Journal of Archaeological Science: Reports 6 (2016) 35–41

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

The use of computed tomography for the study of archaeological coins

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ARTICLE INFO

Article history:
Received 27 July 2015
Received in revised form 17 December 2015
Accepted 11 January 2016
Available online xxxx

Keywords:
Roman
Coin hoard
Computed tomography
3D imaging

ABSTRACT

Computed tomography enables non-destructive three-dimensional densitometric information of the internal structure and external geometry of many archaeological artefacts to be acquired. This paper uses work completed by the μ-VIS X-ray Imaging Centre at the University of Southampton to illustrate how computed tomography can be used to accurately record surface and sub-surface data of intact coin hoards contained within pots. An examination of coin placement, coin identification and segmentation and extraction of individual coins for use within a virtual environment are presented. Computed tomography used in this way will enable numismatists to identify otherwise hidden coins, and to visualise, share and archive coin data.

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1. Introduction

Computed tomography is an imaging technique that generates reconstructions of three-dimensional images via the inverse Radon Transform (Kak et al., 1988). Simply, an object is subjected to a source of radiation, typically X-rays (neutrons and other forms of radiation are possible but less common), which a material will absorb based on the density and atomic number of materials contained in the object (Kardjilov et al., 2006; in Nguyen, 2011). The measurement of a material's local ability to absorb radiation is then calculated from the detected changes in radiation beam intensity (Nguyen, 2011, 16), most commonly via a frequency filtered back projection of multiple radiographic projections taken across a 360° rotation on the sample.

Computed tomography has the potential to make enormous contributions to archaeological studies, providing both extremely efficient and non-destructive three-dimensional imaging of internal and external structure and content of many types of artefact. The μ-VIS Centre at the University of Southampton (μ-VIS, 2012), houses one of the highest energy micro-focus CT systems available today (Supplied by Nikon Metrology Ltd., Derby, UK), and this system was used to investigate two small Roman pots, both full of coins, that was discovered by metal-detectorists in Yorkshire. The pots had been left intact and were reported to the Portable Antiquities Scheme (PAS, 2012) based in the British Museum. Physical extraction would have been required in order to count and identify the coins, which is an expensive and time-consuming process which ultimately results in a loss of information as to the placement and orientation of the coins within the pot. Computed tomography was used to generate three-dimensional data capable of coin identification without physical extraction and enable visualisation of the coin positions in-situ within the pots.

Since its invention in 1896 X-ray radiography has been used to construct images of the internal composition of objects in a non-destructive manner. The first such example was an X-ray photograph taken of the human hand in 1896 (Röntgen, 1896). This method was soon adopted for use within medicine and is still used today. The technique utilises the various chemical and physical composition of different materials within an object and their ability to absorb source radiation. The output images are the product of the level of absorption, or transmission, of incident radiation through the solids and voids that exist within the focus object. However, for many applications the resulting two-dimensional images are not sufficient to give information about internal features and geometries. This is particularly apparent when examining artefacts containing objects which may overlap other internal objects or which are positioned diagonally within the artefact. More information may be obtained by radiographic examination at multiple angles as illustrated in the early work of Garrison et al. (1969), but it was the development of computed tomography and the successful manufacture of the first computed tomography scanner built by Sir Godfrey Hounsfield (1973) that marked a change in the level of information available from radiographic imaging techniques. Since then, numerous developments have occurred: X-ray sources and detectors have developed to allow greater spatial resolution and penetration capabilities; advances in computing hardware and software have reduced reconstruction times and enabled greater fidelity of information to be extracted from images and extended post processing possibilities. With these advances, the technique has now become established as a viable non-destructive method used in many different application areas outside of medicine.

The first significant examples of computed tomography within archaeology can be seen through the work of Lewin et al. (1990);

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http://dx.doi.org/10.1016/j.jasrep.2016.01.019
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Melcher et al. (1997) and Hoffman and Hudgins (2002) who used the technique to aid understanding of mummies and sarcophaguses and has since formed the basis for the development of this technique within archaeology. It was through these studies that X-ray computed tomography could be seen to apply equally to a wider range of different materials through non-intrusive means. A number of examples can be seen in palaeontology. Luo and Ketten (1991); Joeckel et al. (1997) and Maisey (2001) highlight how this development has aided in the research of disciplines other than medicine.

Improvements in both imaging technology and processing software have enabled novel three-dimensional and volumetric measurements to be made across wider ranges of objects or samples, allowing researchers to both visualise and measure numerous aspects of three-dimensional morphology for specimens that would be impossible if the items were fragile or unexcavated. The technique can be applied successfully where artefacts have heavily corroded internal mechanisms, as seen in the examination of a 17th Century watch described by Troalen et al. (2010) where three-dimensional images of the internal components could be identified together with small inscriptions. Further work can be seen through the archaeological study by Fromm et al. (2001) on water content and wood density; Mantler and Schreiner (2001) work with paint layers and weathering of medieval glass; and soil samples through Tracy et al. (2010) work on root architecture. More recent advancements that aid archaeological understandings can be seen in the work by Bello et al. (2013) who utilised computed tomography in the understanding of Magdalenian portable art on bone and antlers; the work by Davey et al. (2014) on dislodged teeth in child mummies from Graeco-Roman Egypt; Szabo et al. (2015) and their study of a 2000 year old pearl from Western Australia; Stelzner and Million (2015) work on anatomical and dendrochronological analysis of archaeological wood; the work completed by Plessis et al. (2015) on the skeleton of an ancient Egyptian falcon mummy; and Cox's (2015) overview of Egyptian mummies from the University of Pennsylvania Museum.

The work competed by Anderson and Fell (1995) and Casali (2006) is also of importance within the case study that will follow, as both focussed on the use of computed tomography within Roman vessels that contained coins. Both studies were able to identify key features within the pots, such as coins, but neither examined the potential of how the method could be used within numismatic studies. Nguyen et al. (2011) develops upon this through their work in penetrating layers of copper alloy corrosion to provide images of surface features within coins. The paper provides a general overview of the difficulties in identifying surface detail but their main focus surrounded the identification of corrosion products that may be problematic for tomographic imaging. Nguyen et al. (2011) falls short within aspect of the archaeological understanding that can be gained using this method. The case study that is presented in this paper will instead focus on how the data can be used and manipulated within a three-dimensional context. It will outline the potential that the technology has within the study of coins and archaeology and through a combination of various three-dimensional techniques, and it will point out how it can be used within conservation and three-dimensional modelling.

2. Materials and methods

2.1. Selby coin hoard

Two small ceramic pots containing silver coins were found by a metal-detector user searching on pasture in the Selby area (Fig. 1) of East Yorkshire on 7th March 2010. One of the beakers was broken and the other still intact. A small spread of coins from the broken beaker was also found. No detail is given as to their original removal or excavation from Selby but these were passed to the British Museum by the PAS Finds Liaison Officer in May 2010 (PAS, 2015). Both pots were brought to the University of Southampton and were first photographed and then laser scanned. Following this the two pots were computed tomography scanned by the μ-VIS centre and then returned to the British

Fig. 1. Selby, East Yorkshire, UK.
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