ROMAN COINS

Proposal for an Exploratory Case Study in 3D Spatial and Spectral Documentation of Material Cultural Heritage

1. Title of the proposed case study: STUDY OF ROMAN SILVER COINS USING SPECTROSCOPIC AND 3D IMAGING APPROACHES
2. Duration/dates: 2014-2016
3. Description and image of the subject (object/site), its significance and suitability for the proposed case study:

Two ancient Roman silver denarii portraying Empress Faustina I, wife of Antoninus Pius, believed to be posthumous deification issues of 141 A.D. The results from the proposed study will allow determining if the methodology can be applied to a larger group of coins in order to discriminate between original and forgeries. The two coins have been specifically chosen in order to establish whether the proposed recording methods can support the comparison of features and properties. The use of other coins will be considered if and when appropriate. Two further silver denarii are available, namely: (1) Emperor Vespasian, c.70 A.D., and (2) Republican Roma, c.120 B.C.

The coins are owned by the proposers. They are offered for the purposes of the proposed examination and possible publication of the results without restriction.

4. The rationale for and the purpose of proposed case study:

The purpose of the proposed study is to apply a number of 3D techniques to record silver coins, compare and evaluate the results; to test possible techniques for 3D visualisation and presentation of multimodal results with meta- and paradata.

At this stage the proposers are uncertain whether the coins are genuine or forgeries. The coins raise many interesting questions concerning their provenance, authenticity, design and iconography, purpose of issue and historic usage. The silver coins (diam. between 17,5 and 20 millimetre) also pose a considerable recording challenge due to particular material and surface properties, some of which may not be original but a result of extensive cleaning. To what extent can the proposed technical examination and 3D recording meet such complex research needs?

Applications of specialist 3D recording techniques to documentation and study of numismatic objects are not as widely adopted as in other areas of cultural heritage.
Numismatic collections continue to rely on traditional documentation and dissemination methods. Museum records and publications rely predominantly on 2D photography, see for example the British Museum online record of a fake Roman denarius (Accession No. 2000,0804.5)
https://www.britishmuseum.org/research/collection_online/collection_object_details.aspx?searchText=denarius&ILINK|34484,|assetId=661907&objectId=1513211&partId=1 Such visual representations are not accurate records in terms of 3D dimensional analysis and spectroscopic information.

By conducting the proposed case study we expect to:

- offer a critical review of current standards in documentation of historic coins in selected collections and assess current use of 3D imaging and recording techniques of historic coins;
- gain a better understanding of applications of select digital recording techniques (structured-light, RTI, structure from motion);
- understand better the surface characteristics of historic coins (topology, chemical and other characteristics);
- investigate the influence of directional reflectance (BRDF) in the appearance of heritage metallic surfaces, and how this may be estimated from multi-illumination image sets;
- analyse the advantages to be gained over conventional trichromatic (R,G,B) colour imaging by multispectral image capture, with four or more channels in narrow wavebands (both visible and near infrared spectrum);
- describe functions of the software, that should be created for end-users (possibility to perform the metric measurements of the object, cross sections, compare the shape of two or more coins from the same type etc.)

- offer examples and explanation of 3D techniques that may be adopted as standard in museum documentation of numismatic objects, replacing - where appropriate - photographs and screenshots that are typical publication formats;
- explore the feasibility of adopting the RTI image format as an archival data representation for coins in museum collections;
- articulate numismatic, scientific, technical and other questions that may be answered by the proposed study;
- produce guidelines to good documentation practice;
- contribute to the relevant digital preservation guidelines.

5. Contribution to the objectives of a particular COSCH Working Group, or Groups, and generally, to the COSCH Knowledge Representation schema:

- WG1. Identification and documentation of surface features such as thin plating or corrosion layers, which may typically be found in Roman coins. Surface mapping using X-ray fluorescence spectroscopy to complement the 3D documentation data. Surface reflectance in the visible and near infrared spectrum at different angles of incidence and reflection, to identify features characteristic of metallic composition and corrosion.
- WG2: Comparative measurements (two or more techniques applied to a single CH object); Examples and use cases supporting the COSCH Knowledge Representation schema under development; Multimodal measurements; Assessment of the techniques.
- WG3: multimodal data integration into single representation; compare the effects of the shape measurements (conducted by the same technique) of two or more coins
- WG4: Comparison by conservation professionals of spatial and/or spectral techniques and limits of their use on a series of CH objects; possibility to detect compounds which are responsible for coins corrosion
- WG5. Visualisation and dissemination: the creation, presentation and use of numismatic 3D records. How does the multi-light RTI representation compare to true 3D for rendering and visualisation?
- COSCH Knowledge Representation: the questions raised by this case study and data collected in the course of recording and analysis will be submitted to the COSCH KR App and are expected to inform its design and content. The questionnaires prepared by WGs 2, 4 and 5 will be used.

6. Target users and their needs:

The proposed case study will examine whether the following groups of users may be helped with finding answers to questions such as:

- Numismatic researchers, historians, coin collectors and dealers: What can be learned about the object from its 3D record? Can RTI and 3D records be used for comparison of coins' size/design/iconography? What would be the benefit of creating a database of

coin collections inclusive of precise 3D measurements (to, for example, extend the scope of scientific investigations)?

- Museum documentation specialists: How can RTI and 3D records be incorporated into standard Collection Management Systems and online catalogues, e-resources and publications?
- Conservators: Can 3D records of coins be used for identification of specific properties, authentication, condition monitoring etc.? Can 3D records be used as a proof of an authenticity in case of long term loan (risk management)?
- Educators, general public: What is the value of virtual coins for these groups of users? How should such virtual artefacts be presented to be useful? Can mobile phones and tablets be used to show convincing virtual surrogates of coins from RTI and/or 3D representations? What is the best way to handle specular highlights?

7. Proposer:

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8. Other collaborators:

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- Krzysztof Lech, PhD candidate, Institute of Micromechanics and Photonics, Faculty of Mechatronics, Warsaw University of Technology will apply for a COSCH STSM. Other researchers and a user group will be determined in due course.

N.B. Formal letters of intent, if required, will be submitted in due course.

9. Description, techniques and schedule of the work to be carried out:

Preliminary tests have been carried out in Warsaw at TU and Wilanów Palace, and at Breuckmann GmbH. The tests using 3D structured light scanning technology have exposed problems to do with the shiny surface of the coins.
Research into current documentation methods, techniques and standards has been initiated and will continue concurrently with the proposed technical work.

Robert Sitnik (WUT) will investigate structured light and structure from motion techniques. Due to high reflectivity of the surface we will try to investigate limits of light diffusion techniques and influence of this parameter on measured geometry accuracy.

Additionally we develop web-based player (using WebGL technology) for multimodal presentation of the results.

Julio del Hoyo Melendez is currently conducting XRF analysis on a group of Roman coins. These are point analyses and they provide information about the chemical composition at the surface of the coins. This is one of the limitations of the technique (depth of penetration). His colleagues at the National Museum are responsible for the hyperspectral imaging (relevant to COSCH WG 1) system. Possible collaboration will be considered.

Lindsay MacDonald will capture sets of 64 images of each face of each coin in the UCL Dome, using a Nikon D200 camera with 200mm macro lens, giving a surface resolution in excess of 60 pixels per mm. RTI representations will be generated and the specularity of the surface of each coin compared. One of the key issues is that of dynamic range in the images, because specular highlights from polished metal may have intensities in excess of 1000 times those of the surface at off-specular angles. Some investigation will be made of the use of multiple exposures, or 'bracketed' image sets, to construct high-dynamic range (HDR) representations that will preserve the full intensity range of the highlights and surface sheen. Another issue is that of spatial resolution, i.e. how finely the surface needs to be digitised in order to capture all man-made information added to the substrate through moulding, stamping, engraving, etc. This can be critical for paleography and detection of counterfeits, as well as for 3D printing of replicas.

Based on the 3D scanning data captured, we will consider whether a 3D print of coins can be used in museum displays, for example, to show the reverse of the rare coins.

10. Description of the main results expected, explaining potential benefits for users and how their needs are likely to be attended and solved:

- Evaluation of potential benefits of using spatial and spectral techniques in documentation of historic coins.
- Chemical imaging through the use of X-ray fluorescence spectrometry maps, which give information about the location and concentration of the main elements present. This

information can be correlated with 3D documentation if one wants to accurately study the composition of coins in terms of their provenance and their minting processes.
- Evaluation of structured light and structure from motion techniques in respect to surface properties (reflective vs diffuse surfaces).
- WebGL based player for 3D multimodal data presentation.
- Discussion of effective and sustainable methods for presenting virtual coins and preparing a description of a software for the end user that should be created in the future.
- Establishing the optimal sampling density of the 3D measurements for the documentation and scientific research (in comparison to the resolution applied in different documentation techniques).
- A guide to 'How to document coins in 3D', results permitting.
- Presentations and COSCH publication summarising the findings of the proposed case study.
- Presenting to and discussing our work with interdisciplinary specialists (archeologists, numismatists, art historians, art conservators) should encourage a wider use of modern measurement techniques in scientific examination.

11. Review of earlier relevant research, projects and literature:

There is a considerable body of literature and guidance on specialist survey techniques (such as 'Metric Survey Specifications for Cultural Heritage',' 3D Laser Scanning for Heritage' and other textbooks published by English Heritage) that can offer a model for producing guidelines for recording coins, but the specialist publications in this area are scarce. There is also a body of about 100 publications over the past 14 years on Polynomial Texture Mapping (PTM) and Reflectance Transform Imaging (RTI), describing the underlying imaging technology and applications in many cultural heritage fields.

Compiling a bibliography will be a task of the proposed case study. A preliminary list includes:

Mark Mudge, Jean-Pierre Voutaz, Carla Schroer, and Marlin Lum, 2005, Reflection Transformation Imaging and Virtual Representations of Coins from the Hospice of the Grand St. Bernard, in 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST, Greece. "This paper can be downloaded for free from the cultural heritage imaging website."

Eleni Kotoula and Maria Kyranoudi, "Study of Ancient Greek and Roman coins using Reflectance Transformation Imaging", *e-conservation magazine* 25 (2013) pp. 74-88, available at http://www.e-conservationline.com/content/view/1101

Jens Hedrich, Dietrich Paulus, Hendrik Mäkeler and Ewert Bengtsson: Image-Based Comparison of Pre-modern Coins and Medals, in: Karl-Heinz Franke and Rico Nestler (eds.): 16. Workshop Farbbildverarbeitung. 7.-8. Oktober 2010, Ilmenau 2010, pp. 156-169, see also Jens Hedrich: Image-Based Comparison of Pre-modern Coins and Medals (video)

Lindsay MacDonald: Colour and Directionality in Surface Reflectance, Proc. Conf. on Artificial Intelligence and the Simulation of Behaviour (AISB'50), London April 2014. Available at: http://doc.gold.ac.uk/aisb50/AISB50-S20/aisb50-S20-macdonald-paper.pdf

We have also started assembling examples of current documentation practice in museums and numismatic records, both paper and electronic.

12. Potential interdisciplinary value of research carried out and any other comments:

In addition to the potential benefits described above, the proposed research can potentially reveal hidden information (not detectable with the naked eye) about the coins through the use of various imaging techniques. The results may offer a way of correlating the chemical data with the information contained in the digital images.

13. Detailed schedule of proposed work with explanation how each phase is to be funded.

Unless stated otherwise, the work will be embedded in the proposers' daily jobs or conducted in their own time.

- Sept-Dec 2014 Preliminary research, review of earlier projects and literature, a pilot study.
- Jan-Mar 2015 independent investigation and recording of coins in 4 labs (Brueckmann, UCL, WUT, NMK). We will be applying for COSCH STSMs for ESRs to support the work through visits to collaborating labs.
- Apr-Jun 2015 Comparison and discussion of results. We will propose COSCH Task Force meetings dedicated (partly or wholly) to the discussion of the work. Repetition of some measurements following the discussion.
- Jul-Dec 2015 Design and development of a 3D viewer, concurrently with user tests and evaluation.
- Preparation of presentations, publications, incl. the proposed guide, and the final report to be submitted to COSCH by 31 July 2016.

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