3D RECORDING OF SCULPTURES AND SMALL OBJECTS

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The main characteristic of the digitisation of sculptures and movable items of cultural heritage, that distinguishes it from the documentation of buildings and archaeological sites, is the size of the documented item. It usually does not exceed the size of the human body, if we do not count monumental sculptures that were not subject to research.[1] A special category of cultural heritage includes museum objects, historical sacral furniture and outdoor historical sculptures. The digitisation of an object performed in the interior poses a specific problem from the perspective of light parameters and parameters of the available space.

The case studies were processed in notebook Lenovo Y50 (Intel(R) Core(TM) i7-4710HQ CPU@ 2,50 GHz, RAM 16 GB, GPU NVIDIA GeForce GTX 860M, OS W8). In the case of SLS application, Artec Eva with Artec Studio 10 software was used. Artec Studio enables the whole workflow pipeline, from scanning through fine registration of particular scans, their alignment and subsequent global registration, up to the fusion encompassing removal of outliers and mesh generation with sharp or smooth fusion algorithm. The final step refers to the mesh simplification and its texturing (Figure 80).

For IbM, Agisoft Photoscan softwarwe was used with the following parameters set for the batch processing workflow: step – align photos (high accuracy with the key point limit of 40,000 and the tie point limit of 20,000 points); step – refinement of alignment (decreasing of global re-projection error to max. 1px); step – build dense point cloud (medium quality, aggressive depth filtering); step – build mesh (arbitrary surface type, dense

1 Large monumental statues, high plague columns and monuments fall into the category of immovable objects; the principles defined in the chapter about the digitisation of architectural objects also apply to these.

point cloud as source data, interpolation enabled, custom face count: various values), and step – build texture (generic mapping mode, texture from all cameras, blending mode Mosaic, texture size 4096 texture count 1, and no colour correction) (Figure 81). When using CapturingReality RC, the parameters were as follows: step – align photos (max. feature per image 120,000, pre-selector feature 60,000, image overlap medium, detector sensitivity medium, max. re- projection error 2px); step – reconstruction (normal detail); step – build texture (Guter 3, texture resolution 8192, large triangle removal threshold 10, maximal texture count style, visibility based texture style) (Figure 82.).

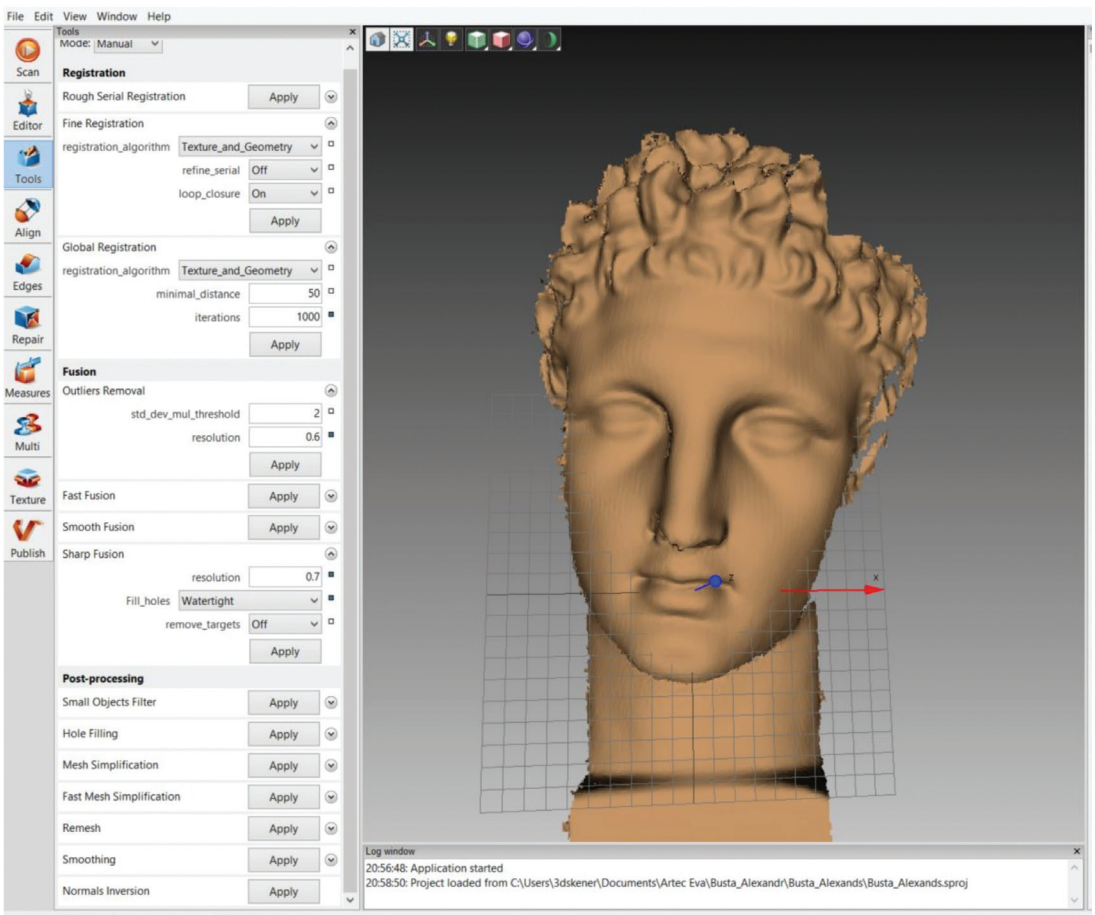


Figure 80. Workspace of Artec Studio with the settings used for processing scans.

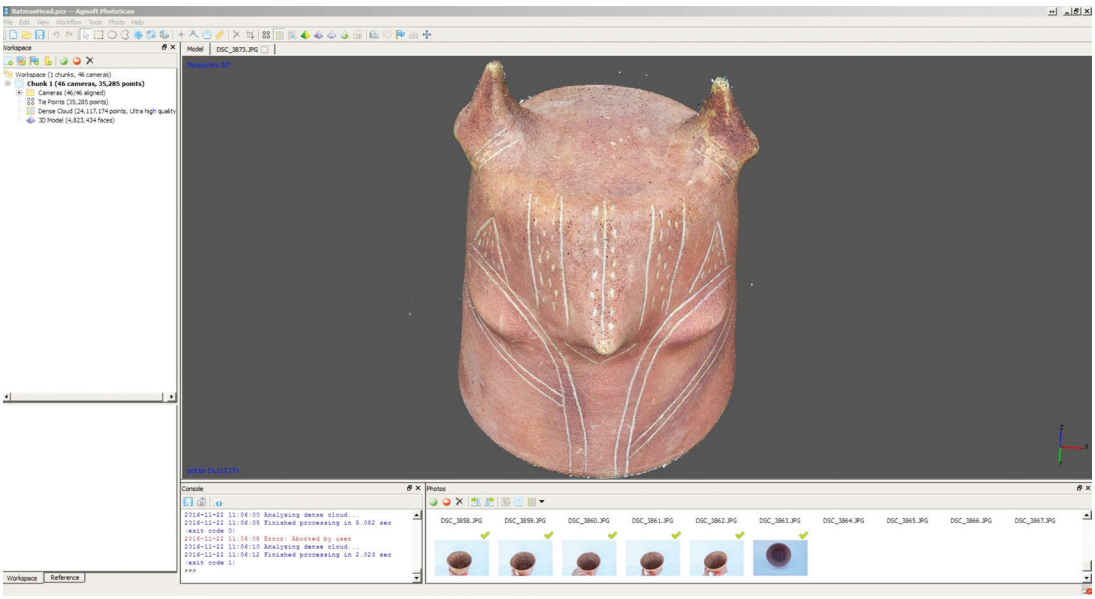


Figure 81. Workspace of Agisoft Photoscan.

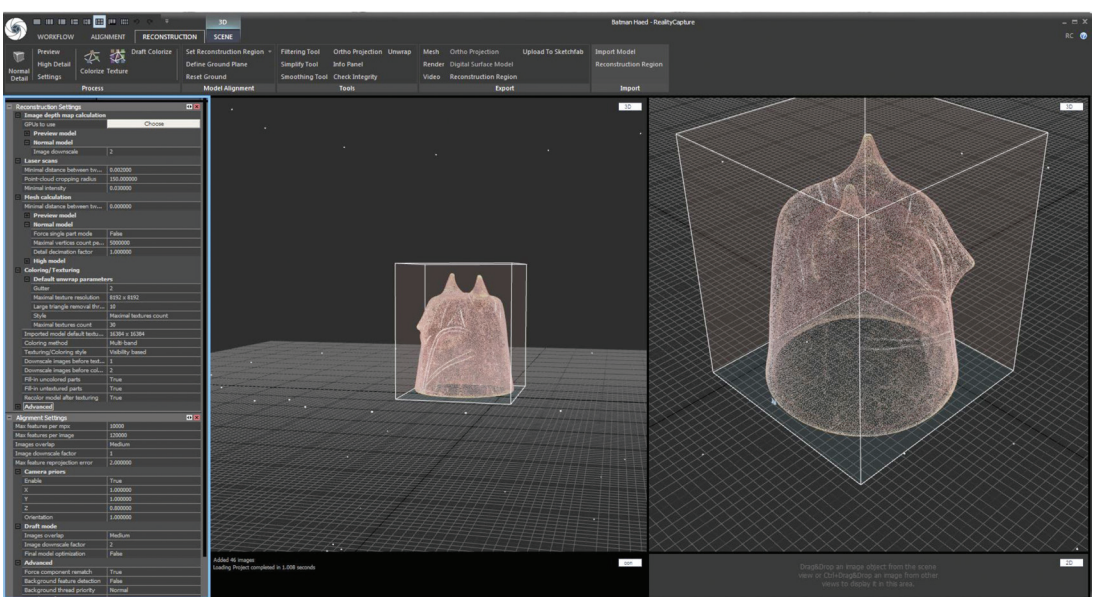


Figure 82. Workspace of CapturingReality RC.

Sculptures of St. John of Nepomuk and St. Florian, Beckov

Location:	Church of St. Stephen the King, Beckov, Nové Mesto nad Váhom District
Object:	Sculptures of St. John of Nepomuk and St. Florian
Material:	Stone without surface treatment (sandstone)
Dating:	18th century
Recording technology:	IbM
Recording equipment:	Camera Nikon D90 (optics AF-S Nikkor 16-85 f/3.5-5.6 ED VR DX)
Software:	Agisoft Photoscan 1.0.0, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figs. 83-85)
Short description:	Both Baroque sculptures sit on pillars flanking the entrance gate leading to the Church of St. Stephen the King. Their rendering represents a good example of the regional Baroque artwork. The pictures were taken by handheld camera (from folding lader). Background masking was not used for the processing in Agisoft Photoscan.

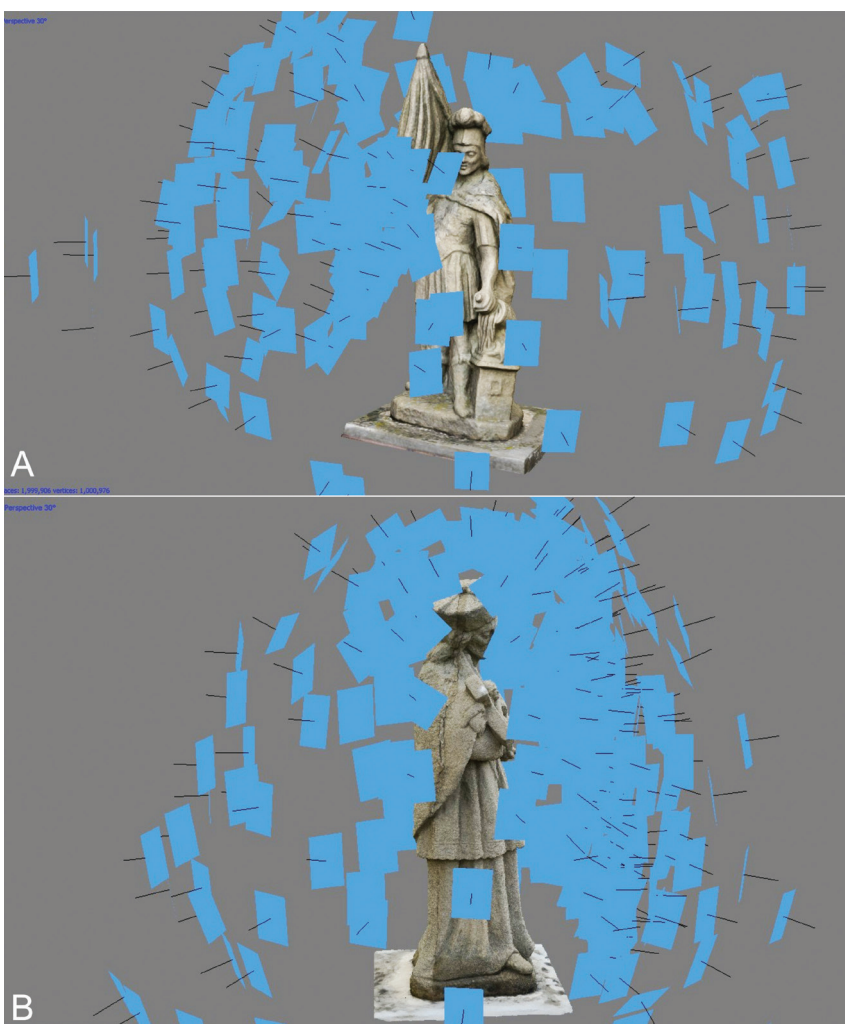


Figure 83. Sculptures of St. John Nepomuk and St. Florian, IbM. Positions of the cameras during photo taking. A: St. Florien (186 photos 24Mpx), B: St. John Nepomuk (269 photos 24Mpx).

Figure 84. Sculpture of St. John Nepomuk. A: textured 3D model, B: shaded 3D model.

Figure 85. Sculpture of St. Florian. A: textured 3D model, B: shaded 3D model.

Sculpture of the Virgin, Nové Mesto nad Váhom

Location:	Premises of the Virgin Mary Prepositure, Nové Mesto nad Váhom, W Slovakia
Object:	Sculpture of the Virgin Mary
Material:	Stone without surface treatment (limestone)
Dating:	18th century
Recording technology:	IbM
Recording equipment:	Camera Nikon D90 (optics AF-S Nikkor 16-85 f/3.5-5.6 ED VR DX)
Software:	Agisoft Photoscan 1.0.0, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figs. 86, 87)
Short description:	The Baroque limestone sculpture of the Virgin Mary is situated on the premises of the Virgin Mary Prepositure on the lawn in front of the northern wall of the Church of the Nativity of the Virgin Mary. It represents a sophisticated piece of Baroque art with an emphasis on the dynamic folds of the drapery and the expressive gestures. Iconographically, it represents a specific type with elements of 'Regina Coeli' (the motif of a crown and a sceptre) and 'Immaculata' (the motif of Earth with a serpent underfoot). The sculpture was made in a life size. The ladder was used for capturing upper parts of the crown. The photographs for IbM were taken by the 'walk-around method'. Background masking was not used for processing of the data in Agisoft Photoscan.

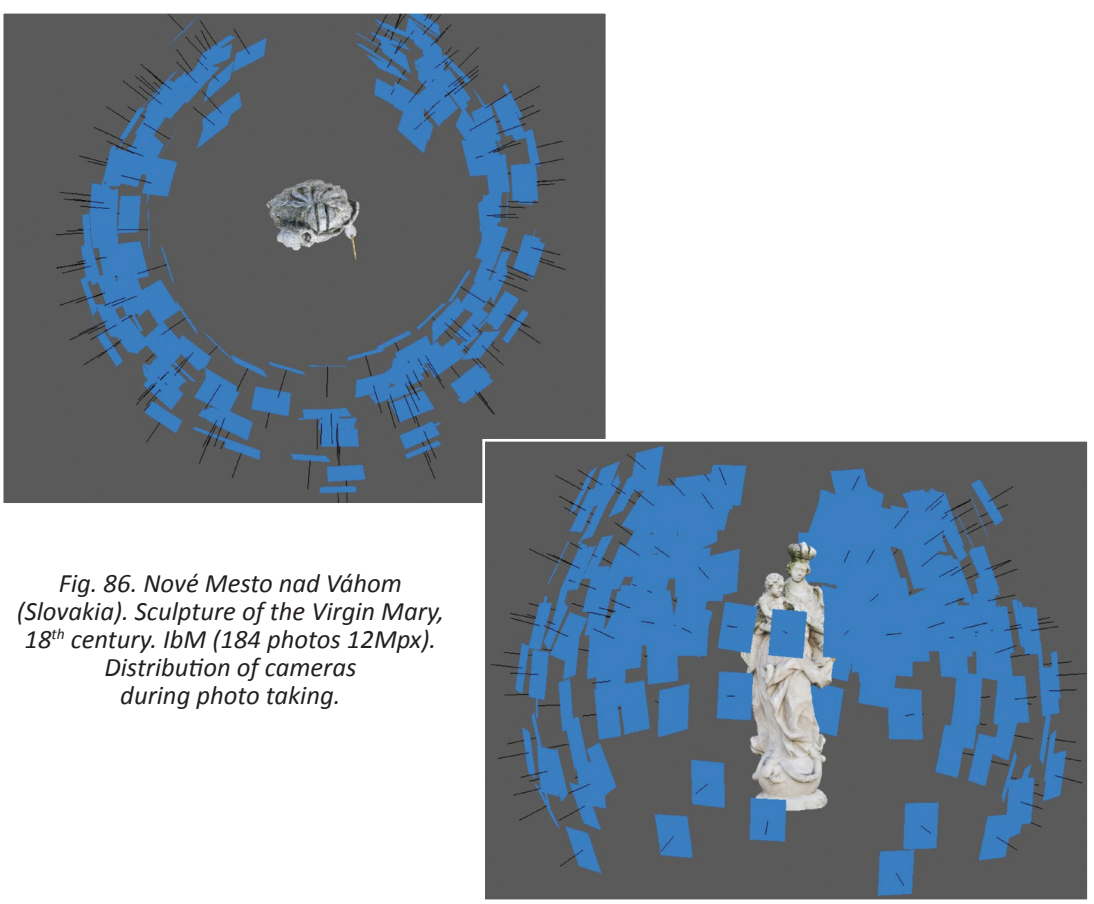


Fig. 86. Nové Mesto nad Váhom (Slovakia). Sculpture of the Virgin Mary, 18th century. IbM (184 photos 12Mpx). Distribution of cameras during photo taking.

Figure 87. Sculpture of the Virgin Mary, Nové Mesto nad Váhom (Slovakia), 18th century. A: textured 3D model, B: shaded 3D model visualised in the ambient occlusion mode, C: shaded 3D model – detail.

Altar sculptures, Church of St. Barbara, Žilina

Location:	Church of St. Barbara, Žilina, NW Slovakia
Object:	Altar sculptures; figure of an angel, figure of St. Joachim
Material:	Polychrome wood (the polychrome is recent)
Dating:	18th century
Recording technology:	SLS
Recording equipment:	Artec Eva Scanner
Software:	Artec Studio 10, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figs. 88-90)
Short description:	The sculptures form part of the main altar decoration of the early 18th century Franciscan Church of St. Barbara in Žilina. They are attributed to the Baroque artist Anton Weissmann. The sculptures were made in a life size and they bear typical features of the so-called Gothicising Baroque, especially visible in the carving of St. Joachim's face, which has markedly sunken cheeks and 'Gothicising' line of the forehead and cheekbones. On the other hand, the drapery is depicted in a dramatic movement in line with the principles of dynamic rhythm of the Baroque. The altar was under comprehensive reconstruction at the time of recording, and parts of it were dismantled. The sculptures were recorded by TLS Artec Eva in the sacristy, without any special lighting, and by using only the local light source. The distance of Artec Eva was between 40 cm and 100 cm from the surface of the sculptures. For this reason, it was rather complicated to capture the inward-facing parts of the drapery folds since they remained outside the range of the structured light created by the primary motion of the scanner. This produced undesirable digitisation shadows. The repeated attempts at capturing these parts of the sculptures consequently multiplied the number of partial scans and this, eventually, prolonged the data processing stage.

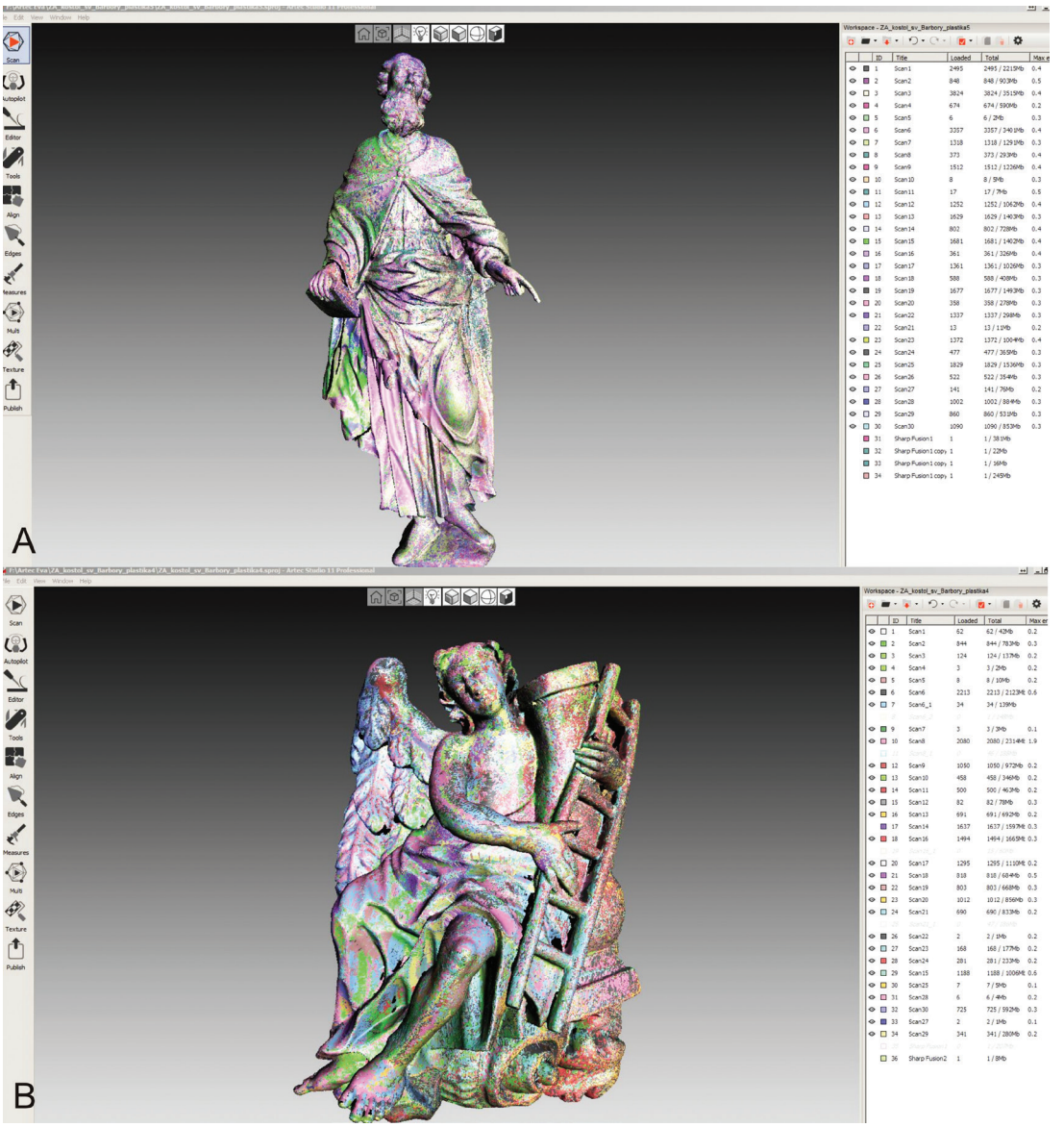


Figure 88. Altar sculptures, church of St. Barbara, Žilina. SLS Artec Eva.
Visualisation of particular scans (each scan is depicted with a unique colour) in Artec Studio.
A: St. Joachim. 30 scans, B: Baroque angel, 29 scans.

Figure 89. Altar sculptures, church of St. Barbara, Žilina. SLS Artec Eva. 3D model of the Baroque angel. A: textured model, B: shaded model with ambient occlusion filter applied.

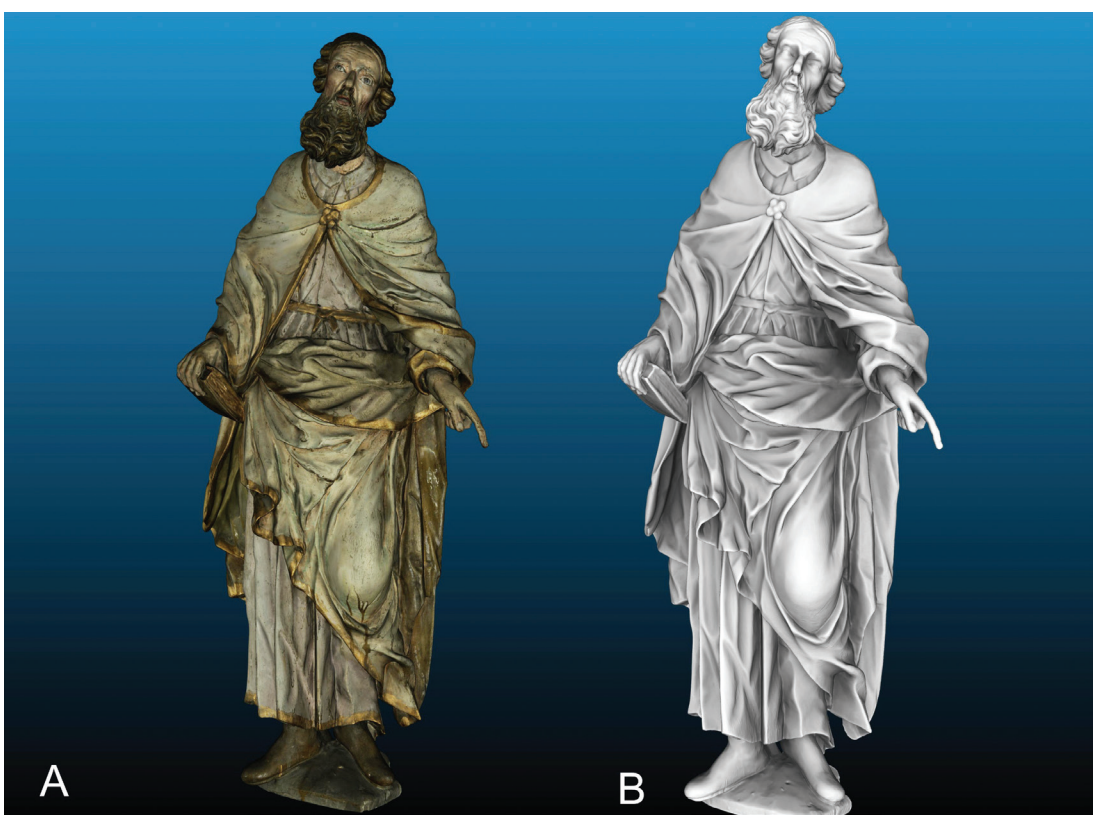


Figure 90. Altar sculptures, church of St. Barbara, Žilina. SLS Artec Eva. 3D model of St. Joachim. A: textured model, B: shaded model with ambient occlusion filter applied.

Copy of the sculpture of Virgin Mary, Žilina,

Location:	Monuments Board Office, Žilina, NW Slovakia
Object:	Copy of the sculpture of the Virgin Mary
Material:	Plaster
Dating:	15th century (original)
Recording technology:	SLS
Recording equipment:	Artec Eva Scanner
Software:	Artec Studio 10, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figs. 91, 92)
Short description:	The recorded sculpture of the Virgin Mary is a life-size replica of the medieval original from Levoča. Scanning using the SLS Artec Eva took place in the interior of an office, using the available lights and without any special lighting.

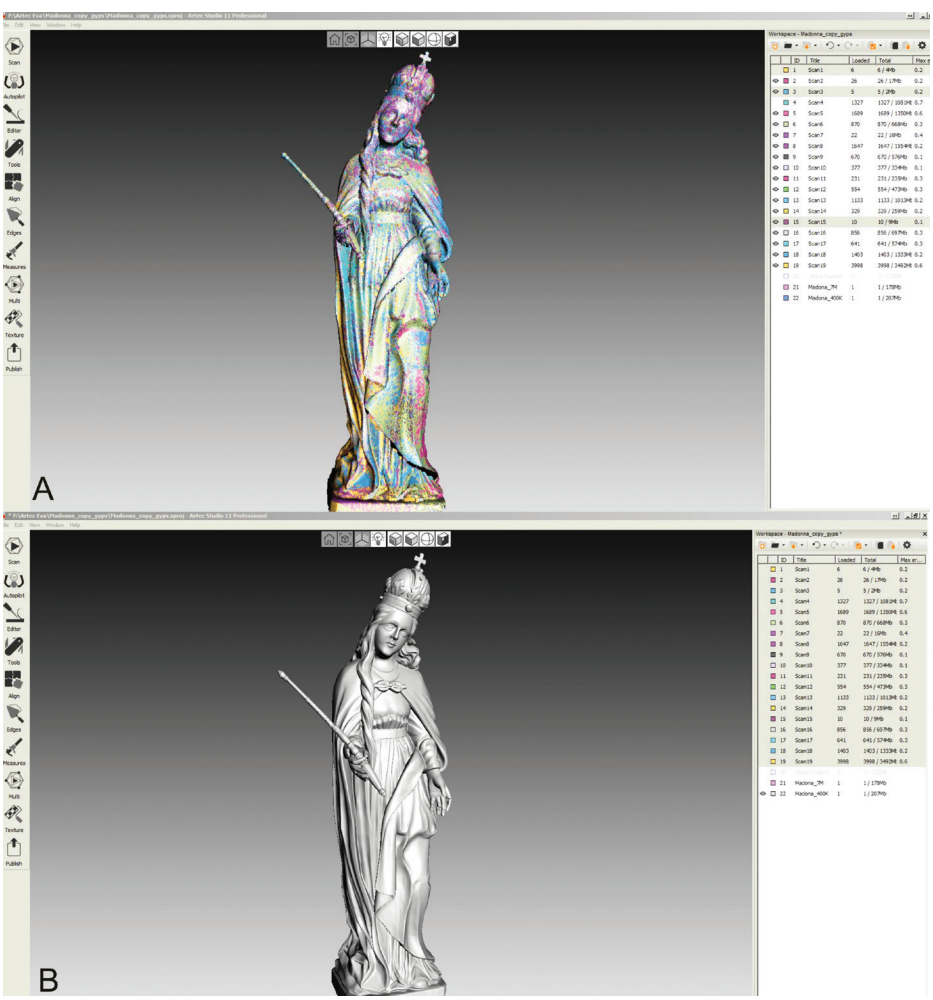


Figure 91. Plaster copy of the Virgin Mary sculpture (15th century, original), Žilina. SLS Artec Eva. A: visualisation of particular scans (each scan depicted with a unique colour) in Artec Studio (20 scans), B: visualisation of the final mesh (3D model) in Artec Studio.

Figure 92. Plaster copy of the Virgin Mary sculpture (15th century, original), Žilina. SLS Artec Eva. Shaded model with ambient occlusion filter applied.

Ceramic pot

Site:	Bratislava Castle, south-western Slovakia
Object:	Pot
Material:	Ceramics
Dating:	9th century
Recording technology:	SLS, IbM
Recording equipment:	Artec Eva Scanner, camera Nikon D90 (optics AF-S Nikkor 16-85 f/3.5-5.6 ED VR DX)
Software:	Artec Studio 10, Agisoft Photoscan Pro1.0.0, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figure 93)
Short description:	Both IbM and SLS (Artec Eva) were used in the digitisation. For IbM, monochromatic background was used and images were taken by the walk-around method. After the upper part and the inside of the vessel were photographed, the vessel was turned over for photographing the lower part and the bottom. The sequences of images from both sets of photographs were processed at the same time. No special lighting was used.

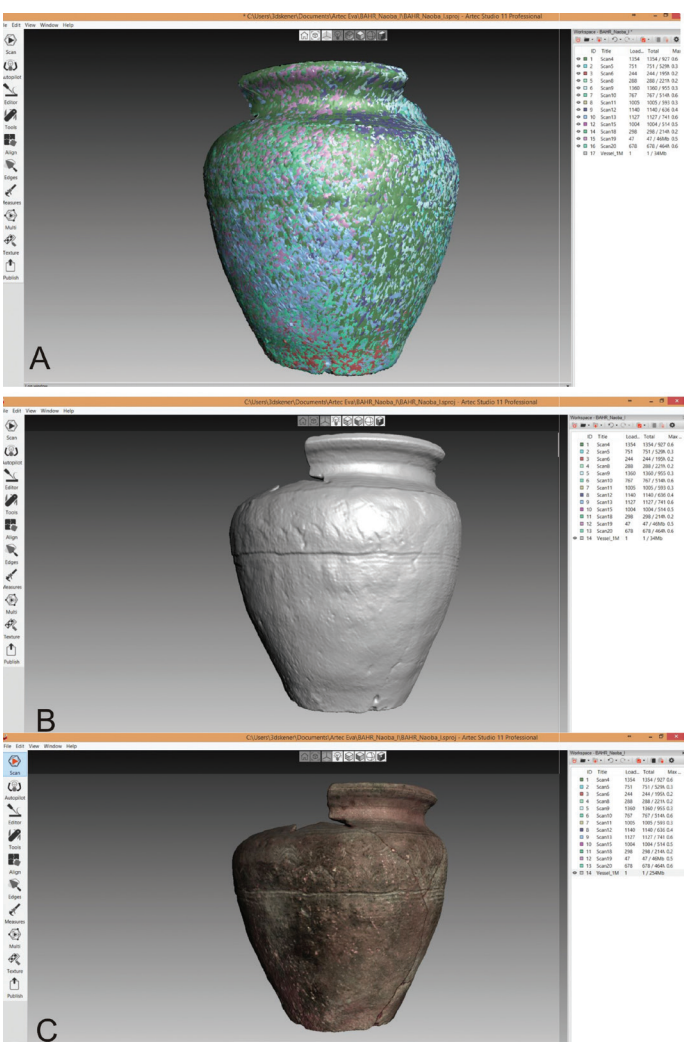


Figure 93. Clay vessel, 9th century, Bratislava Castle. SLS Artec Eva.

A: visualisation of particular scans (each scan is depicted with a unique colour) in Artec Studio (13 scans).

B: visualisation of the textured final mesh (3D model) in Artec Studio.

C: visualisation of the shaded final mesh (3D model) in Artec Studio.

Architectural elements, fragment of a vault rib

Site:	Prepositure of the Virgin Mary, Nové Mesto nad Váhom, SW Slovakia
Object:	Fragment of a vault rib
Material:	Stone
Dating:	14th-15th century
Recording technology:	SLS
Recording equiment:	Artec Eva Scanner,
Software:	Artec Studio 10, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figs. 94, 95)
Short description:	Fragment of a vault rib was found during the archaeological research of the premises of the Prepositure of the Virgin Mary (2014). Individual fragments of the collapsed vault were found in the debris of the building interior. The scanning was performed by SLS Artec Eva in the interior of the structure and without any special lighting.

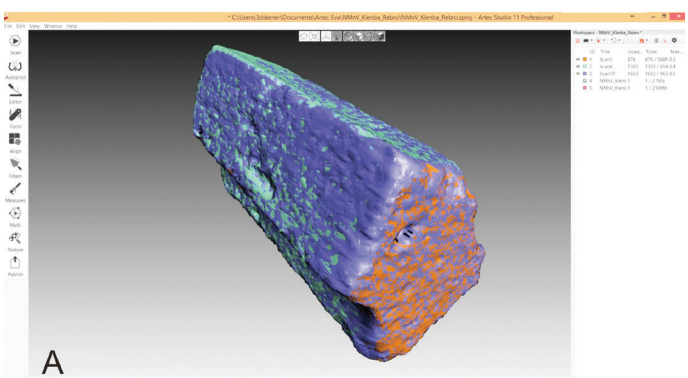
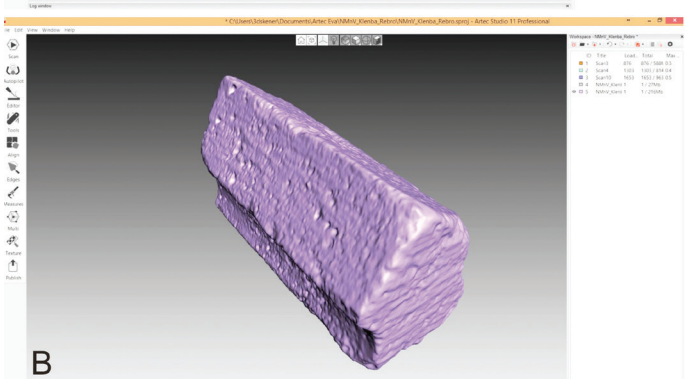
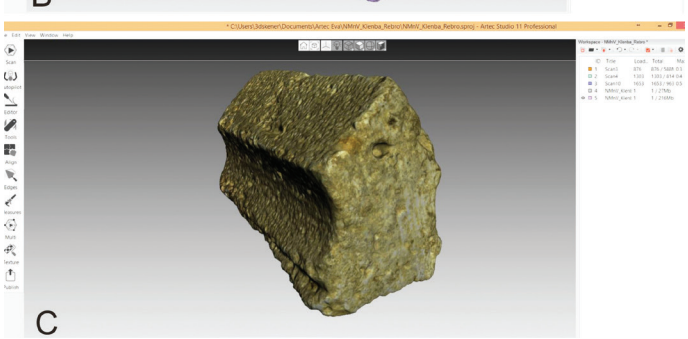


Figure 94. Fragment of a vault rib, 14th-15th century. Nové Mesto nad Váhom. SLS Artec Eva.

A: Visualisation of particular scans (each scan depicted with a unique colour) in Artec Studio (3 scans).



B: Visualisation of the textured final mesh (3D model) in Artec Studio.



C: Visualisation of the shaded final mesh (3D model) in Artec Studio.

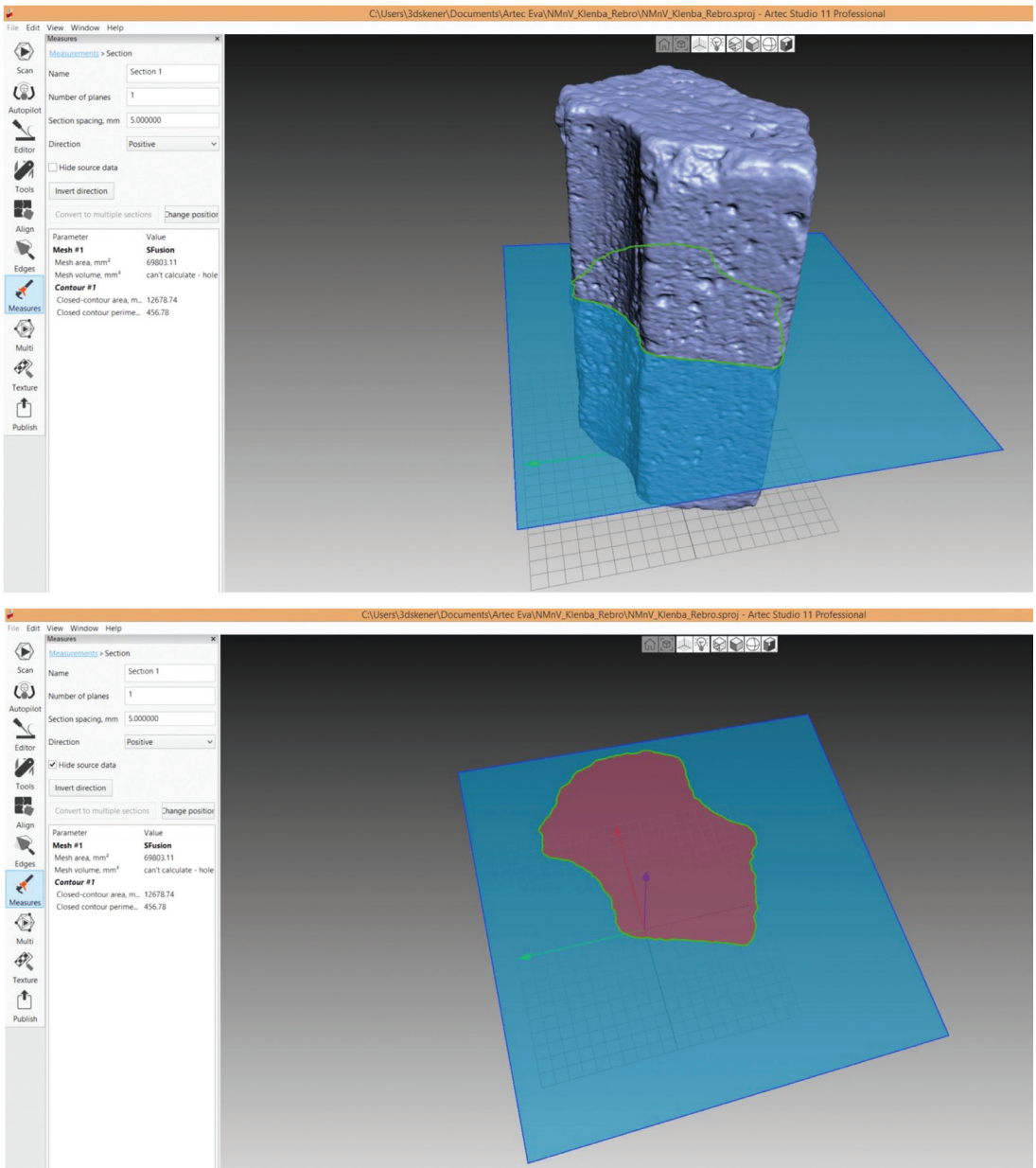


Figure 95. Fragment of a vault rib, 14th-15th century, Nové Mesto nad Váhom. SLS Artec Eva. Cross-section generation in Artec Studio software.

Prehistoric sculptures

Site:	Vinča, Serbia
Object:	Prehistoric sculptures
Material:	Ceramics
Dating:	Neolithic
Recording technology:	IbM
Recording equipment:	Camera Nikon D5100 (optics AF-S Nikkor 16-85 f/3.5-5.6 ED VR DX)
Software:	Agisoft Photoscan Pro1.0.0, CloudCompare 2.7
Record:	Scaled 3D model (mesh) (Figs. 96 - 98)
Short description:	Outdoor recording in IbM ('turntable method', natural light; camera placed on a stand, photos were taken by remote control). The movement (SfM principle), was provided by manual rotation of the object. The object was photographed in several 360 degree-rotation sequences to capture all of its parts. Since the photos were taken with a monochromatic background, they did not have to be de-masked during the processing stage. Processing of all photographed sequences was done at the same time.

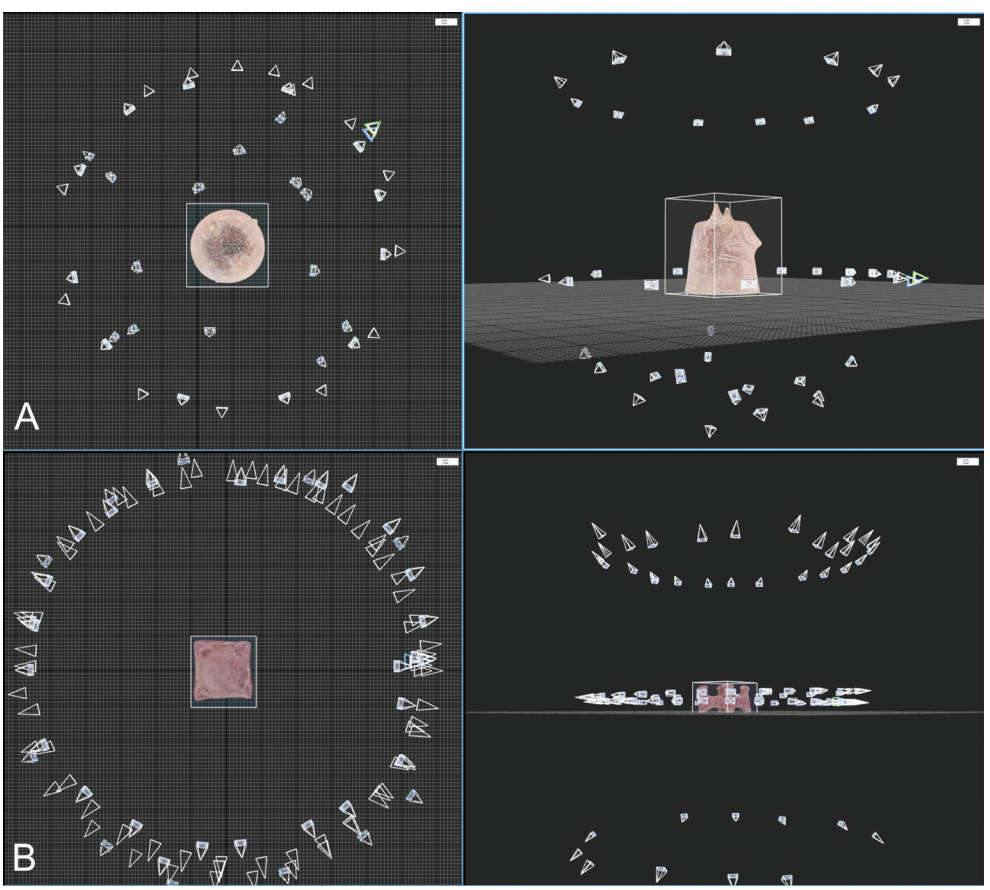


Figure 96. Positions of photographs taken within the IbM 'turntable method'. Software: Capturing Reality RC. Although the camera was static and the object was turned on the turntable, software treats the whole procedure as SfM, i.e. as if the camera was moving. Left window – nadir view, right window – side view. A: ritual object made of clay (46 photos 12Mpx), B: ritual object made of clay (113 photos 12Mpx).

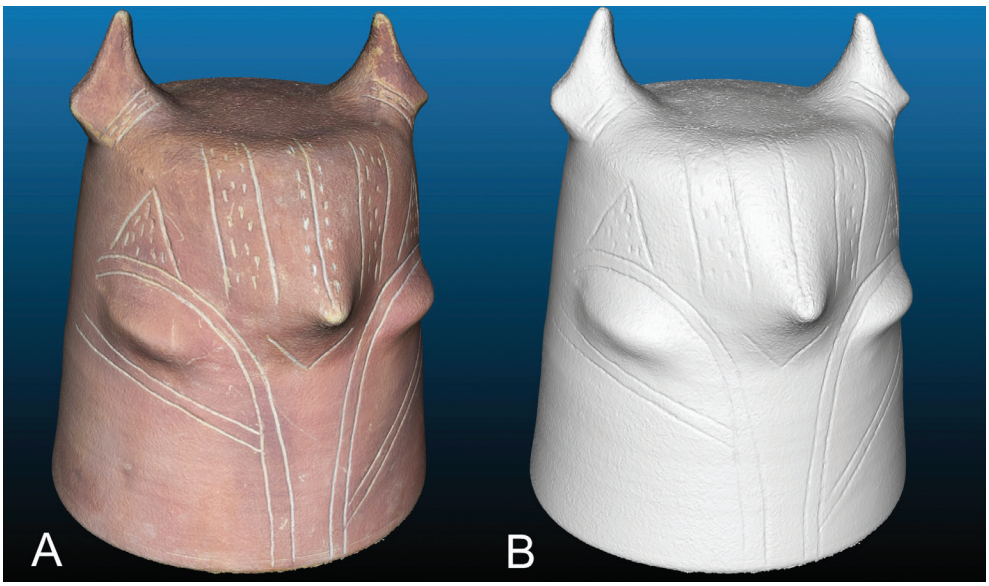


Figure 97. Clay prosopomorphic lids, Neolithic period. IbM, turntable method. A: textured 3D model, B: shaded 3D model.

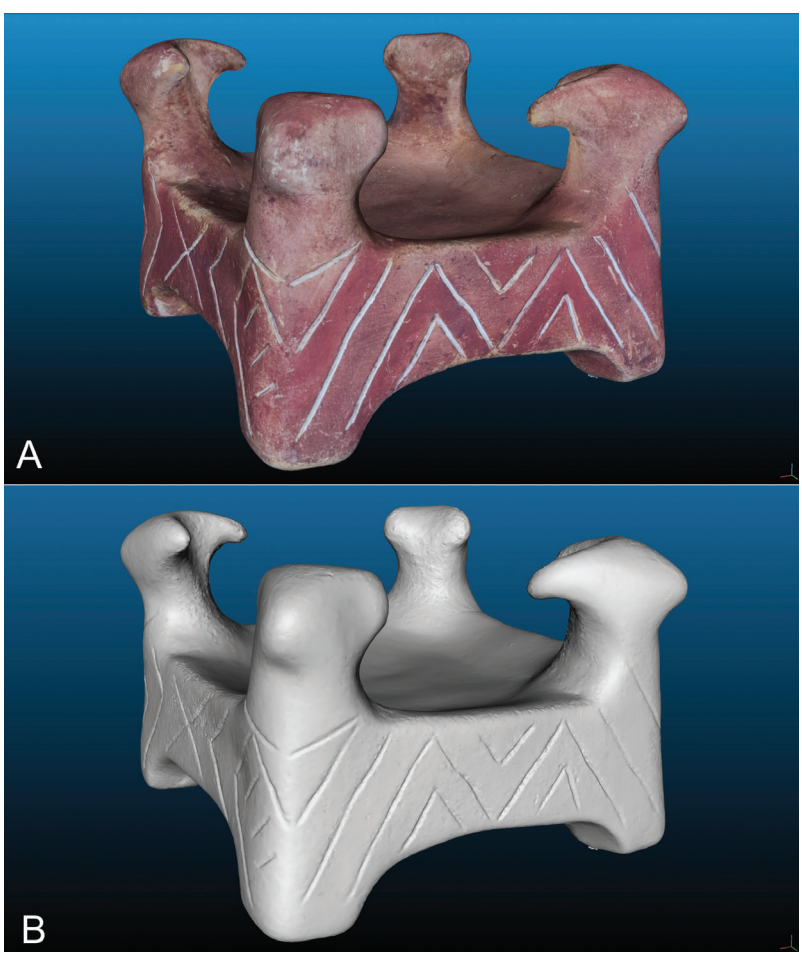


Figure 98. Clay object, Vinča, Neolithic period. IbM, turntable method. A: textured 3D model, B: shaded 3D model.

DISCUSSION

The application of both IbM and SLS methods for the 3D documentation of sculptures and movable objects is a valid approach, whereby each method has its specific benefits and problems. The SLS of Artec Eva type currently represents probably the most widely used type of portable handheld scanner utilising the technology of structured light with declared point accuracy of 0.1 mm and the 3D resolution of 0.5 mm. The most frequent and most effective application is in the documentation of objects of small to medium size in interior spaces.

The Artec Eva instrument operates at the distance range of 40-100 cm from the documented object. This limits its usefulness for capturing very small objects, where it is more suitable to apply another type of the Artec series – Artec Spider, which can capture the surface already from the distance of 17 cm, thus allowing recording of very fine details. The ideal solution is to use both types of scanners (Eva for general views and Spider for intricate details). If only Artec Eva is used, it must be taken into account that some details of the documented surface can be accessible from the operational distance only with difficulty (e.g. inward-facing surface of folds of draperies in sculptures, etc.) and that it is necessary to scan them repeatedly from various positions. It is also necessary to practice scanning in order to successfully use and manoeuvre Artec Eva. This mainly relates to the method of tracking (capturing frames), which requires smooth and slow but at the same time continuous movement of the scanner. Too rapid movements, as well as non-compliance with the recommended distance from the object, can lead to the loss of tracking. The course of scanning can be followed through the interface of native software (Artec Studio) on a notebook or tablet to which the scanner is connected. This presupposes mastering simultaneous tracking of own movement around the documented object and observing the display of the notebook/tablet.

A substantial benefit of SLS application for indoor documentation is the fact that the process can also take place under unfavourable light conditions without the need for any special lighting. On the other hand, the application of SLS in an external space is significantly limited, as the system does not work in (intensive) sunlight.

The most effective way of data collection for IbM in the exterior is the walk-around method, in which the person scans the whole surface of the object by moving around it in several sequences. The number of sequences depends on the height and the general appearance of the object. This procedure is particularly well-suited for 3D documentation of historical sculptures. If IbM is used for the documentation of movable objects in the interior, it is better to use the turntable method because, in order to obtain sharp and high-quality images, the object of documentation must be well-illuminated. In the walk-around method, the light equipment needs to be constantly shifted and the documenter needs to move around the object; this can represent a significant obstacle if the space available for documenting is limited. Further, lighting of the object documented must be of diffuse nature in order to prevent the creation of strong shadows, which, from the perspective of 3D documentation, represent a ‘dead zone’. Diffuse lighting can be best achieved by two oppositely placed light sources whose beams are aimed at the centre of the area documented, whereby the emitted light beams are diffused by a transparent material (translucent sheet, crepe paper, etc.) placed between the object and the light

sources. The movement is created by manually or automatically rotating platform on which the object is placed. The images are taken by means of a remote-controlled camera placed on a stand. Several image sequences are made from all sides of the object. When one sequence is completed, the object is manually turned to allow taking images of a previously obscured part of the surface. It is advisable to make images with the monochromatic background, since it enables very efficient masking of the background based on the principle of colour difference between pixels.[2] In many cases, uniform monochromatic background enables simultaneous registration of individual image sequences in a single file within bundle adjustment in IbM processing. In case the software application does not have the option to align such images, or in case the process of registration in one file fails, the images need to be processed within individual sequences and subsequently aligned according to GCP.

2 Technically, the simplest method of masking, using the principle of difference between pixels in the raster, is to use specialised software (e.g. Adobe Photoshop) and subsequently export the masking layer together with the respective raster as an alpha channel. The majority of IbM software is able to identify the alpha channel of a raster and thus automatically import the masking layer of individual images.