DIGITIZATION OF HISTORICAL ARTWORKS FOR ARCHIVING PURPOSES AND REPRODUCTION WITH USE OF AVAILABLE REVERSE ENGINEERING METHODS

JOZEF DOBRANSKY, JOZEF TOROK, PETER BARON, MONIKA TELISKOVA, JAKUB KASCAK,

Faculty of Manufacturing Technologies with a Seat in Presov, Technical University of Kosice,

Bayerova 1 Street, 080 01 Presov, Slovakia State

Reverse engineering offers a wide range of application options for engineering production, but its techniques can also be applied while preserving the cultural heritage. The following article highlights the possibilities of spatial digitization of a work of art using affordable means. Gradually describes the digitization process, point cloud processing, and the creation of output formats for the preservation or reproduction of the artwork.

KEYWORDS

3D digitization, artwork, scanner

1 INTRODUCTION

Digitization, in this case 3D digitization has become an integral part of today´s modern industry. All production purpose created data are gradually being converted/transfered, archived in a digital form, facilitation the achiving and sorting on data carriers, allowing it to be quickly edited into a new form. Reverse engineering techniques can be applied in each sector of industry. For example, when designing new ergonomic car seats or unique protective features for athletes, the digitization work on the human body is performed to create optimal shape of final product. Applying these procedures is possible and even required in archeology, where virtual models of found property will allow us in the future to gain new knowledge that has been overlooked by discovering of the found property. [DEDIK 2017]

2 OPTIONS FOR USING 3D SCANNERS

The main advantage of spatial scanner lies in its ability to accurately capture the spatial characteristics of digitized bodies for simulation, drawing documentation and simple reproducibility of processed data. [DEDIK 2017] An example of the use outside the field of mechanical engineering at the university´s surroundings is a reproduction/scanning and supplementation of the skeleton of the cave lion (Panthera spelaea) in the SNP Museum in Banská Bystrica in Figure 1. [TASR 2018]

Figure 1. Reconstruction of cave lion skeleton [TASR 2018]

Thanks to the cooperation of Slovak and Czech teams of professionals, several skeletal remains of this long-extinct animal and now living lion have been reconstructed and combined for the purpose of completion of full skeleton. Using a prototyping equipment, the next step was to create a plastic replica of the skeleton for exhibition purposes. Thanks to the 3d scanners, a model has been created that can be distributed to other museums and educational institutions for study or fabrication at the required scale. [TASR 2018]

These procedures should also be used to preserve existing cultural heritage sites. It is our duty to protect our cultural heritage from various dangers. Many documents are a subject of natural decomposition due to the surrounding environment, upredictable natural disasters and the devastating force of humanity. An example can be the Temple of Baalshamin in Syria Figure 2 marked by ravages of time and completely destroyed by the Islamic state. [UNESCO 2018]

Figure 2. Temple of Baalshamin in 2010 [UNESCO 2018]

In the past, many monuments were also made of wood , which is less resistant than stone. Some have been irreversibly destroyed by devastating fires, others have been completely disintegrated due to excessive humidity. [GUIDI 2014]

Before starting the preservation of such antiques, it is advisable to use a spatial scanner which allows to capture not only the dimensions of the body, but also its texture that can be damaged during the restoration works. [DEDIK 2017] [Vuga 2015]

Next sections of the article describe the work of the Reverse Engineering laboratory of the Faculty of Manufacturing Technology (in short FVT) outside of ordinary engineering

practice. In Figure 3 were performed test cleaning probes on the artwork's surface in purpose to make sure that the statue will handle the ongoing cleaning procedure.

Figure 3. Test samples of cleaned surface

Restoration is often needed due mechanical damage from careless handling or for example due to wood-worm infestation as shown in Figure 4.

Figure 4. Artwork damaged by wood-worm and holes visible on digitized surface

In the past, replicas of well-known artists works arisen, which does not lower their historical significance. [GUIDI 2014] Same with the abovementioned skeleton of the lion, also in arts we encounter the necessity of joining pieces of the individual works, respectively, on the basis of preserved replica to complete the missing pieces. On Figure 5 a 3D print of Jesus Christ strand of hair based on the scan of a slightly larger template is presented.

Figure 5. Reproduction of hair strand

This model was produced by the personnel of the FVT department during the cooperation with Mgr. art. Štefan Siváň during conservation of crucified Jesus Christ and Mary Magdalene statue shown in Figure 6. This shape copy of strand of hair based on part of a smaller statue from the same autor served as a bearing part for a final material – a part of future restored work, that will be completed by an experienced restorer.

Figure 6. Statue of Mary Magdalene

Scanners can also be used to create new works of art. For example, the staff at the Department of Computer Aided of Manufacturing Technologies applied their experience in reverse engineering to support the sacred artist Martin Daniel Skočovský. He created a model at 1:10 scale of the future memorial for unborn children for the cemetery in Svidník. [Skocovsky 2018]

Figure 7. Model of future monument in 1:10 scale

By the creation of the miniature, he used the combination of wax and plasticine, that is supported internally by a complex reinforcement. Figure 8 shows the rontgen of model with the armature.

Figure 8. Rontgen of model statue [Skocovsky 2018]

On the basis of spatial data (the digitization process described in Section 3) a virtual model was designed, which was used by structural engineer for dezign of new internal reinforcement for the final sandstone monument. The model could be relatively quickly divided into individual parts for analyzing purposes. Subsequently, the individual parts were thicken to meet the conditions set by the statics.

Figure 9 shows measurement near the right foot, where the dimension of statue must be changed for implementation of support structure. For the measurements the model was scaled to the future real dimensions.
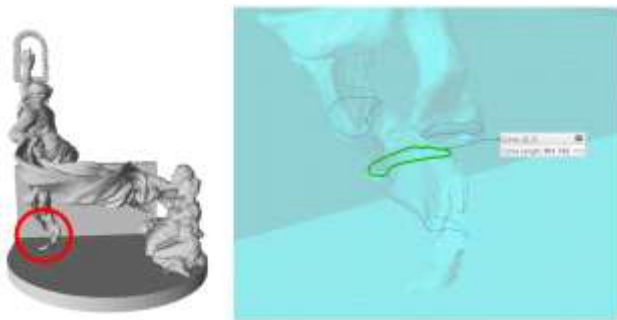

Figure 9. Measurement of problematic dimensions

3   PROCESS OF 3D DIGITIZATION

Before the start of a scanning process, it is important to choose the available hardware correctly. Appropriately chosen equipment will greatly help to increase the efficiency of the work.
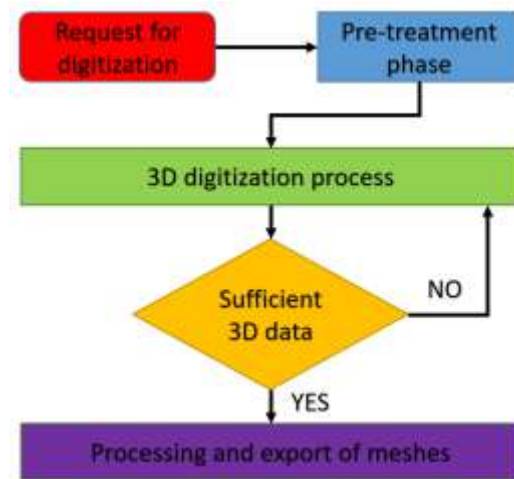

Figure 10. Workflow diagram for 3D digitization [TOROK 2014]

To digitize the memorial at the Figure 11 we used laser scanner ZScanner 700 to create the reference model. The device can operate with resolution of 0.1 mm and accuracy up to 0.05 mm. Thanks to position labels (scanner reference) we were able to scan the pieces of model from different angles and capture the details in hard-to-reach locations. Individual, though at first glance unrelated part had the correct position based on the reference labels.

Figure 11. Digitization using ZScanner and DAVID scanner

In the second step, all possible missing views were captured by the SLS scanner DAVID version 4.5.3, where individual partial polygonal nets were subsequently connected. DAVID is a structured – light scanner which can be precise up to 0.05 mm based on used calibration panel. In this specific case we worked with accuracy of 0.1 mm.

The same procedure was applied to the digitization of a wooden sculpture of Mary Magdalene by Master Pavol of Levoča. In this case, the ZScanner could not be used to create the reference model, as it could damage the surface coating when sticking and unsticking the labels. A less time-consuming alternative was to use the depth sensor Xtion PRO live and SKANECT software. It allows us to scan the whole statue in relatively short time and create a virtual copy of the body in a resolution accuracy of only one millimeter.

Figure 12. Statue scanned with 1 mm precision

The SLS scanner DAVID was once again used for a trustworthy capture of sculpture details along with the texture surface. Before digitization process itself, the scanner had to be calibrated to the appropriate triangular parameters. At the top of triangle glass calibration plate was placed with a scale of 240 mm at the distance of 1 m from the triangulation base. The scanner base is formed by a scanning camera and a projector. During the scanning process, the projector highlights a selected sequence of horizontal and vertical stripes of different thicknesses (Figure 13) on the surface of the scanned body and based on their curvature, the camera interprets them (based on the calibration parameters) as a spatial pointcloud.

Figure 13. Different light patterns projected on scanned surface

Due to the black-and-white camera used, the surface is additionally lighted by blue, red and green color (Figure 14).

Figure 14. Color mapping based on different color illumination

Depending on the shades of gray on the surface being scanned, the software automatically performs the color reconstruction.

Figure 15. Reconstructed surface without and with texture

For the complete body shape reconstruction, it is necessary to repeat this process from every angle possible in order to ensure a fully closed model. In order for the individual parts to be scanned with constant parameters, it is necessary to ensure the gradual rotation of the sculpture in the scanner´s field of view, or to move the scanner sequentially, but without changing the triangulation triangle parameters. In case of the change, it is necessary to perform calibration procedure again.

Individual polygonal nets are gradually positioned based on overlapping surfaces in combination with less accurate reference model. While working on computer with less performance, it is necessary to reduce the individual scans to a sufficient value.

Figure 16. Mesh with different polygons density

Subsequent connecting and eliminating of all duplicate points results into creation of watertight shell with desired surface quality for further use. Example of merging of several scans into one mesh is presented in Figure 17.

Figure 17. Merging of surfaces

4 CONCLUSIONS

The purpose of this paper was to evaluate the possibilities of using reverse engineering technology to preserve cultural heritage and art. Their virtual copies allow a detailed view of

the general public and the creation of a replica for study purposes. These techniques have prospective use in touring in so-called visual surveys. They are interesting for those who cannot come and see the relict for their own eyes. For example, for financial or health reasons.

REFERENCES

Technical reports or thesis:
[DEDIK 2017] DEDIK, L and MINAROVIECH, J. Project of the Digital Monuments Funds: Digitization of the Cultural Heritage of Slovakia, Studies in Digital Heritage, 2017. [online] [20.09.2018].
Available from
<https://scholarworks.iu.edu/journals/index.php/sdh/article/view/23286/29900>.
[GUIDI 2014] GUIDI, G. et al Massive 3D Digitization of Museum Contents, Springer International Publishing, 17 October 2014, [14.10.2018] ISBN 978-3-319-08532-6

[TOROK 2014] Torok, J. Research of new methods of computer visualization and simulation of manufacturing systems / dissertation thesis TUKE FVT, 2014.

[Vuga 2015] VUGA, M and Semion, M. Typical conservation problems of polychrome wooden sculptures in Slovenia, 2015 [online]. [12.09.2018]. Available from < http://revista.arp.org.pt/pdf/2015009.pdf>.

WWW page:
[Skocovsky 2018] Skocovsky, M.Asociácia za život a rodinu., 2018, [online]. [15.09.2018]. Available from < https://www.nenarodenym.sk/ >.
[TASR 2018] The digitization center completed the skeleton of the cave lion, 2018, [online]. [15.09.2018]. Available from < http://skolskyservis.teraz.sk/zaujimavosti/b-bystrica-digitalizacne-centrum-sko/42298-clanok.html?combinedGlobalTab_webmagazin=1 >.
 [UNESCO] Palmyra's ancient temple of Baalshamin, Syria, 2018, [online]. [15.09.2018]. Available from < http://whc.unesco.org/en/documents/137815>.

CONTACTS
Ing. Jozef Török, PhD.
Faculty of Manufacturing Technologies with a Seat in Presov,
Technical University of Kosice,
Bayerova 1 Street, 080 01 Presov, Slovakia
+421 55 602 6432, jozef.torok@tuke.sk, https://kppvt.fvt.tuke.sk/katedra/pracovnici/