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Precise 3D documentation – between the need of a high resolution and the limit of visualization possibilities

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Abstract

Since 2007 Museum of King Jan III's Palace at Wilanów and Warsaw University of Technology, Faculty of Mechatronics are together developing precise, structured light-based scanning methods. This cooperation was established in order to elaborate solutions allowing documenting characteristics of the surface of different cultural heritage objects. The gathered data are intended to support the processes of conservation, education, historical analysis as well as the sharing of the visualizations of the especially fragile objects. In order to fulfill those requirements for most of the historic artifacts, scanning with a spatial resolution of at least 2500 points per square millimeter is needed. As a result of those assumptions, files of a very large size are produced. Today's software environments for such a huge data processing and applications to visualize those data are very limited. Consequently, this raises the need for either a significant simplification of visualization process or a reduction of the shared results of measurements (by showing data concerning only a small parts of the heritage objects). Which path would be most suitable for the end-users? Should this insufficiency of the visualization software cause a reduction of the quality of the measurement processes?

Introduction

In 2009-2011 Museum in Wilanów carried out the project, which aim was to determine the reference measurement sampling density (MSD) for different types of historic objects (grant No. N R17 0004 06/2009 'Realization of the idea of preventive conservation by the means of precise 3D documentation' financed by the Polish Ministry of Science and Higher Education) [1].

At that time we have decided that raw measurement data (just after noisy points removal) is the best representation of the measured objects surface. It could be stored in a form of a set of measurement points known as cloud of points. Any other format developed by some processing of data (like triangle mesh) generates modification of the original representation and it is always worse and less informative than the original one. In the course of the project we have prepared more than 60 technical samples (10 cm x 10 cm each) and measured them on three levels of MSD (1000, 2500 and 10000 points per square millimeter). Over centuries various technologies and materials have been used to manufacture works of art. Damage marks and effects of aging, which appear on the surface depend on its base and the technology used. We strongly believe that documentation techniques can be defined as 'good' when they are able to register all that features as well the esthetic nuances of the art object.

Basing on the experience from that project we established that the MSD of 2500 points per square millimeter appears to be pleasing for the majority of applications, putting aside complicated technological analysis and following aging processes. Since then, most of the objects scanned in Wilanów museum is documented with such a precision.

So far, we have created 3D documentation records for more than 110 objects from the collections of few Polish museums, gathering more than 70 TB of data. In the meantime we have mostly focused on the problem of increasing the capabilities of the measuring systems and automation of the data post-processing. Currently, the crucial difficulty is to share those data and their visualization at full resolution.

For instance, documentation of one page from the famous 'Great Dürer Trilogy' (49 cm x 33 cm) (from collection of Museum of Warsaw Archdiocese; Figs. 1,2) required about 320 directional measurements which constituted about 3 billion sample points (ca. 210 GB of measurement data). The distance between the points in the cloud is 20 μm.[2]

***Figure 1**. Fragment of the print "Four Horsemen of the Apocalypse". On right side there is a close-up of the hand drawing a bow.*

Taking into account the desire to provide universal access to the digitized objects, we have developed several, complementary methods of presenting measurement data online, which are currently tested: a) preparing renderings of data in full resolution (posted on YouTube in a form of films lasting dozens of seconds); b) creating a gallery of the 3D models (simplified to 2 million triangles) available on the external provider's server, c) creating a gallery of the 3D models (simplified to 4 million points) available on the museum's server; d) visualization of point clouds in full resolution available at the museum's digital laboratory.

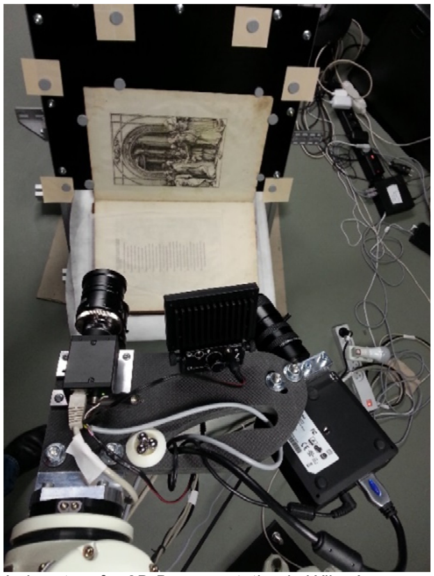

***Figure 2**. Laboratory for 3D Documentation in Wilanów. 3D measurement of a print (December 2016).*

Research problem

Conducted studies allow us to make an assumption that for most historic objects a scanning resolution reaching ca. 2500 points per mm^2 is required. This value is optimal as far as the purpose of the documentation is to record in detail all vital object's characteristics (such as surface properties). This approach gives us an opportunity not only to record the aesthetic nuances of a particular artwork, but also to gather documentation that can be used for a variety of identification and comparison studies. The need for such a high accuracy was confirmed not only by research provided by Wilanow [1] but also, for example, by independent project run at the London College of Communication [5]. English research, based on different assumptions and referring to 2D documentation, determines the reference resolution of the documentation produced with 50 samples per mm (1200 dpi), which corresponds precisely to the spatial resolution of 2500 points per mm^2 for 3D documentation. On the other hand, documenting at such a high level of precision is quite difficult from the technical point of view, it is very expensive and leads to very large amounts of a source data (hundreds of GB for a single object), which we are unable to present in a full resolution to the end users. In this situation, popularisation of the researchers work becomes crucial, because in this way we can inform and convince society about the need of creating such a strict requirements of the documentation. Even if today we are unable to use all its effects, we create guidelines and standards for the future.

Proposed solutions

3D documentation is a method of gathering information about the actual shape of the historical object. This seemingly obvious statement is extremely important because in today's world many technologies are considered as 3D, even though they do not use fully 3D spatial models. It is enough to mention here the 360° panoramas, which, due to the animations of 2D images give the impression of perfect spatiality. It is understandable that all visualization techniques developed for computer games or the film industry strive to achieve the best possible 3D impression and realism with the smallest amount of data that needs processing. This results in the use of a whole array of texturing of 3D models techniques designed to make the user seem to perceive details of a geometry in a place which in fact was not registered on the level of a triangle mesh. On the contrary, in case of documentation of heritage objects, which should serve for next generations, we represent a different point of view. Our target is to register the actual geometry of the object at the level of documentation. Considering the problems arising with this goal, most probably the only rational solution in our case is to combine the two and three dimensional documentation of one object. For objects such as oil painting on canvas (with very smooth surface, additionally covered with varnish) there is a solution more effective than scanning the entire artwork with a measurement sampling density of 2500 points per mm^2. Alternative, but also effective method is to create a three dimensional model with a lower level of accuracy (by using for example photogrammetry) as well as two-dimensional photographic file in gigapixel technology for the entire surface, which would be later supplemented with precise 3D measurements for chosen fragments. In addition, for some types of the objects, mentioned methods can be combined also with RTI (Reflectance Transformation Imaging) files made for selected surface fragments.

Exemplary proposals of visualisation

It can be assumed that the choice of type of visualization method is determined by the mutual relation of three main parameters:

1. Data-sharing range (dependent on the ability to be open accessed via Internet and hardware requirements for the end user)

2. The degree of interactivity of the data (depending on whether the end user can freely control the model and its lightning, or is he doomed to view data according to a previously imposed scheme - for example in the form of a rendering)

3. Quality of shared data (it can be assessed by examining the level of accuracy in representing the details of geometry in reference to the quality of a high resolution data collected during the digitization process).

By analysing different methods of data sharing, we can observe a simple dependency resulting from the limitations of today's visualization methods. If we want to ensure universal access to the presented data, a compromise is necessary: we either resign from the high degree of interactivity of the data or simplify (sometimes even up to 50 – 60 times) the presented model. In turn, the desire to display interactive, as well as very detailed models limits the number of recipients, because it is available only via museum's computer infrastructure.

Rendering data in full resolution

Rendering data in full resolution can be posted in a form of a movie lasting dozens of seconds. This way it can even be accessed via website such as YouTube. As a great example of this solution can serve for example a 57-seconds long rendering (HD file of 100 MB) showing a ceramic sculpture from Wilanów collection (Wil.489) known as "Wielka Herkulanka" (Figs. 3,4). The model of a 18.8-centimeter high sculpture was shared in the form of a film based on a cloud that consists of 880 million points (26 GB model size). In this case, the data obtained from the 2500 points per mm^2 resolution were simplified ‘only’ five times (https://www.youtube.com/watch?v=2FNRt35FhZc). This way of presenting the models provides world-wide availability, as they could be opened even on smartphones. The degree of interactivity of the data however must be radically reduced.

Figure 3. Ceramic sculpture “Wielka Herkulanka” (Wil.489) – rendering at YouTube portal

Figure 4. Ceramic sculpture “Wielka Herkulanka” (Wil.489) – close up

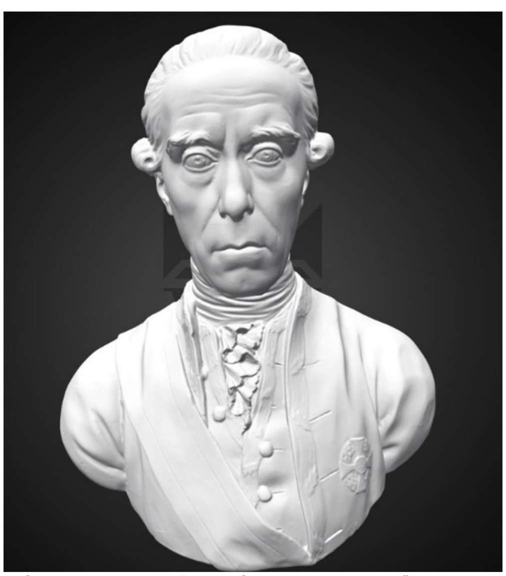

Figure 5. Ceramic sculpture “Ernst Gideon von Laudon” (Wil.727) – textured triangle mesh from Wilanów Museum Sketchfab gallery

Figure 6. Ceramic sculpture “Ernst Gideon von Laudon” (Wil.727) – textured triangle mesh (left) and raw triangle mesh close-up (right)

Gallery of the 3D models available on external service (triangle mesh models)

Visualization models in a form of textured triangle meshes simplified to 2 million triangles (which equals ca. 1 million points) can be presented through an external service (for instance Museum of King Jan III's Palace at Wilanów uses the Sketchfab browser for several months from now, Figs. 5,6). Models have to be highly simplified but high level of availability and interactivity compensate for this (https://sketchfab.com/search?q=willan%33B3w).
Another advantage of described way of presentation is that it can also be handled by smartphones.

Gallery of the 3D models available on the museum server (cloud of points models)

The gallery of 3D models using OpenGL technology provides us the ability to publish models as clouds of points that consist of ca. 4 million (establishing this size of the file results from the tests comparing the level of rendering and the amount of data transferred). In this case the sharing process depends on the museum’s infrastructure. It requires downloading approximately 90 MB of data to the end-user’s computer (depending on the quality of the Internet connection it takes about 1 minute). In the presented example (Fig. 7) the model has been simplified more than 25 times in comparison to the output data (http://muzeum-wilanow.pl:8001/).

Figure 7. Ceramic sculpture “Wielka Herkulanka” (Wil.489) – cloud of points model (OpenGL based gallery) – diferent lighting conditions

Visualization of point clouds in full resolution available at the museum's digital laboratory

Below we present (Figs. 8, 9) a possibility to view models in the form of a very dense clouds of points with full interactivity (which means the motion of a model and lighting control), which is possible thanks to use of the unique, original software developed by the Warsaw University of Technology, called Massive. However, it requires a prior conversion of the archival model into a special visualization file. This solution allows to see the entire objects or, in the case of interiors, its very large fragments (such as the whole wall) in full scanning resolution.

Figure 8. The King's Chinese Kabinet (Wilanów) – east wall. Dense cloud of points visualization (Massive software)

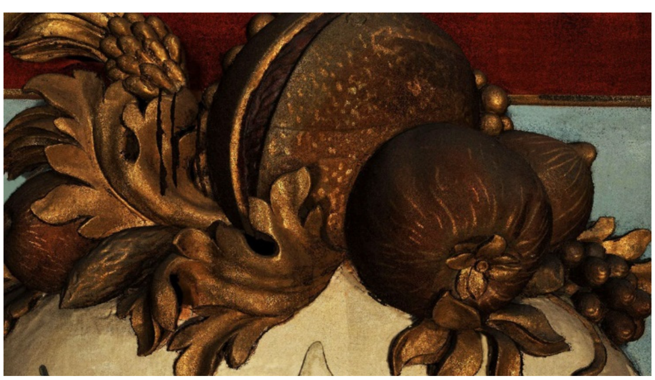

Figure 9. The King's Chinese Kabinet (Wilanów) – east wall, close-up

Conclusions

Currently, technical limitations do not allow us to visualize data acquired from precise 3D measurements in a full resolution. In spite of this, documenting process should not be adjusted to today's reduced ability to share this kind of data through the Internet. Only keeping the highest standards that meet the results of the already conducted research, will give us the chance that the data we produce today will retain high value in the future. Last few years prove that the visualization capabilities of software and information networks are developing very quickly - so over time we will be able to progressively share more of today's data. At the same time, there will be no need to repeat the whole process of digitization for the already scanned objects in order to obtain higher quality data. It should be underlined, that 3D data is (and will be) used not only in the form of two-dimensional visualizations on computer screens, but they are also the basis for 3D printing techniques. Along with the progress in automation of precision 3D scanning, data processing and visualization development, establishing some standards would be desired. Those should specify the recommended accuracy of the measurements and confirm the need to produce source data with a high quality. Only this approach will allow us to fully meet the main goal of our efforts, which is protection of the artwork. It will also protect us from the time- and cost-consuming repetition of digitization process.

References

[1] Eryk Bunsch, Robert Sitnik, Jakub Michoński, Art documentation quality in function of 3D scanning resolution and precision, Proc. SPIE-IS&T, Vol. 7869-12, (2010)

[2] E. Bunsch, R. Sitnik, Method for visualization and presentation of priceless old prints based on precise 3D scan, Proc. SPIE-IS&T, Vol. 9018-26, Electronic Imaging (2015)

[3] E. Bunsch, R. Sitnik, E. Hołowko et al., In search for the perfect method of 3D documentation of Cultural Heritage, EVA Berlin, pg. 72-81, (2015)

[4] R. Sitnik, E. Bunsch, G. Mączkowski et al., Towards automated, high resolution 3D scanning of large surfaces for cultural heritage documentation, 3DIPM-051, Electronic Imaging (2016)

[5] L. MacDonald, The Limits of Resolution, EVA London, pg. 149-156 (2010)

Author Biography

Eryk Bunsch, M.Sc., dipl. conservator of art. Collaborates with National Institute for Museums and Public Collections and National Audiovisual Institute since 2011 as an expert in the field of modern 3D documentation of cultural heritage. Head of Laboratory for 3D Documentation at Museum of King Jan III's Palace at Wilanów. His current scientific interest considers developing technology of precise 3D scanning of cultural heritage objects. He has managed many research projects related to 3D documentation. His articles are combining different spheres of his scholar activity: conservation of art, 3D precise documentation and archaeology.

Robert Sitnik (Member of SPIE) received his MSc Eng (1999), PhD (2002), Habilitation (2012) in applied optics (3D imaging) from the Warsaw University of Technology. He has authored and co-authored more than hundred scientific papers. His interests are structured light shape measurement (3D/4D), triangulation methods, digital image processing, computer graphics, animation software development and virtual reality techniques. He is head of Virtual Reality Techniques Division at WUT.

