Journal of
open archaeology data

Medieval Coins of Three Different Types and of Various States of Preservation

DATA PAPER

]u[ubiquity press

THOMAS DUNKER
ANIKA TAUSCHENSKY
HUBERT MARA
ERIK TROSTMANN

*Author affiliations can be found in the back matter of this article

ABSTRACT

We have developed a device for digitizing coins using photometric stereo, which serves two purposes. For inventory it allows identifying a coin, which has been digitized before, and avoids mixing up similar coins. This is important because the classic marking directly on the object is not possible without obscuring the design. Secondly, one can view a digitized coin on screen and interactively change the light direction similar to Reflectance Transformation Imaging (RTI). This enables researchers to better recognize details, especially in the case of often corroded coin finds, and also enables location independent investigations and exchanges. The digitization result consists of color (albedo) and normal information for each pixel, which allows to analyze topographic properties apart from color. We think that this type of data can enable the development of new algorithmic analysis methods. The classification of coins, especially medieval coins, requires specialist knowledge and a great deal of experience. Digital support can help archaeologists without numismatic knowledge to classify coins correctly by providing initial clues and showing, which coins in a comparative data base show similarities with a newly found coin. For the development of such digital tools, we provide a selection of coin data as an open dataset.

For the dataset we have selected samples of medieval coins from three different types, which are described in Mehl 499, 595 and Bahrfeldt 19. The dataset contains 2D and 3D data only for their obverses.

A possible research direction could be to measure similarity between these samples, such that samples of the same type are more similar than samples of different type. Many samples show only a part of a complete coin. This increases the challenge e.g. for shape correspondence. Multi-scale integral invariant (MSII) features included with the 3D data may help to focus on minting features.

CORRESPONDING AUTHOR:
Thomas Dunker
Photometric stereo image analysis, Fraunhofer Institute for Factory Operation and Automation IFF, Magdeburg, Germany
Thomas.Dunker@iff.fraunhofer.de

KEYWORDS:
Numismatics; medieval coins; multi-light single-camera digitization; surface normal; 3D data; multi-scale integral invariant features; similarity

TO CITE THIS ARTICLE:
Dunker T, Tauschensky A, Mara H, Trostmann E 2024 Medieval Coins of Three Different Types and of Various States of Preservation. *Journal of Open Archaeology Data,* 12: 1, pp. 1–6. DOI: https://doi.org/10.5334/joad.116

(1) OVERVIEW

CONTEXT

Having the question in mind "how to measure similarity between digital representations of find coins" we think that a dataset for such research needs to contain at least three different but similarly minted types and a sufficient variation within the types. Based on these two goals, we selected the following coins from a digitization campaign comprising more than 28,500 coins. A follow up project will run until 2026, meaning that the data basis will triple at least.

In our selection there are 204 coins of type Mehl 499 and 77 of type Mehl 595 [1] from a coin find in a field close to Dreihäuser, Germany, Saxony-Anhalt, Jerichower Land. They were minted in Magdeburg between 1232 and 1253. The remaining 156 more recent coins of type Bahrfeldt 19 [2] from a coin find on a deserted site close to Uthmöden, Germany, Saxony-Anhalt, Börde Rural District were minted in Stendal between 1440 and 1470. The samples are of different states of preservation (damaged, bent, partial).

Numismatists recognize similarities and differences in the minting of these coins. Having digital representations of coins, we are interested in algorithms that are able to quantify similarities and differences between different samples. There are different approaches possible. One can extract geometric features, e.g. in 2D representations like [3], and analyze common features and their distribution. For analysing variations within one type, a visualization would be interesting for numismatists, which shows where corresponding parts of the minting match well and where are differences. A rigid transformation of one sample onto the other will not be sufficient to cope with deformations of the coins. That is why we think that applying shape correspondence methods [4, 5] could be a research direction. Multi-scale integral invariant (MSII) features [6] could be of interest for correspondences in 3D.

The dataset is conceived for testing such algorithms. It contains significant variation within each type and common geometric features between different types, which makes it challenging to obtain the same three clusters.

SPATIAL COVERAGE

Dreihäuser, Germany, Saxony-Anhalt, Jerichower Land, https://www.geonames.org/2935177 (http://hdl.handle.net/428894.vzg/45583c85-2e6d-49c5-81bc-99a98f568f27)

Northern boundary: 52.44008 12.26122
Southern boundary: 52.44008 12.26122
Eastern boundary: 52.44008 12.26122
Western boundary: 52.44008 12.26122

Uthmöden, Germany, Saxony-Anhalt, Börde Rural District, https://www.geonames.org/2818057 (http://hdl.handle.net/428894.vzg/17eda5c2-7115-40a9-a6d5-60afe3675b10)

Northern boundary: 52.35401 11.3554
Southern boundary: 52.35401 11.3554
Eastern boundary: 52.35401 11.3554
Western boundary: 52.35401 11.3554

TEMPORAL COVERAGE

Minting period 1232 – 1253 and 1440 – 1470.

(2) METHODS

The data for each coin was extracted from multiple images of the same camera view with different illuminations, see also [7]. A photometric stereo algorithm estimates surface normal and albedo. The principles of photometric stereo were introduced by Woodham in 1980 [8]. Many contributions to this technique followed, see e.g. the survey [9].

Our device is shown in Figure 1. The most recent version uses an Allied Vision MANTA G-2040C with 4512 × 4512 pixel of 2.74 µm and a 50 mm lens ZEISS DIMENSION 2.0/50. Two motorized axes allow changing working distance and focus in order to have a field of view between 30 x 30 and 60 x 60 mm^2. An older version of the device with an Allied Vision Prosilica GT4905C 4896 × 3264 pixel of 5.5 µm is used with a 50 mm lens ZEISS INTERLOCK 2.0/50 for a larger and a 100 mm lens ZEISS INTERLOCK 2,0/100 for a smaller field of view. Geometrical calibration gives the micrometers per pixel in the field of view. This value is always part of the metadata of a digitization. This allows to recompute the digital representation of different coins to the same resolution, even when they were digitized with different devices or fields of view.

Given surface normal and albedo one can interactively relight the coin image in order to recognise details more easily, as shown in Figure 2.

There are also other methods for relighting images from a single camera view with multiple illuminations, see [10, 11].

If we interpret the surface as a function $f(x,y):\mathbb{R}^2 \rightarrow \mathbb{R}$ and denote the estimated normal vector by $\vec{n}(x,y)=[n_x(x,y),n_y(x,y),n_z(x,y)]^T$ then we can set the gradient field $\nabla f(x,y) = -[n_x(x,y),n_y(x,y)]^T / n_z(x,y)$. Although this field may not be conservative, there are methods that can integrate this field to obtain the function (up to a constant). We use a program[1], which implements the integration method described in [12], and obtain a 2.5D representation of the coin surface. In our case the lateral resolution is about 25.8 µm. From the gridded 2.5D representation one can easily generate a triangle mesh 3D model. This 3D model does not represent the real surface like a scan with a coordinate measurement machine would do, where we

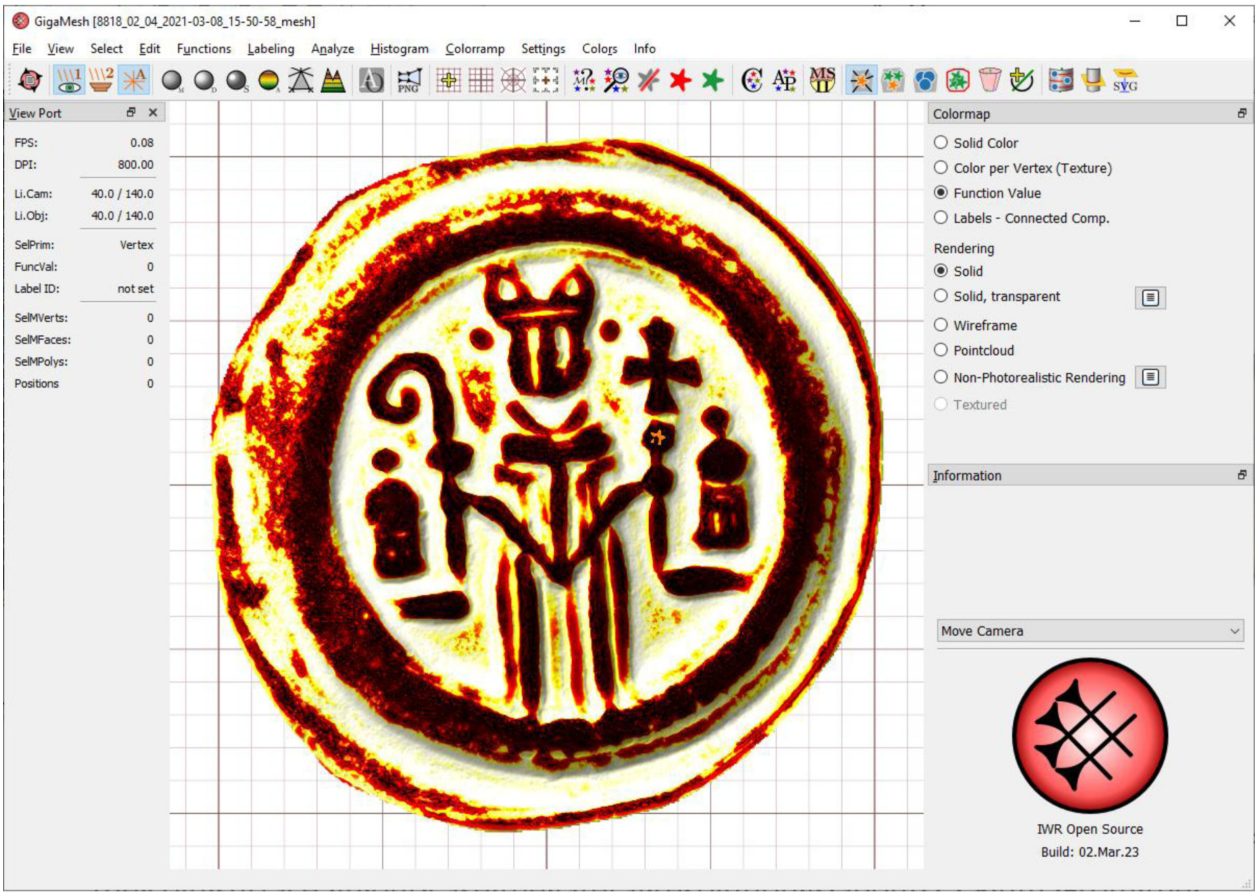
Figure 1 O.S.C.A.R. (Optical System for Coin Analysis and Recognition) device for automatically collecting images with illumination from 24 different LEDs.

Figure 2 Interactive relighting (a snapshot left) uses albedo (middle) and surface normal (right). Moving with the mouse over the coin changes the direction of light. Together with turning and zooming, this facilitates the study of details.

can quantify the difference between model geometry and real surface by the measurement uncertainty. Lateral dimensions come from a camera calibration and are true for the focus plane. The used photometric model assumptions simplify the real light conditions – vignetting and spatial intensity profile of the LEDs are ignored. This leads to long wave geometric errors of the 3D model. Local features are captured with good precision.

These mesh models open up the possibilities to use 3D techniques like MSII filtering, which were successfully used to analyze 3D scans of other archaeological artifacts like cuneiform tablets [13]. The MSII feature vector precomputed for each vertex of the mesh contains 16 values. A single value is obtained by intersecting the volume below the mesh with a sphere centred in the vertex. The ratio of this volume and the sphere volume is mapped to (–1, 1). This is done for 16 radii in decreasing order r_{max} [16,...,1]/16, for details see [6]. Figure 3 gives an impression, how to use the MSII features for extracting minting features.

Each sample is linked to an entry of the numismatic online data base https://www.kenom.de. There is a key "kenom" in the metadata (JSON). Its value gives the identifier, e.g. "record_DE-MUS-805310_kenom_318015", which allows to access a visualization https://www.kenom.de/objekt/record_DE-MUS-805310_kenom_318015/1/, the OAI API https://www.kenom.de/oai/?verb=GetRecord&metadataPrefix=lido&identifier=record_DE-MUS-805310_kenom_318015 or the IIIF API https://www.kenom.de/api/v1/records/record_DE-MUS-805310_kenom_318015/metadata/source/ (numismatic data) and https://www.kenom.de/api/v1/records/record_DE-MUS-805310_kenom_318015/pages/sequence/base/ (links image data).



FPS: 0.08
DPI: 800.00
Li.Cam: 40.0 / 140.0
Li.Obj: 40.0 / 140.0
SelPrim: Vertex
FuncVal: 0
Label ID: not set
SelMVerts: 0
SelMFaces: 0
SelMPolys: 0
Positions 0

Colormap
○ Solid Color
○ Color per Vertex (Texture)
● Function Value
○ Labels - Connected Comp.

Rendering
● Solid
○ Solid, transparent
○ Wireframe
○ Pointcloud
○ Non-Photorealistic Rendering
○ Textured

Figure 3 GUI for interactive feature analysis showing a color-coded feature distance with respect to features of the vertex marked with a star (functions – feature vectors extra functions – feature distance to selected vertex (Tanimoto)). The smallest unit of the background grid is one millimetre.

STEPS

The digitization of the selected coins was part of an extensive numismatic digitization project, which produces albedo and normal image for interactive relighting. The task was to select three types of coins with at least 50 samples, which represent a variety of preservation states typical for coin finds.

For the selected samples from the two coin finds we generated 3D models by normal integration described above, which gives for each pixel belonging to the coin a 3D vector $\vec{p}_{i,j} = [x, y, f(x,y)]^T$. We use the pixel grid to connect these points to form triangular faces by assigning the four neighboring points $\{\vec{p}_{i,j}, \vec{p}_{i+1,j}, \vec{p}_{i+1,j+1}, \vec{p}_{i,j+1}\}$ e.g. to two faces $\{\vec{p}_{i,j}, \vec{p}_{i+1,j+1}, \vec{p}_{i,j+1}\}$ and $\{\vec{p}_{i,j}, \vec{p}_{i+1,j}, \vec{p}_{i+1,j+1}\}$. Finally, we applied a MSII feature vector computation to all 3D models using GigaMesh[2] with parameter $r_{\max} = 0.75$ *mm* in order to capture small minting features of typical width less than 1.5 mm. The size of the voxel volume for discretization was set to 512. The MSII features can also be analyzed on the pixel grid.[3]

For each coin there are two tiff-files with three channels of 8-bit. In the case of *_albedo.tif the RGB channels represent an estimate for illumination independent color. The second image *_normal.tif codes an estimate of the pixelwise surface normal. The RGB channels represent the xyz-coordinates of each normal. The 8-bit values in [0, 255] need to be mapped linearly to [–1, 1], in order to obtain coordinate values. Background pixel have the value 127 in all three channels – a color, which does not represent a normal vector.

There is one file *_mesh.ply in Polygon File Format (binary_little_endian 1.0). Besides the triangle mesh model of the coin obverse, it includes for each vertex a 16-dimensional MSII feature vector.

Finally *_meta.json contains identifiers and type information.

SAMPLING STRATEGY

A minority of the samples was digitized with the mentioned lateral resolution. Yet, in order to limit the data volume, we decided to reduce the resolution of all other samples from 8 µm per pixel to 25.8 µm per pixel. As these bracteates made of stamped silver sheet are one-sided – the reverse shows a hollow copy of the high relief coin image of the obverse side – we did not include the reverse in the data set.

(3) DATASET DESCRIPTION

OBJECT NAME

There are five ZIP archives

- Mehl-499-a.zip, Mehl-499-b.zip each with 102 samples
- Mehl-595.zip with 77 samples
- Bahrfeldt-19-a.zip, Bahrfeldt-19-b.zip each with 78 samples

They contain for each sample four files ending with _albedo.tif, _normal.tif, _meta.json and _mesh.ply. Those four files share the first part of their names, which is composed of the collection identifier and the digitization time stamp.

DATA TYPE

Processed data (albedo image, surface normal image, 3D mesh with MSII features) and metadata (identifier for accessing numismatic online data).

FORMAT NAMES AND VERSIONS

ZIP archives
TIFF (*_albedo.tif, *_normal.tif)
PLY 1.0 (*_mesh.tif)
JSON (*_meta.tif)

CREATION DATES

08/03/2021 – 24/05/2023.

DATASET CREATORS

Andreas Brunn,[4] data base specialist
Veit Dresely,[4] project management and funding
Thomas Dunker,[5] photometric stereo image analysis
Hubert Mara,[6] characterization by multi-scale integral invariants
Tino Polzin,[4] numismatics and digitization
Michael Schiller,[5] software development
Silvio Sperling,[5] hardware development
Anika Tauschensky,[4] numismatics and digitization
Erik Trostmann,[5] development and project management

LANGUAGE

English.

LICENSE

Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0)

REPOSITORY LOCATION

http://dx.doi.org/10.24406/fordatis/210

PUBLICATION DATE

16/08/2023

(4) REUSE POTENTIAL

There are several motivations for finding techniques to analyze the similarity between different coin samples. Medieval coins, or more precisely bracteates without inscriptions, are sometimes difficult to classify even for experienced numismatists. For archaeologists without numismatic knowledge, classification is hardly possible, but extremely important for interpreting the findings. In Central Germany in particular, there is an enormous variety of types due to the many small rulers, some of whom issued new coins several times a year. Motifs, attributes of the rulers, symbols, insignia etc. are repeated, but are never depicted in exactly the same way. Small details in the shape (size, thickness, width) can be decisive in assigning a coin to one ruler or another. The identification of a find coin may be very time-consuming as it may be necessary to check multiple hypotheses. Given a data base of digitized coins, which covers the known coin types of the period of interest, an algorithm could search for the most similar samples and return a ranked list of hypotheses to test first.

A possibility to analyze by non-rigid overlaying visually similarities and differences of two coins would be useful for the following studies. The die study is used to reconstruct, which combination of lower and upper die was used for minting. This makes it possible to create minting series and to calculate the coin output and thus to draw conclusions about the economic conditions at the time of minting. Of interest are also the stylistic evolution of individual elements of motifs, coats of arms etc. Such methods could also be used to identify forgeries. In this case, the aim is to identify stylistic differences or to show that the elements of the motif are similar to those of other coins but that no recognized coin has the same combination.

NOTES

1 https://github.com/yqueau/normal_integration.
2 https://www.gigamesh.eu/?page=tutorials&topic=11._MSII_Filtering_.
3 See https://gitlab.com/fcgl/msii-coin-data for example code.
4 State Office for Heritage Management and Archaeology Saxony-Anhalt, Halle (Saale), Germany.
5 O.S.C.A.R.-team at Fraunhofer Institute for Factory Operation and Automation IFF, Magdeburg, Germany.
6 Institute of Computer Science, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany.

FUNDING INFORMATION

The development of O.S.C.A.R. – the device for coin digitization – was funded by Staatskanzlei und Ministerium für Kultur des Landes Sachsen-Anhalt. Coins were digitized within the projects “Digital Heritage” funded by Investitionsbank Sachsen-Anhalt and “Rares-Bares” funded by the Federal Ministry of Education and Research.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Thomas Dunker orcid.org/0000-0003-1136-7118
Photometric stereo image analysis, Fraunhofer Institute for Factory Operation and Automation IFF, Magdeburg, Germany,

Anika Tauschensky orcid.org/0009-0002-8918-1663
Numismatics and digitization, State Office for Heritage Management and Archaeology Saxony-Anhalt, Halle (Saale), Germany

Hubert Mara orcid.org/0000-0002-2004-4153
Characterization by multi-scale integral invariants, Institute of Computer Science, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany

Erik Trostmann orcid.org/0009-0006-5030-9593
Development and project management O.S.C.A.R., Fraunhofer Institute for Factory Operation and Automation IFF, Magdeburg, Germany

REFERENCES

1. **Mehl M.** *Münz-und Geldgeschichte des Erzbistums Magdeburg im Mittelalter*. Hamburg; 2011.
2. **Bahrfeldt E.** *Das Münzwesen der Mark Brandenburg. Unter den Hohenzollern bis zum Großen Kurfürsten, von 1415 bis 1640*. Kühl, Berlin; 1895.
3. **Anwar H.** *Invariant image representations for object category-based image classification*; 2015. DOI: https://doi.org/10.34726/hss.2015.32010
4. **Eisenberger M, Lähner Z, Cremers D.** Divergence-Free Shape Correspondence by Deformation. *Computer Graphics Forum*. 2019; 38(5): 1–12. DOI: https://doi.org/10.1111/cgf.13785
5. **Sahillioğlu Y.** Recent advances in shape correspondence. *Vis Comput*. 2020; 36(8): 1705–1721. DOI: https://doi.org/10.1007/s00371-019-01760-0
6. **Mara H.** *Multi-Scale Integral Invariants for Robust Character Extraction from Irregular Polygon Mesh Data*; 2012. DOI: https://doi.org/10.11588/heidok.00013890
7. **Trostmann E, Dresely V, Tauschensky A.** Identifizierung von Münzen anhand eines digitalen Fingerabdrucks 21–26 Seiten/Online Zeitschrift zur Antiken Numismatik, Bd. 1; 2019. 2019. DOI: https://doi.org/10.17879/OZEAN-2019-2477
8. **Woodham RJ.** Photometric Method for Determining Surface Orientation from Multiple Images. *Opt. Eng*. 1980; 19(1). DOI: https://doi.org/10.1117/12.7972479
9. **Ackermann J, Goesele M.** A Survey of Photometric Stereo Techniques. *FNT in Computer Graphics and Vision*. 2015; 9(3–4): 149–254. DOI: https://doi.org/10.1561/0600000065
10. **Vanweddingen V, Hameeuw H, Vandermeulen B, Vastenhoud C, Watteeuw L, Lemmers F, van der Perre A, Konijn P, van Gool L, Proesmans M.** Pixel+: integrating and standardizing of various interactive pixel-based imagery. *Optics, Photonics and Digital Technologies for Imaging Applications VI*. 6–10 April 2020, online only, France. 2020; 15. DOI: https://doi.org/10.1117/12.2555685
11. **Pintus R, Dulecha TG, Ciortan I, Gobbetti E, Giachetti A.** State-of-the-art in Multi-Light Image Collections for Surface Visualization and Analysis. *Computer Graphics Forum*. 2019; 38(3): 909–934. DOI: https://doi.org/10.1111/cgf.13732
12. **Quéau Y, Durou J-D, Aujol J-F.** Variational Methods for Normal Integration. *J Math Imaging Vis*. 2018; 60(4): 609–632. DOI: https://doi.org/10.1007/s10851-017-0777-6
13. **Mara H, Krömker S, Jakob S, Breuckmann B.** *GigaMesh and Gilgamesh – 3D Multiscale Integral Invariant Cuneiform Character Extraction*. The Eurographics Association; 2010. DOI: https://doi.org/10.2312/VAST/VAST10/131-138

TO CITE THIS ARTICLE:
Dunker T, Tauschensky A, Mara H, Trostmann E 2024 Medieval Coins of Three Different Types and of Various States of Preservation. *Journal of Open Archaeology Data,* 12: 1, pp. 1–6. DOI: https://doi.org/10.5334/joad.116

Submitted: 22 August 2023 **Accepted:** 20 December 2023 **Published:** 04 January 2024

Journal of Open Archaeology Data is a peer-reviewed open access journal published by Ubiquity Press.