

# On the study of 3D digital models of historical silver coins: an integrated approach

*Vera Moitinho de Almeida*

## STSMs

### "Geometrical comparison of 3D data of silver coins"

Virtual Reality Techniques Division (ZTRW),  
Institute of Micromechanics and Photonics,  
Faculty of Mechatronics, Warsaw University of Technology, Poland.

*Robert Sitnik (& Eryk Bunsch)*

March.2016



### "Evaluating 3D digital models of historical silver coins: a methodological approach"

AICON 3D Systems GmbH, Scanner Innovation Center, Meersburg,  
Germany.

*Dirk Rieke-Zapp (& Lewis Homer)*

June-July.2016



## STSMs' Aims

to contribute to:

- The development of an efficient and comprehensive **methodological framework** for the **3D digital data capture, processing and analysis of historical silver coins**;
- Establish whether the selected **recording 3D systems and techniques** can support the comparison of certain **features and properties**;
- A better knowledge about the **surface characteristics** of historic coins, by characterizing and analysing a number of relevant **geometrical** and **topological** features, using distinct **metrological software, techniques and procedures**;
- **Publication of a guide to good documentation practice**, including relevant digital preservation guidelines.

# STSMs' Aims

to address COSCH's:

- **Case study:** *Study of Roman silver coins using spectroscopic and 3D imaging approaches.*
- **WG2:** Spatial object documentation
  - Topic 6** - Comparative analysis of measurements realized for one single object.
- **WG3:** Algorithms and procedures
  - Topic 1** - Registration processes.
  - Topic 3** - Data access and formats.
- **Think tank on vocabularies:** by making use of metrology standards (JCGM, VDI/VDE), terms, methods and techniques.
- **COSCH Knowledge Representation (KR) App.**

# Case Study

## *Study of Roman silver coins using spectroscopic and 3D imaging approaches*

### Test coins

coin A

obverse



Inscription/figure:  
DIVA FAUSTINA

coin B



Inscription/figure:  
DIVA FAUSTINA

avers



Inscription/figure:  
AETER-NITA



Inscription/figure:  
VES-TA

(photos by L.W. MacDonald)

# Coins

## Typical online data record

Portable Antiquities Scheme  
www.finds.org.uk

### COIN

**Unique ID:** SWYOR-2B322B

Object type certainty: Certain  
Workflow status: Awaiting validation

A Roman silver coin; a denarius of Faustina II struck under Marcus Aurelius and dating from the period AD 161 to 175. IVNONI REGINAE reverse. Rome mint. RIC III, p. 270, no. 696. The coin is 17.5mm diameter, 2.6mm thick and 2.99g. Compare LEIC-2E1151.

**Find of note status**  
This is a find of note and has been designated: County / local importance

**Subsequent actions**  
Subsequent action after recording: Returned to finder

**Chronology**  
Broad period: ROMAN  
Period from: ROMAN  
Period to: ROMAN  
Date from: Circa AD 161  
Date to: Circa AD 175

**Dimensions and weight**  
Quantity: 1  
Thickness: 2.6 mm  
Weight: 2.99 g  
Diameter: 17.5 mm

**Image use policy**  
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cm  
0 1 2 3 4 5

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SHARE: EXPORT: NUDS/XML RDF/XML TTL JSON-LD KML GeoJSON

### RIC III Antoninus Pius 344 (denarius). 1937.158.506

Obverse: DIVA FAUSTINA  
Reverse: AETERNITAS

**Physical Description**  
Axis: 7  
Measurements  
Weight: 2.89  
Diameter: 17

**Typological Description**  
Date: AD 141  
Object Type: Coin  
Manufacture: Struck  
Denomination: Denarius  
Material: Silver

**Authority**  
Authority: Antoninus Pius

**Geographic**  
Mint: Rome  
Region: Italy

**Obverse**  
Description: Bust of Faustina I, draped, right, hair elaborately waved in several loops round head and drawn up and coiled on top.  
Portrait: Faustina the Elder

**Reverse**  
Description: Juno(?), veiled, draped, standing, front, head left, extending right hand and holding nearly vertical sceptre in left.  
Deity: Juno

**References**  
Reference: RIC III Antoninus Pius 344 (denarius)  
Reference: BMC.345

**Administrative History**  
Identifier: 1937.158.506  
Department: Roman  
Collection: American Numismatic Society

**SubjectSet**  
series: RIC.1.3

**Map**

<http://numismatics.org/collection/>

# Coins

## Typical online data record

### Roman Provincial Coinage Online

Home Database Introduction Imperial Family Map

Volume 4, № 13655 (temporary)



Pictured: Image of specimen #1

Large image Full-size image All specimen images

Coin type	
Volume	4
Number	13655 (temporary)
Province	Egypt
Region	Egypt
City	Alexandria
Reign	Antoninus Pius
Person	Faustina I (Augusta)
Issue	Year II = 13
Date	149/50
Obverse inscription	ΦΑΥΣΤΙΝΑ ΣΕΒΑΣΤΗ
Obverse design	draped bust of Faustina II, r.
Reverse inscription	L II
Reverse design	Athena standing, facing, head, l., holding Nike and long spear; beside, shield
Metal	Silver
Average diameter	23 mm
Average weight	12.09 g
Type reference	D 3235, M 2033

Correction

Specimens of this coin type						
#	Collection	Bibliography	Diameter	Weight	Axis	Image
1	O 2033		23 mm	11.72 g	12	Pictured
2	NY 1944.100.61958		22 mm	12.64 g	12	None
3	B (Lobb)		24 mm	11.90 g	12	None
4		Historical Coin Review (Victor England) XIII, 2 (Spring, 1988), 47	24 mm			None

<http://rpc.ashmus.ox.ac.uk/coins>

### OCRE

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RIC III Antoninus Pius 344 (denarius). 1951.117.16

Collection	American Numismatic Society
Axis	7
Diameter	15.5
Weight	3.32



RIC 344\_denarius, Antonino Pio, 37752

Collection	Archaeological Museum of Liria
Axis	6
Weight	3.22
Hoard	Liria Hoard



<http://numismatics.org/ocre>

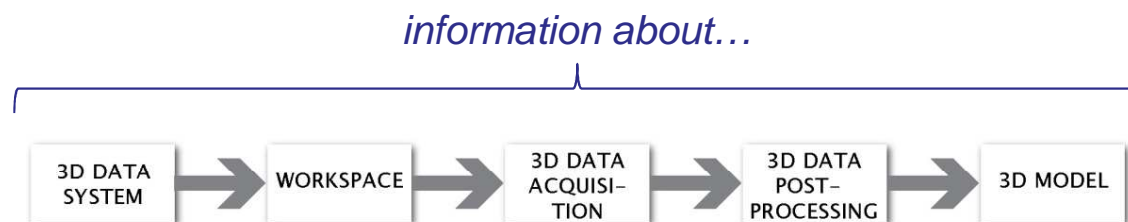
# Method

## Used

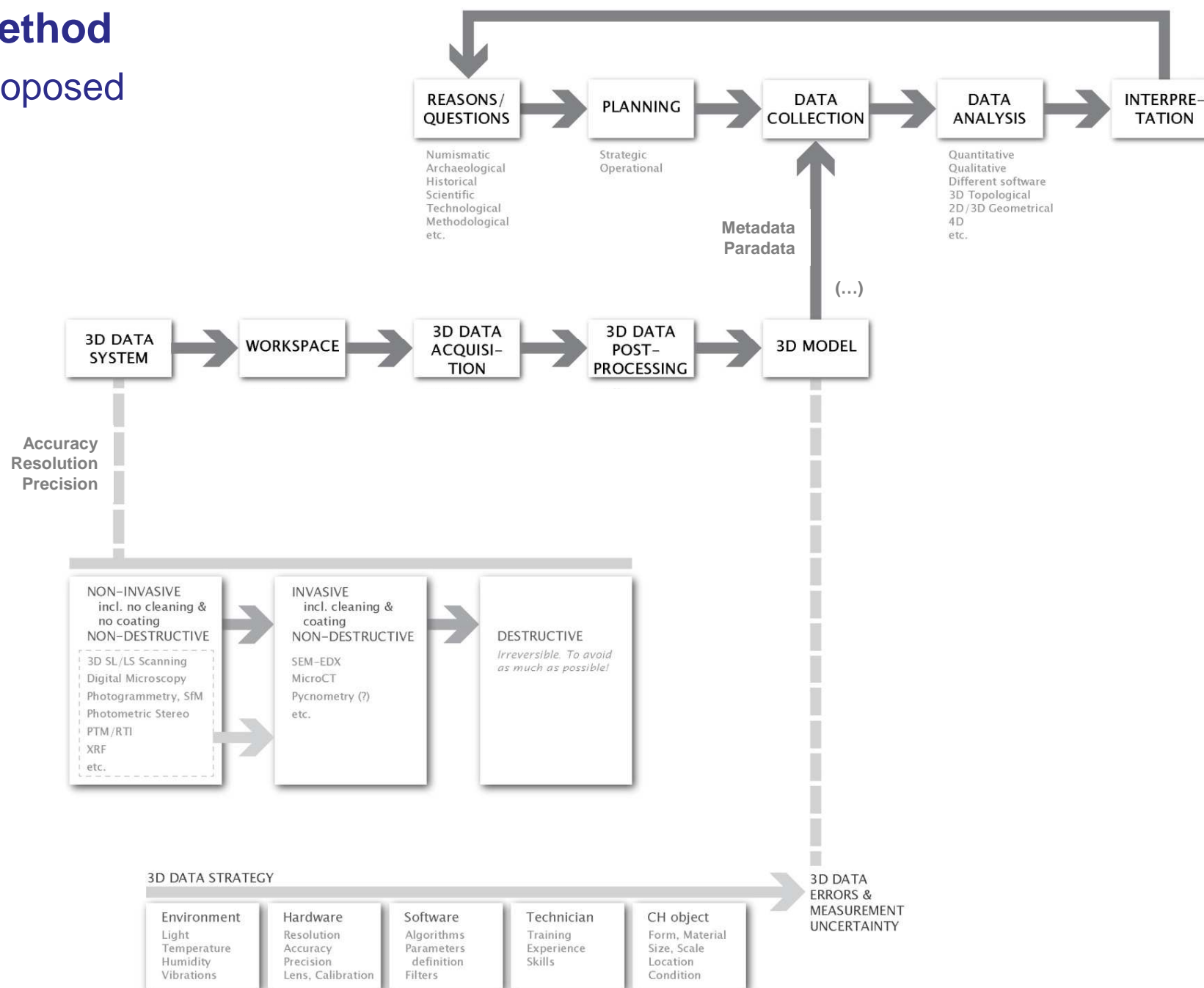


# Method

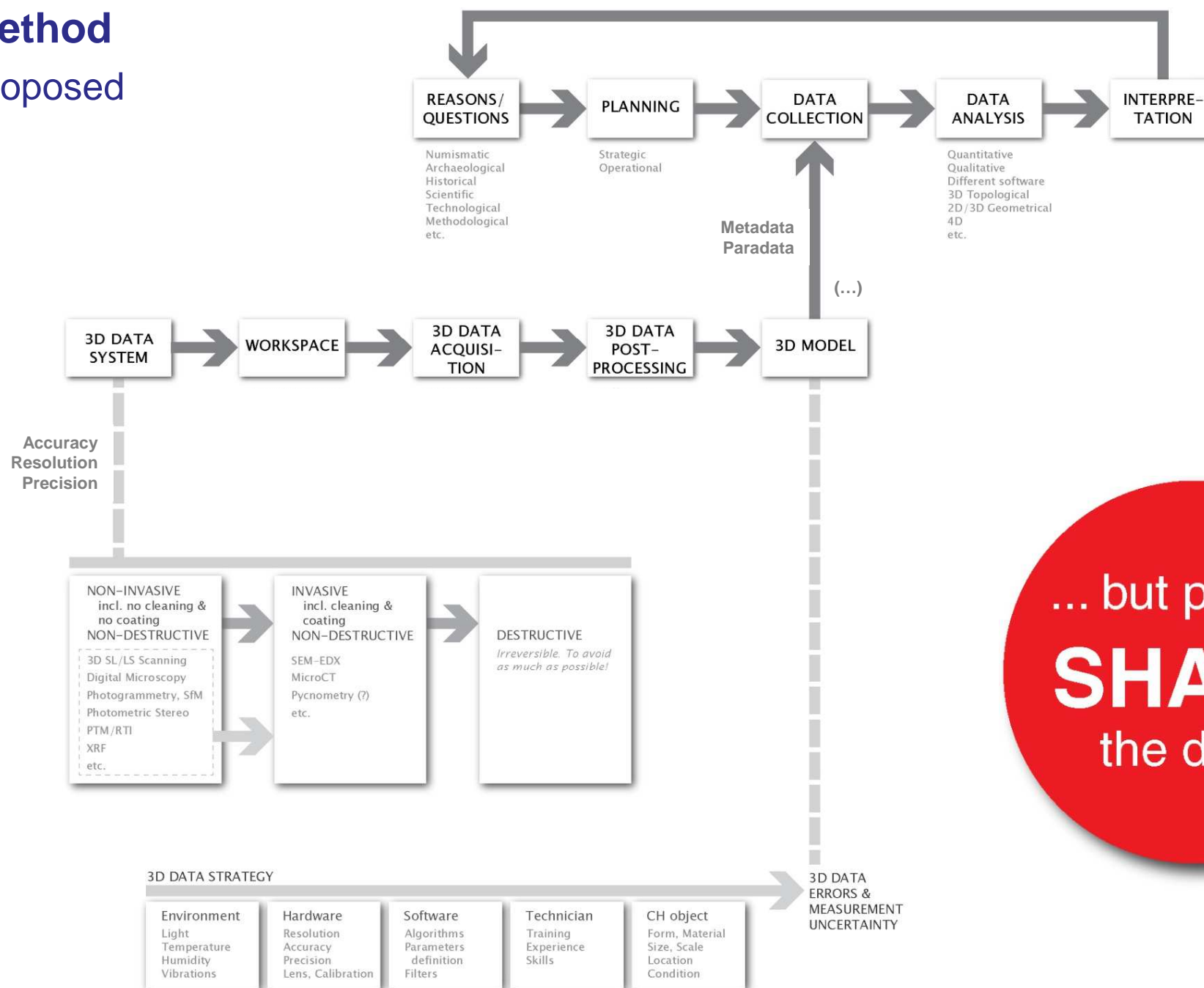
Used (*sometimes...*)



# Method Proposed



# Method Proposed



# Data Acquisition Systems & Techniques

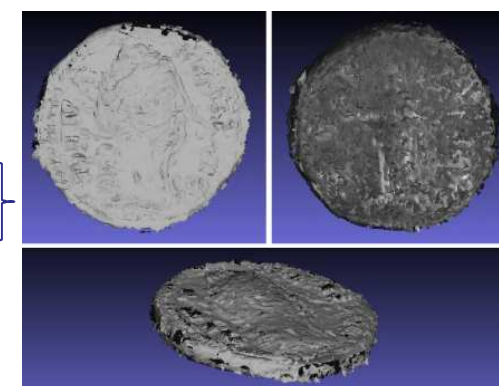
## Used

Date & Institution	System/Technique	Cleaning	Coating	observations
2014.09 WUT	. 3D Structured Light (SL) Scanning	Yes	Yes	Coating applied: <i>Helling 3D Scanning Spray</i> , Helling GmbH. Titanium dioxide (TiO <sub>2</sub> ) powder dispersed into an alcohol solvent. Applied with airbrush and compressor; removed mechanically with brush; cleaned with distilled water; dried with hot air. 3D models not included for further comparisons: computational artefact caused by systematic error during 3D data acquisition.
2014.10-11 SAS	. MicroCT	x	x	Data to be used as Ground Truth (GT): not made available in time for STSM.
	. SEM	Yes	x	Used isopropanol for ultrasonic cleaning the coins. Conservators from BM were dubious about ultrasonic cleaning techniques.
	. EDX	Yes	x	Used isopropanol for ultrasonic cleaning the coins. Conservators from BM were dubious about ultrasonic cleaning techniques.
2014.12 NMK	. XRF	x	x	
2015.01 AICON	. 3D SL Scanning	x	x	3D data acquisition repeated 2015.10.
2015.01 RBINS	. 3D SL Scanning	x	x	3D models: not representative of the possible highest resolution outcome of system.
	. SfM	x	x	
	. PTM/RTI	x	x	
2015.02-03 UCL	. 3D Laser Scanning	?	?	3D models: only obverse recorded. Not representative of the possible highest resolution outcome of system.
	. PTM/RTI	?	x	
	. Photometric Stereo	x	x	3D models derived from PTM/RTI and 3D laser scanning - (LS) Arius - from UCL.
2015.04-05 Cyl	. 3D Laser Scanning	x	x	3D models not included for further comparisons: data quality too unreliable and low (see report).
	. PTM/RTI	x	x	
	. XRF	x	x	
2015.10 AICON	. 3D SL Scanning	Yes	Yes	Coin A: coating applied; removed with water. Coin B: no cleaning performed; no coating applied. 3D models: not representative of the possible highest resolution outcome of system. Used as Reference for 2 <sup>nd</sup> STSM (system has values according to standard procedures for estimation of accuracy: VDI/VDE 2634).
2016.01 RBINS, UCL, US	. 3D SL Scanning	x	x	3D models: not representative of the possible highest resolution outcome of system.
	. SfM	x	x	
	. PTM/RTI	x	x	Images revealed changes in the reflectivity of the surface's material, possibly due to cleaning, whitening of TiO <sub>2</sub> , handling, storage and/or metal oxidation.
2016.06 ITAM	. 3D Laser Scanning	?	?	3D models not made available in time for STSM.
	. Digital Microscopy	?	?	
	. PTM/RTI	?	?	
	. Photometric Stereo	?	?	3D models not made available in time for STSM.
	. Pycnometry	?	?	Coins exposed to Helium gas.
	. SEM-EDX	?	?	Elemental composition determined some contaminated points.

# 3D Data Acquisition Systems & Techniques

Used (10): 3 Laser Scanners, 1 microCT, 2 Photometric Stereo,  
1 Structure from Motion, 3 Structured Light Scanners.

Coin	3D Model	Survey Institution	3D data acquisition system type	3D data acquisition system model	3D data acquisition software	3D data processing software	Acquisition resolution ***
A, B	(LS) Arius-obv*	3DIMPact, UCL	Multi-stripe Colour Laser Scanner	IDENTIK 300L / AriusTechnology	<i>n.a.</i>	CloudCompare	100 µm
	(LS) ITAM**	ITAM, Academy of Sciences, Czech Republic	Laser Scanner	Micro-Epsilon	<i>n.a.</i>	<i>n.a.</i>	10 µm
	(LS) NextEngine	STARC, Cyl	Multi-stripe Laser Scanner	NextEngine Desktop 3D Scanner	ScanStudio HD 1.3.2 (NextEngine)	Meshlab	127 µm
	(mCT) SAS	SAS	MicroCT	Phoenix Nanotom 180 (GE)	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>
	(PS) ITAM**	ITAM, Academy of Sciences, Czech Republic	Photometric Stereo	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>	50 µm
	(PS) Ls-Ptm	3DIMPact, UCL	Photometric Stereo	IDENTIK 300L, Arius Scanner; Nikon D200, Nikkor 200mm Macro Lens, f/5.6	Matlab	Matlab	13 µm (XY)
	(SfM) Canon	RBINS	Structure from Motion	Canon 600D; Canon Macro Lens EF 100mm 1:2.8, f/18 (v0.8, ISO100)	<i>n.a.</i>	Photoscan (Agisoft)	<i>n.a.</i>
	(SLS) Mechscan	RBINS	Structured Light Scanner	MechScan 3D Macro Scanner; Makro-IRIS Schneider-Kreuznach Componon-S 4/80 Unifoc f/6	FlexScan3D	FlexScan3D	<i>n.a.</i>
	(SLS) Smartscan	AICON 3D Systems GmbH	Structured Light Scanner	smartSCAN HE with 8MP colour stereo cameras, FOV 75	OPTOCAT 2015R2	OPTOCAT 2015R2	20 µm (XY) 3 µm (Z)
	(SLS) WUT	ZTRW, WUT	Structured Light Scanner	Custom	<i>n.a.</i>	<i>n.a.</i>	<i>n.a.</i>



# 3D Data Acquisition Systems & Techniques

Used for comparisons (5): 1 Laser Scanner, 1 Photometric Stereo,  
1 Structure from Motion, 2 Structured Light Scanners.

Coin	3D Model	Survey Institution	3D data acquisition system type	3D data acquisition system model	3D data acquisition software	3D data processing software	Acquisition resolution ***
A, B	(LS) Arius-obv*	3DIMPact, UCL	Multi-stripe Colour Laser Scanner	IDENTIK 300L / AriusTechnology	n.a.	CloudCompare	100 µm
	(LS) ITAM**	ITAM, Academy of Sciences, Czech Republic	Laser Scanner	Micro-Epsilon	n.a.	n.a.	10 µm
	(LS) NextEngine	STARC, Cyl	Multi-stripe Laser Scanner	NextEngine Desktop 3D Scanner	ScanStudio HD 1.3.2 (NextEngine)	Meshlab	127 µm
	(mCT) SAS	SAS	MicroCT	Phoenix Nanotom 180 (GE)	n.a.	n.a.	n.a.
	(PS) ITAM**	ITAM, Academy of Sciences, Czech Republic	Photometric Stereo	n.a.	n.a.	n.a.	50 µm
	(PS) Ls-Ptm	3DIMPact, UCL	Photometric Stereo	IDENTIK 300L, Arius Scanner; Nikon D200, Nikkor 200mm Macro Lens, f/5.6	Matlab	Matlab	13 µm (XY)
	(SfM) Canon	RBINS	Structure from Motion	Canon 600D; Canon Macro Lens EF 100mm 1:2.8, f/18 (v0.8, ISO100)	n.a.	Photoscan (Agisoft)	n.a.
	(SLS) Mechscan	RBINS	Structured Light Scanner	MechScan 3D Macro Scanner; Makro-IRIS Schneider-Kreuznach Componon-S 4/80 Unifoc f/6	FlexScan3D	FlexScan3D	n.a.
	(SLS) Smartscan	AICON 3D Systems GmbH	Structured Light Scanner	smartSCAN HE with 8MP colour stereo cameras, FOV 75	OPTOCAT 2015R2	OPTOCAT 2015R2	20 µm (XY) 3 µm (Z)
	(SLS) WUT	ZTRW, WUT	Structured Light Scanner	Custom	n.a.	n.a.	n.a.

Most 3D models used for comparisons are not representative of the possible highest resolution outcome of the system, as the objectives of this case study had not been formulated prior to their 3D scanning.

# 3D Data Acquisition Systems & Techniques

## Accuracy, Resolution and Precision

### Accuracy

*The higher the accuracy, the closer the measurement result is to the true object (JCGM 2012).*

Ground Truth (GT) data not made available to determine Accuracy; (SLS) Smartsan was later used as Reference data, as it follows VDI/VDE 2634 standard.

Moreover, most 3D models used for comparisons are not representative of the possible highest resolution outcome of each system.

### Resolution

May be understood as *the smallest distance between two measured 3D coordinates* (JCGM 2012).

Most 3D models used for comparisons are not representative of the possible highest resolution outcome of the system. Resolution data (when available) provided by manufacturer/partner.

### Precision

*The higher the precision, the higher the similarities between different measurements of a same area* (JCGM 2012).

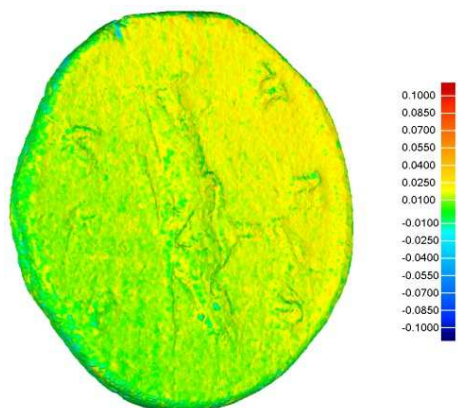
Not possible to determine precision, as only one 3D model from each system were made available.

# 3D Data Analysis

## Complete 3D models: alignment deviation

The same procedures and settings were used for coherency of the comparisons:

- Feature-based alignment, using  $\geq 3$  points, for a first rapid alignment.
- Best fit alignment, for a more refined alignment. Settings: Sample size: 100000 (max. allowed); Tolerance: 0,01mm; High precision fitting; Automatic deviator elimination.



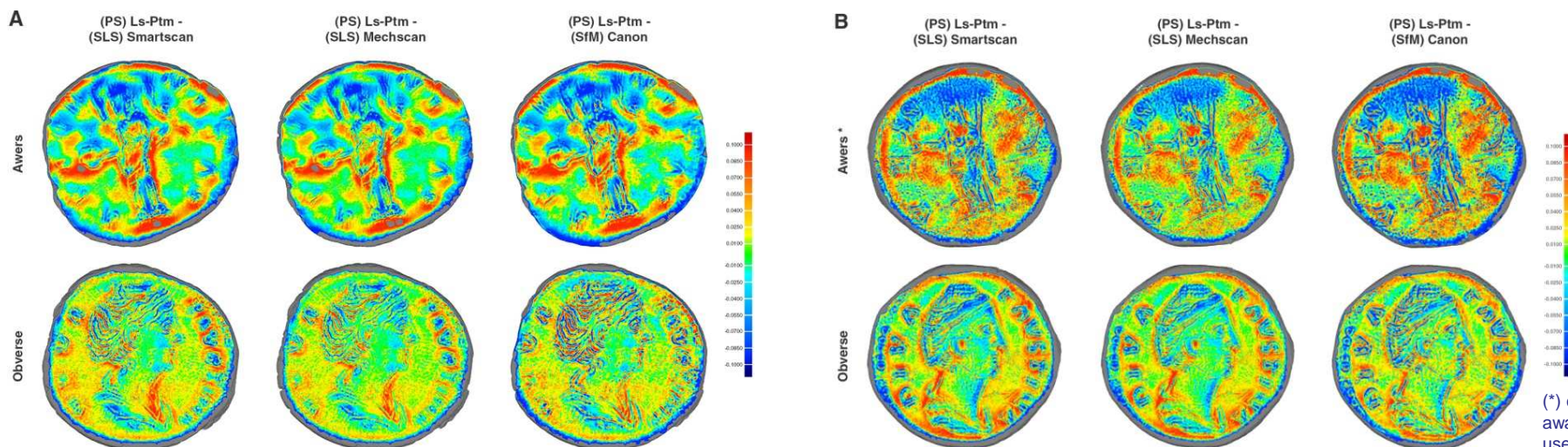
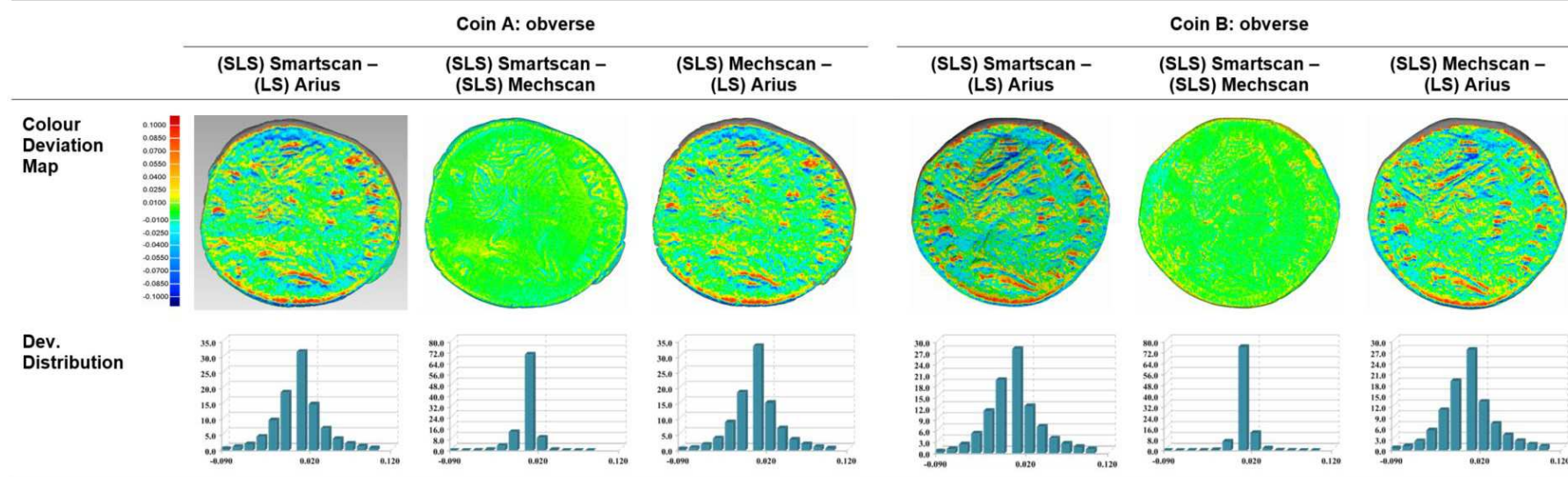
Coin	3D Model [REF: (SLS) Smartscan]	Alignment		Deviation		
		Convergence	RMS Dev.	Max./Min.	Mean	Std.
A	(SLS) Mechscan	$3.01512 \times 10^{-10}$	0.007	-0.01 / 0.01	-0.005	0.004
	(SfM) Canon	$7.801784 \times 10^{-9}$	0.006	-0.01 / 0.01	-0.004	0.005
B	(SLS) Mechscan	$4.12135 \times 10^{-10}$	0.006	-0.01 / 0.01	-0.003	0.005
	(SfM) Canon	$3.193722 \times 10^{-9}$	0.006	-0.01 / 0.01	-0.003	0.005

Alignment between faces not efficient:  
colour deviation map clearly showing an  
angular difference between the faces' planes.

The resulting 3D model of each coin is directly dependent on  
the alignment and merging of its obverse and awers.

# 3D Data Analysis

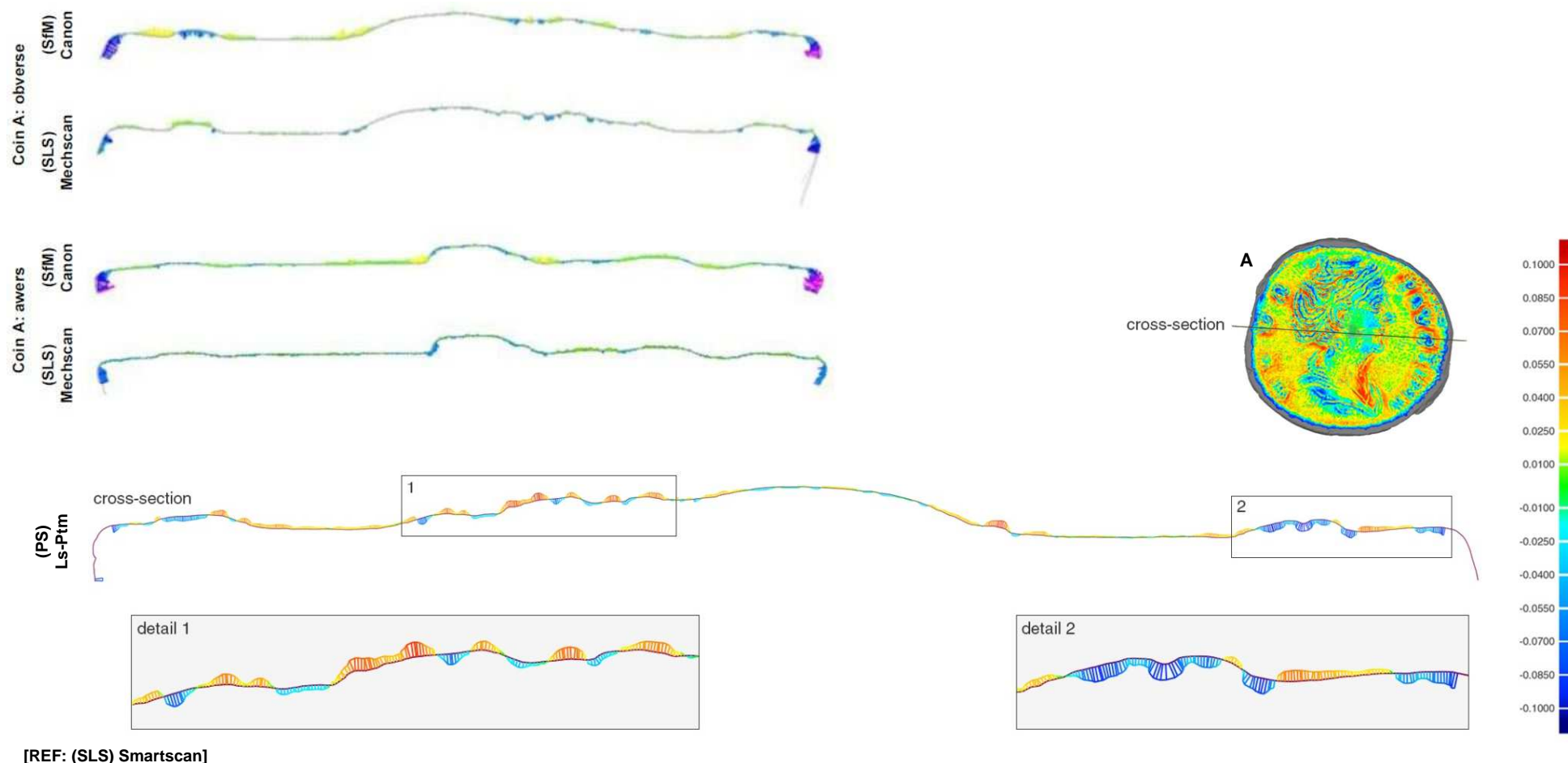
## Obverse & awers: alignment deviation



No angular difference between the face's planes was detected.

# 3D Data Analysis

## Obverse & awers: alignment deviation



Differences in the overall and fine morphology of the coins, due to:  
characteristics of used systems & techniques, as well as used 3D data acquisition and post-processing strategies.

# Data Analysis & Results

## Complete 3D models: topological

3D Model	Software	Coin A		Coin B	
		Vertices (Points)	Triangles (Faces)	Vertices (Points)	Triangles (Faces)
(SLS) Smartscan	CloudCompare	518454	1036902	251967	503930
	Geomagic	518454	1036902	251967	503930
	Meshlab	518454	1036902	251967	503930
	Polyworks	518454	1036902	251967	503930
(SLS) Mechscan	CloudCompare	1342685	2685266	1262963	2525663
	Geomagic	1342685	2685266	1262963	2525663
	Meshlab	1342685	2685266	1262963	2525663
	Polyworks	1342685	2685266	1262963	2525663
(SfM) Canon	CloudCompare	200002	400000	421118	842232
	Geomagic	200002	400000	421118	842232
	Meshlab	200002	400000	421118	842232
	Polyworks	200002	400000	421118	842232

All tested software calculated equally topological data.

# Data Analysis & Results

## Complete 3D models: geometrical and other measurements

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri- meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin A	(real world coin)	-	-	-	323.5	-	-	9.57
	<b>(SLS) Smartscan</b>						0.96	
	CloudCompare	17.95	2.59	539.11	336.42	-	-	9.2
	Geomagic	18.03	2.58	539.11	336.42	-	-	9.2
	Meshlab	17.95	2.59	539.11	336.42	-	-	9.2
	Polyworks	17.95	2.59	539.11	336.42	56.25	-	9.2
	<b>(SLS) Mechscan</b>						0.92	
	CloudCompare	17.99	2.56	549.13	325.39	-	-	9.51
	Geomagic	18.00	2.57	549.13	<i>inv. value</i>	-	-	-
	Meshlab	17.99	2.56	549.18	325.39	-	-	9.51
	Polyworks	17.99	2.56	549.13	325.39	57.24	-	9.51
	<b>(SfM) Canon</b>						0.96	
	CloudCompare	18.28	2.54	525.42	318.6	-	-	9.71
	Geomagic	17.80	2.55	525.42	318.6	-	-	9.71
	Meshlab	18.28	2.54	525.43	318.6	-	-	9.71
	Polyworks	18.28	2.54	525.42	318.6	55.58	-	9.71

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri- meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin B	(real world coin)	-	-	-	338.3	-	-	8.42
	<b>(SLS) Smartscan</b>						0.99	
	CloudCompare	17.72	2.56	530.64	350.44	-	-	8.13
	Geomagic	17.75	2.56	530.64	350.44	-	-	8.13
	Meshlab	17.72	2.56	530.65	350.44	-	-	8.13
	Polyworks	17.72	2.56	530.64	350.44	54.18	-	8.13
	<b>(SLS) Mechscan</b>						0.97	
	CloudCompare	17.77	2.51	539.28	342.35	-	-	8.32
	Geomagic	17.74	2.54	539.28	<i>inv. value</i>	-	-	-
	Meshlab	17.77	2.51	539.3	342.15	-	-	8.33
	Polyworks	17.77	2.51	539.28	342.17	54.59	-	8.32/3
	<b>(SfM) Canon</b>						0.98	
	CloudCompare	16.48	2.56	514.93	337.51	-	-	8.44
	Geomagic	17.54	2.49	514.93	337.5	-	-	8.44
	Meshlab	16.48	2.56	514.94	337.5	-	-	8.44
	Polyworks	16.48	2.56	514.93	337.5	53.88	-	8.44

The tested software did not calculate equally all geometrical data.

The distinct 3D models show differences in the overall and fine morphology.

# Data Analysis & Results

## Complete 3D models: geometrical and other measurements

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri-meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin A	(real world coin)	-	-	-	323.5	-	-	9.57
	(SLS) Smartscan						0.96	
	CloudCompare	17.95	2.59	539.11	336.42	-	-	9.2
	Geomagic	18.03	2.58	539.11	336.42	-	-	9.2
	Meshlab	17.95	2.59	539.11	336.42	-	-	9.2
	Polyworks	17.95	2.59	539.11	336.42	56.25	-	9.2
	(SLS) Mechscan						0.92	
	CloudCompare	17.99	2.56	549.13	325.39	-	-	9.51
	Geomagic	18.00	2.57	549.13	inv. value	-	-	-
	Meshlab	17.99	2.56	549.18	325.39	-	-	9.51
	Polyworks	17.99	2.56	549.13	325.39	57.24	-	9.51
	(SfM) Canon						0.96	
	CloudCompare	18.28	2.54	525.42	318.6	-	-	9.71
	Geomagic	17.80	2.55	525.42	318.6	-	-	9.71
	Meshlab	18.28	2.54	525.43	318.6	-	-	9.71
	Polyworks	18.28	2.54	525.42	318.6	55.58	-	9.71

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri-meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin B	(real world coin)	-	-	-	338.3	-	-	8.42
	(SLS) Smartscan						0.99	
	CloudCompare	17.72	2.56	530.64	350.44	-	-	8.13
	Geomagic	17.75	2.56	530.64	350.44	-	-	8.13
	Meshlab	17.72	2.56	530.65	350.44	-	-	8.13
	Polyworks	17.72	2.56	530.64	350.44	54.18	-	8.13
	(SLS) Mechscan						0.97	
	CloudCompare	17.77	2.51	539.28	342.35	-	-	8.32
	Geomagic	17.74	2.54	539.28	inv. value	-	-	-
	Meshlab	17.77	2.51	539.3	342.15	-	-	8.33
	Polyworks	17.77	2.51	539.28	342.17	54.59	-	8.32/3
	(SfM) Canon						0.98	
	CloudCompare	16.48	2.56	514.93	337.51	-	-	8.44
	Geomagic	17.54	2.49	514.93	337.5	-	-	8.44
	Meshlab	16.48	2.56	514.94	337.5	-	-	8.44
	Polyworks	16.48	2.56	514.93	337.5	53.88	-	8.44

## Shape Factor

aka **Circularity** =  $(4\pi A) / p^2$

“As the **appearance** of an ancient coin is often unique (...), the **shape of the coin edge** is regarded to be an important feature to characterize a coin” (Huber-Mörk et al., 2012).

# Data Analysis & Results

## Complete 3D models: geometrical and other measurements

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri-meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin A	(real world coin)	-	-	-	323.5	-	-	9.57
	(SLS) Smartscan						0.96	
	CloudCompare	17.95	2.59	539.11	336.42	-	-	9.2
	Geomagic	18.03	2.58	539.11	336.42	-	-	9.2
	Meshlab	17.95	2.59	539.11	336.42	-	-	9.2
	Polyworks	17.95	2.59	539.11	336.42	56.25	-	9.2
	(SLS) Mechscan						0.92	
	CloudCompare	17.99	2.56	549.13	325.39	-	-	9.51
	Geomagic	18.00	2.57	549.13	inv. value	-	-	-
	Meshlab	17.99	2.56	549.18	325.39	-	-	9.51
	Polyworks	17.99	2.56	549.13	325.39	57.24	-	9.51
	(SfM) Canon						0.96	
	CloudCompare	18.28	2.54	525.42	318.6	-	-	9.71
	Geomagic	17.80	2.55	525.42	318.6	-	-	9.71
	Meshlab	18.28	2.54	525.43	318.6	-	-	9.71
	Polyworks	18.28	2.54	525.42	318.6	55.58	-	9.71

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri-meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin B	(real world coin)	-	-	-	338.3	-	-	8.42
	(SLS) Smartscan						0.99	
	CloudCompare	17.72	2.56	530.64	350.44	-	-	8.13
	Geomagic	17.75	2.56	530.64	350.44	-	-	8.13
	Meshlab	17.72	2.56	530.65	350.44	-	-	8.13
	Polyworks	17.72	2.56	530.64	350.44	54.18	-	8.13
	(SLS) Mechscan						0.97	
	CloudCompare	17.77	2.51	539.28	342.35	-	-	8.32
	Geomagic	17.74	2.54	539.28	inv. value	-	-	-
	Meshlab	17.77	2.51	539.3	342.15	-	-	8.33
	Polyworks	17.77	2.51	539.28	342.17	54.59	-	8.32/3
	(SfM) Canon						0.98	
	CloudCompare	16.48	2.56	514.93	337.51	-	-	8.44
	Geomagic	17.54	2.49	514.93	337.5	-	-	8.44
	Meshlab	16.48	2.56	514.94	337.5	-	-	8.44
	Polyworks	16.48	2.56	514.93	337.5	53.88	-	8.44

*“In some coinages the comparison of **Weights** among series may determine the **standard** to which that **series** was struck; this in turn may be significant for **chronology** or **attribution**”*  
(<http://numismatics.org/>).

Coin	Survey Institution	Digital Scale model	Weight (g)
A	RBINS	Sartorius B120S	3.0939
	ITAM	n.a	3.0944
B	RBINS	Sartorius B120S	2.8486
	ITAM	n.a	2.8484

# Data Analysis & Results

## Complete 3D models: geometrical and other measurements

	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri-meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin A	(real world coin)	-	-	-	323.5	-	-	9.57
	(SLS) Smartscan						0.96	
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	Geomagic	18.03	2.58	539.11	336.42	-	-	9.2
	Meshlab	17.95	2.59	539.11	336.42	-	-	9.2
	Polyworks	17.95	2.59	539.11	336.42	56.25	-	9.2
	(SLS) Mechscan						0.92	
	CloudCompare	17.99	2.56	549.13	325.39	-	-	9.51
	Geomagic	18.00	2.57	549.13	inv. value	-	-	-
	Meshlab	17.99	2.56	549.18	325.39	-	-	9.51
	Polyworks	17.99	2.56	549.13	325.39	57.24	-	9.51
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	3D Model & Software	Max. Diameter (mm)	Max. Thick. (mm)	Surface Area (mm <sup>2</sup> )	Volume (mm <sup>3</sup> )	Peri-meter (mm)	Shape Factor	Density (g/cm <sup>3</sup> )
Coin B	(real world coin)	-	-	-	338.3	-	-	8.42
	(SLS) Smartscan						0.99	
	CloudCompare	17.72	2.56	530.64	350.44	-	-	8.13
	Geomagic	17.75	2.56	530.64	350.44	-	-	8.13
	Meshlab	17.72	2.56	530.65	350.44	-	-	8.13
	Polyworks	17.72	2.56	530.64	350.44	54.18	-	8.13
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	CloudCompare	17.77	2.51	539.28	342.35	-	-	8.32
	Geomagic	17.74	2.54	539.28	inv. value	-	-	-
	Meshlab	17.77	2.51	539.3	342.15	-	-	8.33
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	Meshlab	16.48	2.56	514.94	337.5	-	-	8.44
	Polyworks	16.48	2.56	514.93	337.5	53.88	-	8.44

### Density $\rho = m / V$





Relevant “to identify **differences** between the **theoretical** and the **real density** when coins were plated (for instance, a silver over a copper core)” (Zambanini, 2009). It does not take into consideration >2 elements, alloys, etc.

- Using Gas Pycnometer (ITAM).** Method takes into consideration accessible voids (i.e. total amount of empty space, e.g., cracks or bubbles, accessible from surface of real coin).
- Using Volume of 3D digital surface model.** Method may not take into consideration possible voids.

Coin	Survey Institution	Digital Scale model	Weight (g)
A	RBINS	Sartorius B120S	3.0939
	ITAM	n.a	3.0944
B	RBINS	Sartorius B120S	2.8486
	ITAM	n.a	2.8484

# Test Coins

## Brief characterization

	coin A		coin B		
obverse		<p>Inscription/figure: DIVA FAUSTINA, AETER-NITA</p> <p>Border 'of dots'.</p> <p>No control-marks.</p> <p>Max. Diameter</p> <p>Thickness</p> <p>Surface Area</p> <p>Volume</p> <p>Perimeter</p> <p>Circularity</p> <p>Axis</p> <p>Weight</p> <p>Density</p> <p>...</p>			<p>Inscription/figure: DIVA FAUSTINA, VES-TA</p> <p>Border 'of dots'.</p> <p>No control-marks.</p> <p>Max. Diameter</p> <p>Thickness</p> <p>Surface Area</p> <p>Volume</p> <p>Perimeter</p> <p>Circularity</p> <p>Axis</p> <p>Weight</p> <p>Density</p> <p>...</p>
avers					

(photos by L.W. MacDonald)

However, it's not the measurement *per se* that matters, it's what we do with it.

To get **useful information!**

Larger dataset needed for comparison and interpretation of relevant geometrical and other features.

# Test Coins

## Brief characterization

coin A

obverse



Inscription/figure:  
DIVA FAUSTINA,  
AETER-NITA

Border 'of dots'.  
No control-marks.

Max. Diameter

Thickness

Surface Area

Volume

Perimeter

Circularity

Axis

Weight

Density

...

avers



coin B



Inscription/figure:  
DIVA FAUSTINA,  
VES-TA

Border 'of dots'.  
No control-marks.

Max. Diameter

Thickness

Surface Area

Volume

Perimeter

Circularity

Axis

Weight

Density

...

boarder

legend

field

type



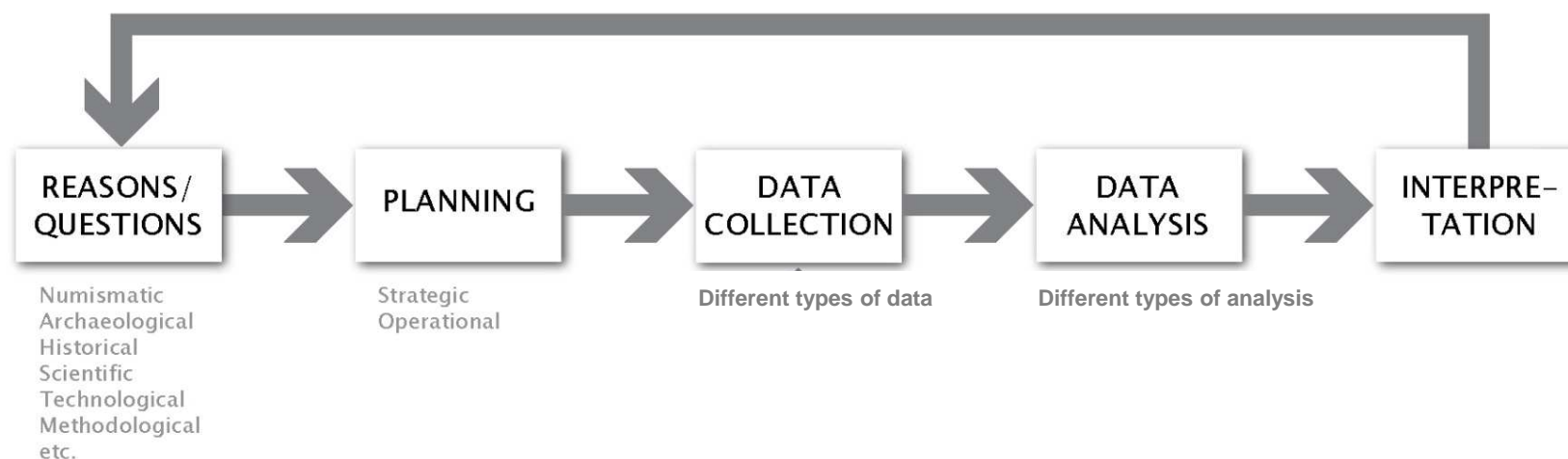
(photos by L.W. MacDonald)

**Advantages:** digital documentation, extraction of additional features, quantitative characterization and analysis. Also enabling digital databases and querying, dissemination, etc.

# STSM's Aims

to contribute to:

- ✓ The development of an efficient and comprehensive **methodological framework** for the **3D digital data capture, processing and analysis of historical silver coins.**



Every project should start with a **Reason/Question**.

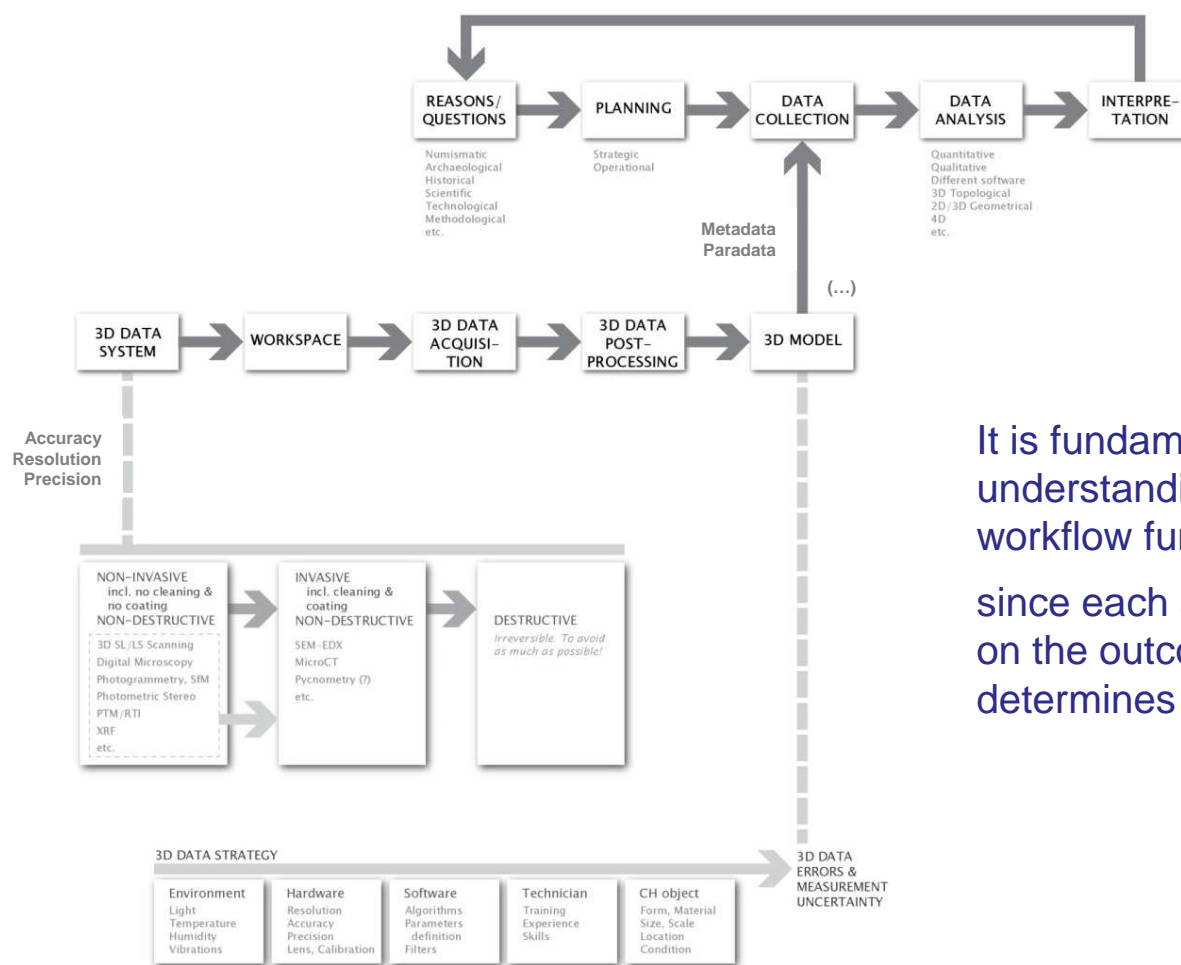
**Before acquiring 3D (or other) data**, set clearly:

*Why is 3D data required? What for is it needed? What resolution, accuracy and outputs are required?  
Are all the necessary equipment, software and know-how available? What are the alternatives?...*

# STSM's Aims

to contribute to:

- ✓ The development of an efficient and comprehensive **methodological framework** for the **3D digital data capture, processing and analysis of historical silver coins.**



It is fundamental to have a thorough understanding and knowledge of how the workflow functions,

since each stage of the process depends on the outcome of the previous ones and determines the subsequent ones.

# STSM's Aims

to contribute to:

- ✓ Establish whether the selected **recording 3D systems and techniques** can support the comparison of certain **features and properties**;
  - As expected, **distinct systems, techniques and methods** used to acquire and process 3D data lead to **differences** in the **topology**, as well as in the **overall and fine morphology** of the coins.
  - **Depending** on the **reasons/questions** behind and **scale of analysis**, the accuracy, resolution and precision of the 3D systems and techniques should be high enough to fulfil the needs for an improved scientific documentation and study of coins.
  - These issues are of great importance, as they **may affect** the **analysis, classification, and interpretation of the CH object** - e.g. variations in the hammering process, die, mint signs, scratches, wear pattern of the used stamp, or cut and punch-marks.
  - Which also raises the importance of linking **metadata, paradata** and other meaningful information to the data when dealing with it.

# STSM's Aims

to contribute to:

- ✓ A better knowledge about the **surface characteristics** of historic coins, by characterizing and analysing a number of relevant **geometrical** and **topological** features, using distinct **metrological software, techniques** and **procedures**;
- The 3D models enabled a **quantitative characterization** of the coins, as opposed to descriptive and subjective ones.
- All tested **software calculated equally topological data**.
- A few basic and advanced **geometric and other measurements** of the coins were undertaken.
- The tested **software did not calculate equally all geometrical data**.
- The distinct **3D models** show **differences** in the **overall and fine morphology**.
- The **sample** (2 coins) is **too small** to help resolving **numismatic questions**, such as: changes of die (e.g., reworked version), type, wear/damage, etc., over time; attribution of die, technique of production, producer, place, period.  
Larger dataset/reference collection needed for the comparison and interpretation of relevant geometrical and other features.
- Although a **3D digital model** does not provide a complete picture of the object, it **should be understood as a highly powerful tool – potentially, with valid data – for CH research**, and complementary to other measurement techniques (e.g., used in this case study) and fields of knowledge.

# STSM's Aims

to contribute to:

**Ongoing Publication of a guide to good documentation practice**, incl. digital preservation guidelines.

<https://coschromancoins.wordpress.com/>

BENTKOWSKA-KAFEL, A., DEL HOYO MELENDEZ, J.M., MACDONALD, L.W., MATHYS, A., MOITINHO DE ALMEIDA, V. (2016). "Colour and Space in Cultural Heritage in 6Ds. The interdisciplinary connections". In *Keep the Revolution Going*. S. Campana, R. Scopigno, G. Carpentiero & M. Cirillo (eds.). Oxford: Archaeopress. Vol.1, pp. 953-962.

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MOITINHO DE ALMEIDA, V. (2015). Metadata and Paradata record template. COSCH's case study "Study of Roman silver coins using spectroscopic and 3D imaging approaches" internal document. COST Action TD1201.

(...)

## In short,

- Start with a reason or question
- Draw a plan
- Use the same method & procedures (or state which were used),  
for coherency of comparisons
- Save raw data
- Save metadata & paradata
- Share data (in time)



(photo by J. Valach)

London meeting – UCL, 22.June.2016.