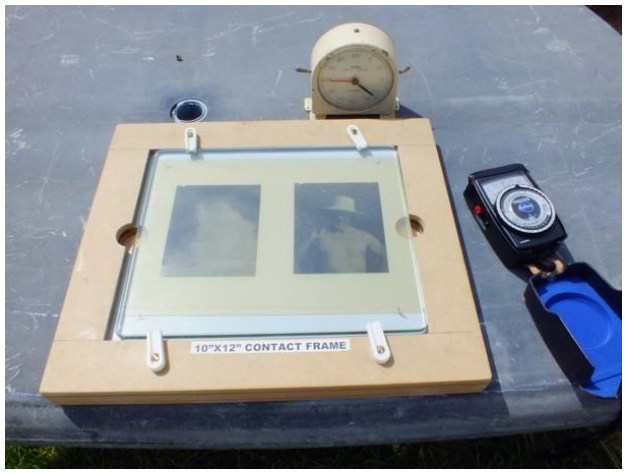

Figure 2. *Photopolymer plate with transparent positive film in a contact frame.*

The printing plates were made from Toyobo Printight KF95 plates size A4. These plates consist of a photosensitive polymer film mounted on a transparent polyester film. The KF95 has a maximal relief depth of 0.65 mm. The plate cures when exposed to light between 300 and 400 nm [15]. Due to current limitations and access to equipment under lockdown we used the UV fraction of sunlight as our UV source. The plates were exposed between 12:00 and 14:00 BST to exploit the maximum UV index and keep exposure times manageable. Photogravure plates were made by first exposing the photosensitive film through the so- called screen for 45 sec with a UV intensity of about 5 mW/cm^2 followed by 80 sec exposure through each of the greyscale films corresponding to the digital separation of the image according to the cyan, magenta and yellow content (see Figure 2). The plate was then developed by washing it in water at 20°C with a sponge for 3 min. Once dried, the plate was hardened for another 15 min under sunlight.

The plate for embossing is a photopolymer with a variable depth that corresponds to the height information of a surface. A height map is a grayscale image where depth information of a surface is registered as opacity values going from (zero) white to black (one). Here, the clearest areas represent the lowest height and the darker correspond to the higher areas. For this work we purpose a height map that resemble the relief that the original stucco relief could have had. Based on a greyscale version of figure 1a) a height map has been created and printed via inkjet onto a transparent film. The height map printed on film is then used to mask a photopolymer plate, so the surface is cured according to the grayscale. The variable opacity of the film then regulates how the photopolymer hardens, creating variable depth when the plate is washed off. When applying pressure upon the plate and the paper, a positive relief or surface structure is created in the final print. This is only a first approximation to generate the appearance of the frieze. An approach truer to the accurate representation of the height profile of the artefact would require 3D scanning or photogrammetry. Recording of the original intact frieze and/or similar friezes from the same time period and executed in the same technique was planned for 2020 but this had to be postponed due to travel restrictions caused by Covid-19.

Relief colour plates are made by curing a photopolymer flexographic plate under a film carrying the colour separation information in a negative grayscale. In the resulting plate, the highest parts hold the ink, so they are the lightest part in the negative. To create embossing plates, from digital height maps according to the Acanceh frieze, the procedure in Photoshop was as follows: from the digital image in black and white mode a height map was generated through the function *generate bump*, assuming the higher parts were highlighted and making the background darker manually for simplicity. The height map was then saved as a grayscale image, where the higher areas appear clearer. The background will appear black as it is the lowest area. Then the image was inverted. In the negative, the higher areas will appear darker and vice versa. Finally, the image was printed on transparent film via inkjet. For embossing plates, the photopolymer plate was placed face down. The darker areas (higher in the original height map) will harden less than the lighter areas. Then the photopolymer plate was washed to remove the non-cured areas. The image has become a polymer relief. When applying pressure with the printing press, the relief is transferred to the paper as embossing.

To generate the appearance of the relief in a print, we chose the following three combinations of impact printing methods.

- Photogravure with process colours and a relief plate for the embossing.
- Photogravure with spot colours and a relief plate for the embossing.
- Relief plates with spot colours.

The plates were inked and printed following traditional hand printing methods. For photogravure, linseed oil-based etching inks were applied generously and wiped off with a piece of cotton muslin, until the image was visible and clear. The plate was then mounted on a Polymetal HPV 60 printing press, damp paper aligned with the plate and the plate/paper sandwich was compressed between the two rollers of the press. Since the printing plates were transparent, the three colour prints could be aligned by eye. Alternatively, pin registration could be used, that is aligning the plates to each other and aligning the paper with the plates by using a pin and tab system. The print was then dried. For the embossing, the print was dampened again and then put through the press on the ink free embossing relief. The relief can be embossed straight after the colour printing, but the disadvantage is that too much ink is then transferred from the fresh print onto the embossing plate, resulting in a loss of hue. This effect nonetheless can be used for colour transfer.

Printing spot colour with relief plates does not require an embossing step since the relief of the different plates is embossed during the printing process. The disadvantage of this approach is a negative relief in the print. Figure 3 demonstrates the subtle difference when the embossed relief is added to the print. Now the print conveys the appearance of a frieze.

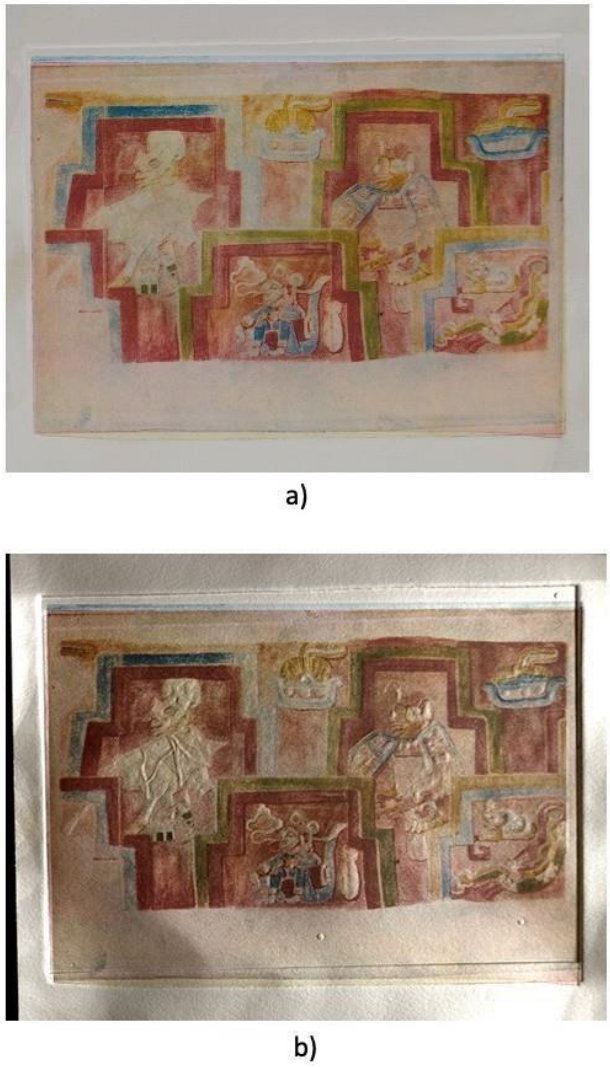

Figure 3. *a) CMY print, b) CMY print with relief.*

Reflectance Transformation Imaging of the prints

To understand the relief produced with our method, the prints were captured with the highlight based RTI method described in [17].

Reflectance Transformation Imaging is a technique that captures the surface shape and colour of opaque materials at per pixel level using traditional photographic techniques [16]. RTI images are produced by photographing an object several times from a fixed position but illuminating it from multiple angles. Ideally, to obtain a good surface reconstruction the light source is kept at a constant distance using a string or a laser meter and the object is sampled at multiple angles creating a virtual hemisphere around the object. An extendable monopod can be used to position the light at different repetitive heights.

The prints were placed on a flat table. A black reflective sphere positioned next to the print and within the field of view of the camera was used to calculate the positions of the light. The camera used was a Fujifilm X-T10 digital camera with a

MP APS-C sensor fitted with a 50mm lens providing a 35mm equivalent focal length. This was attached to a tripod and positioned perpendicular to the surface of the print. The light source used was a handheld flashlight (Power Flash PR400).

The various sequences of images were captured in a darken room. About forty-five images from different angles and positions were shot for each print. Images with harsh shadows caused by the tripod were discarded as they can affect the surface normal reconstruction. The images were registered before processing to improve the alignment of the sequence as small movements of the camera or the tripod during the capture session can translate into blurry RTI images and hence, inaccurate surface normals. The alignment was done with the Fiji's plugin Linear stack alignment with SIFT [18] with subpixel accuracy. Processing was done with the open- access software developed by Cultural Heritage Imaging [19].

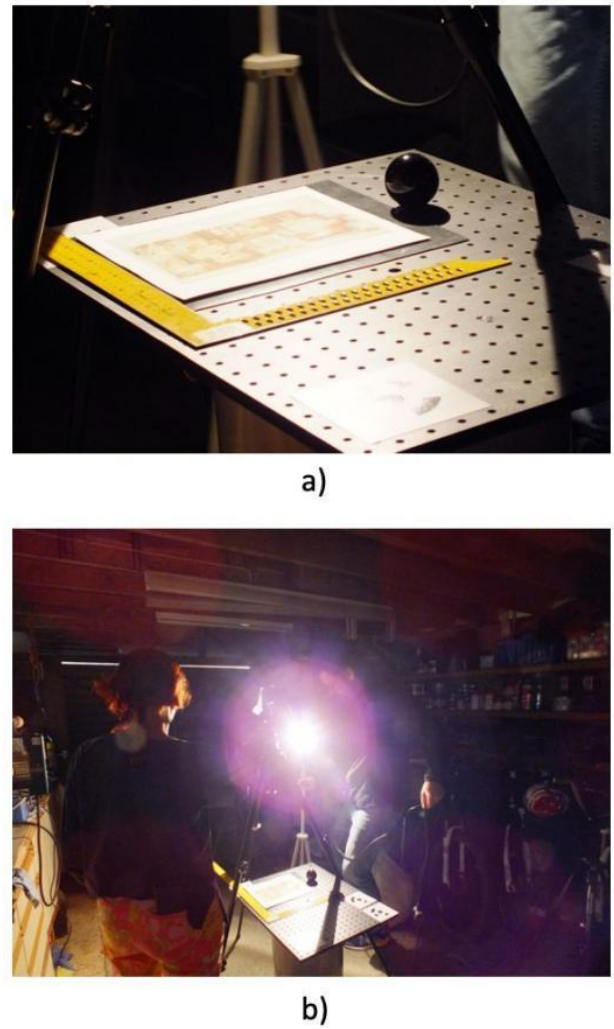

Figure 4. *a) arrangement of the print and the black reflective sphere. b) snapshot of RTI recording.*

Preliminary results

Test prints have been made in drafting linen, two types of paper, and plaster. Process inks, intaglio inks, and iron oxide-based inks have been used. Maya blue pigment is being investigated in a parallel project. A study of colour was made by using different colour sets, for instance:

- Halftoning: printing with cyan, magenta and yellow process inks
- Spot colour separation: printing with commercial inks
- Spot colour separation: mixed inks

- Halftoning: printing with cyan, red oxide and yellow ochre, substituting magenta and yellow respectively.

Figure 5. *CMY + relief transfer on plaster*

It was observed that if the embossing is applied just after printing the colours, then the relief plate collects colours from the paper. The result is a relief plate that has ink as well. This effect was exploited to transfer colour information and relief at the same time onto damp paper and plaster. For making a coloured relief on plaster, the plate with relief and colour was used as the base for a cast block, and then the block acquired colour and relief while drying (Fig. 5). The maximum relief height that is possible to obtain is .65 mm. It will be possible to measure it properly with a profilometer or confocal microscope once access to equipment resumes. It should also be possible to use higher plates.

Even though the resulting relief is not proportional to the original relief, it allowed testing and assessing the printing method. A better approximation between the height maps and the original surface relief will be addressed later in the project. As the drafting linen is not commercially available anymore, new linen samples were prepared by the authors. We starched, dried and ironed pieces of linen and applied two layers of acrylic gesso on it. For printing we tested printing on damp and dry drafting linen, and best results were obtained with the latter.

Figure 6. *Photogravure on drafting linen, halftoning process.*

Gloss measurements

Measurements of gloss were performed on prints made on paper using intaglio inks and samples produced with a flatbet inkjet 2.5D Arizona Canon printer, using the same height map to produce surface structure. Gloss measurements were made with a Canon surface reflectance analyser RA532H, according to the standard ISO 2813 for the standard geometries 20° for high gloss, 40° for semi-gloss and low gloss 85°. The results shown in Figure 7 demonstrate a difference in gloss between the different areas within the same kind of print, and between a surface made of UV curable ink and a surface obtained from an intaglio print on paper. It is observed that the gloss of inkjet made surfaces is considerably higher except for the measurements made at 20 degrees angles. The results show that the appearance of the 2.5D prints produced with this hybrid technique on paper are more mate than the ones produced via 2.5D inkjet printing.

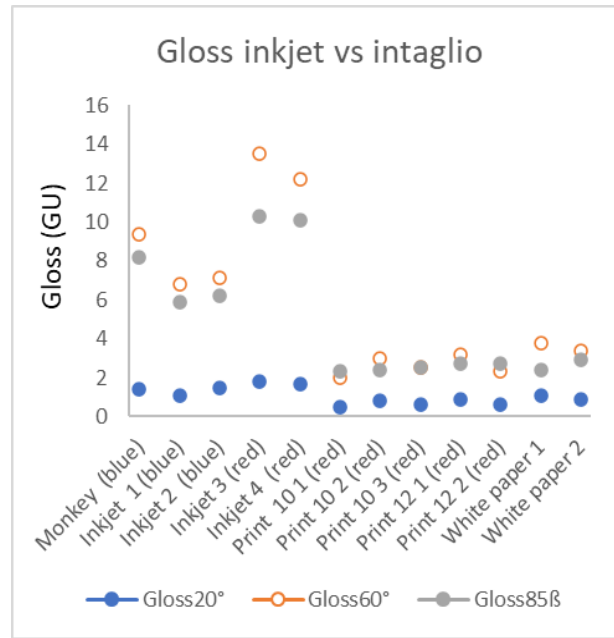

Figure 7. *Gloss measurements of 2.5D prints made by inkjet and intaglio printing.*

Conclusions

In this project we aimed to combine Adela's artistic gaze with present-day technology in order to retrieve elements of the art from the Americas. The difference of the 2.5D printing method here proposed, to a two-dimensional photograph or drawing is that haptic qualities can be captured and moving shadows under different illuminations are made possible. We have generated prints while testing different methods and materials to generate colour and surface structure. We have obtained positive results in transferring colour and surface structure in a single application and we are expanding the range of materials to print on. The reconstruction of the appearance of the Maya frieze of the Palace of the Stuccoes in Acancéh Yucatán is a test case to establish a new tool for the preservation, reconstruction and dissemination of archaeological artefacts. Steps are being carried out to develop quantitative control measurements related to appearance, one of them is the measure and control of gloss. The appearance of the

2.5D prints we have produced on paper is more mate than 2.5D inkjet printing which might make them an alternative for printing applications where this feature is critical, such as fine arts or heritage representations.

Future work includes the creation of colour profiles for the printing methods using a colorimeter and/or spectrometer. Authentic wall paintings and reliefs and embossed prints will be recorded with RTI and photogrammetry. Comparisons with existing reliefs of Mexico will be made when it is possible to travel. Three prints were already recorded with RTI to document and gain qualitative feedback on the relief generated via embossing.

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Author Biography

Abigail Trujillo-Vazquez, is a research associate at the Centre for Fine Print Research and part of the Appearance Printing European Advance Research School (ApPEARS). She has a background in Physics and Art History, focused in optics and spectroscopy, Mesoamerican art and ceramics. In her PhD studies in Art and Design at the University of the West of England she is working on the development of printing methods and materials for recreating the material appearance of ancient art.

Susanne Klein is a physicist by training and has lived and worked in the UK since 1995, first as a Royal Society Research Associate at the University of Bristol, and then as a Senior Research Scientist at Hewlett Packard Labs Bristol. She has been appointed an EPSRC Manufacturing Fellowship at the Centre for Fine Print Research starting January 2018. She is working on the reinvention of old printing technologies, such as Woodburytype and Lippmann photograph.

Xavier Aure is a Research Fellow at the Centre for Fine Print Research. His background is in conservation of paintings and decorative historic interiors. His PhD research investigated the use and applications of 2.5D and 3D technologies applied to the study, documentation and presentation of paintings. Currently, he is working on the development of affordable custom scanning systems to record surface texture information and material appearance for cultural heritage applications.

Carinna Parraman's understanding of 2.5D printing has evolved through her training in in fine art print-making. She is Professor of Design Colour and Printing and Director at the Centre for Fine Print Research, and has in-depth knowledge of traditional colour mixing, colour printing and photomechanical printing processes. She collaborates with many different sectors including industry, heritage and fine-art print.