

3D scanning and analysis of acquired data of historically and culturally significant objects referring to the work of Adalbert Stifter

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Abstract. The aim of the paper is to bring new findings from ongoing specific university research. Within this project, the light scanner scanned historically and culturally significant objects referring to the work of Czech-Austrian writer Adalbert Stifter in South Bohemia and Lower Austria. It also analyzed the data obtained with the light 3D scanner. The data was generated as a cloud of points. With respect to object's size, multiple parts of each object were scanned individually. By combining individual scans and removing unwanted points (noise), models - digital twins of objects - were developed. Created models are valuable for their use for virtual tours of historically and culturally significant places. The final models were modified for printing on a 3D printer, where they were subsequently printed.

1 Introduction

Nowadays technology 3D scanning takes an important position in the field of civil engineering. Its application has also role in other fields, including archeology, medicine, film industry, and mechanical engineering. This technology evolves very quickly and provides a number of new options for users. Using a 3D scanner allows to collect object data such as information about its shape, structure, and eventually color. Depending on the way this data is collected, we can divide the scanners into laser scanners and light scanners, which work on the principle of photogrammetry.

3D geometric content acquisition from real world is an essential task for many applications in computer graphics. Unfortunately, even for static scenes, there is no low-priced system, which can provide good quality, high resolution distance information in real time. [1]

In the construction industry, 3D scanning is mostly used for the reconstruction of historic and listed buildings - for this purpose, laser scanners are used, and further in the creation of modern architecture or art. Light scanners are used for creation BIM libraries for specific projects - smaller objects such as sculptures, or for scanning room surfaces. The data thus obtained can serve as a very accurate and detailed basis for the creation of replicas of, for example, sculptural works, that are part of a reconstructed building. At the same

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time, it is possible to work with the digitized objects in professional software as needed, including the software commonly used by architects and designers. There is the opportunity to transfer any object to their project and visualizations. 3D scanning technology also provides the ability to print scanned object in reduced form using a 3D printer.

Specific university research, which this paper describes, deals with the creation of digital twin of Adalbert Stifter's memorials. The first scanned monument is the statue of this master in Horní Planá.

2 Basic information about the scanned object

The subject of this research is the analysis of data obtained by scanning important historical objects related to the work of the Czech-Austrian writer, painter and pedagogue Adalbert Stifter and the subsequent use of data for the creation of a digital twin.

Oversized statue embodying Adalbert Stifter was scanned and digitized. The monument (Fig. 1), of which the statue is part, is located in Horní Planá. In this South Bohemian town on the shores of Lipno water reservoir, Adalbert Stifter was born in 1805. His birth house is now used for exposure purposes.



Fig. 1. Monument of Adalbert Stifter in Horní Planá

The monument is located in a park north of the square by the way to the Chapel of Good Water. It was built in 1906. It is placed on a pedestal on which it is possible to climb the stairs. On both sides of it, there are stones placed in the ground. There are two stone blocks on the pedestal. At the first block, the writer's statue is standing on and his name is carved in. The statue with the book in its hand is leaning on the second block and a bronze table with text is placed on it. The statue itself is also cast from bronze and is about two meters high. Since 31 December 1963 is a protected monument.

3 Data acquisition

3.1 Technical equipment

For scanning, Artec Eva Lite 3D light handheld scanner was used to create high-quality and accurate scans without color and texture. This more affordable model is particularly suited for objects that have a rough surface that the scanner is oriented accordingly. It works on the principle of so-called trigonometric triangulation. This means in practice that the scanner projects a light pattern consisting of regular shapes on a scanned object. The scanning sensor is then oriented along the edges of these shapes to derive the shape of the object. The raw model is a cloud of points. Suitable objects for scanning by this scanner are, for example, the human body, so this type of scanner finds use in scanning sculptures, archeological or artwork. Less suitable objects are those that are not sufficiently diversity shaped or with flat (even textured) surfaces.

For this reason, it was decided that the stone blocks, that are part of the statue, will be modeled on the computer. There are not any points that the scanner could capture. If the surface of the scanned object is too uniform and straight, it is easy to interchange the checkpoint for another. This may distort the complete scan. Shiny objects, from which the reflected light will be reflected at a bad angle, aren't also suitable. However, this problem can be solved by chalk sprays, which can reduce the reflectivity of the surface, and the scanned object is not impaired.

The Artec Eva Lite scanner can be amended by extension enabling to scan color and texture of the selected item. Outdoor equipment includes an external scanner battery that lasts about 5 hours.

The Dell Precision M3800 was used for data processing. It has a touch screen display, quad-core processor, NVIDIA Quadro K1100M graphics card and 8GB operating memory.

The software includes Artec Studio 12 Professional software, which stores individual scans, and in which the data is further processed. The Archicad 21 software was used to model the blocks. The individual models were exported in the .stl format, where both 3D objects were then joined together.

3.2 Preparation for scanning

At first, the object needs to be cleaned of all impurities, such as fallen leaves in this case. If it is not possible for some reason to remove some of the impurities manually in physical reality, it could be done with subsequent editing of model on the computer by deleting a portion of the cloud of points that the unwanted element is represented by.

It was also necessary to lay out how the sculpture would be scanned. Scanning can't be done at one time with respect to such a large object, so it is necessary to determine the parts in which scanning is performed separately. The suggestion was to scan the sculpture progressively from the bottom to the top and separately scanned parts were overlapped in lanes. Mainly buttons on Stifter's coat were used as capture points. Buttons should be part of most of the scans to make it easier to combine them.

3.3 Scanning

Before scanning, it is necessary to prepare the scanner. He must be connected to an external battery and the notebook to which the data is transferred during scanning. The Artec Studio software must also be running in the notebook. In this program, you need to create a new project that will save all scans. In the left part of the window next to the main menu, there is

a scanning setting where we check that the required sensitivity and speed are selected - not always the highest sensitivity and scanning speed leads to the best result.

Now you can start scanning by layout. First, when you press the play button on the scanner, a preview appears on the computer monitor. We set the scanner at the required distance to point to the selected part of the object that was in this case the legs of the statue. Then you can push the "scan" button. In the preview in the notebook, we see the parts that have already been scanned (gray color) and from which data is being collected (green color). The sculpture must not be enlightened by direct sunlight during work. If so, it would have the same effects as if it were made of glossy material. That's why the statue was shaded by an umbrella during scanning.

All the time, you need to keep the scanner distance from the scanned object. In right side of the monitor, there is the scan settings graph that expresses this distance and varies according to the current situation. The ideal situation is, when the graph is roughly half of it, which is a distance of about 700 mm from object to scanner. If we were outside the graph, it would lose signal, and then the scan could be distorted. In this case, the best solution is to delete the distorted scan and create a new one. Deformation can occur even when scanning overly flat surfaces.

When scanning the statue of Adalbert Stifter in Horní Planá, a total of 28 successful and partially successful scans were created (Fig. 2), from which the final 3D model was created. The problem area was, for example, a book that was flat and thin and had to be scanned from all sides (that is from a side that was close to one of the stone blocks). Another such place was the bottom of the coat and the space between the coat and the boots. This part of the sculpture was poorly accessible, and there were points close to each other that had a large difference in the distance from the scanner, so it was very important to do it very carefully. The access problem was generally with the entire upper part of the statue, which could only be reached with a folding ladder. The last obstacle was the coat that was very straight, so there was often a deformation of the scans being made.

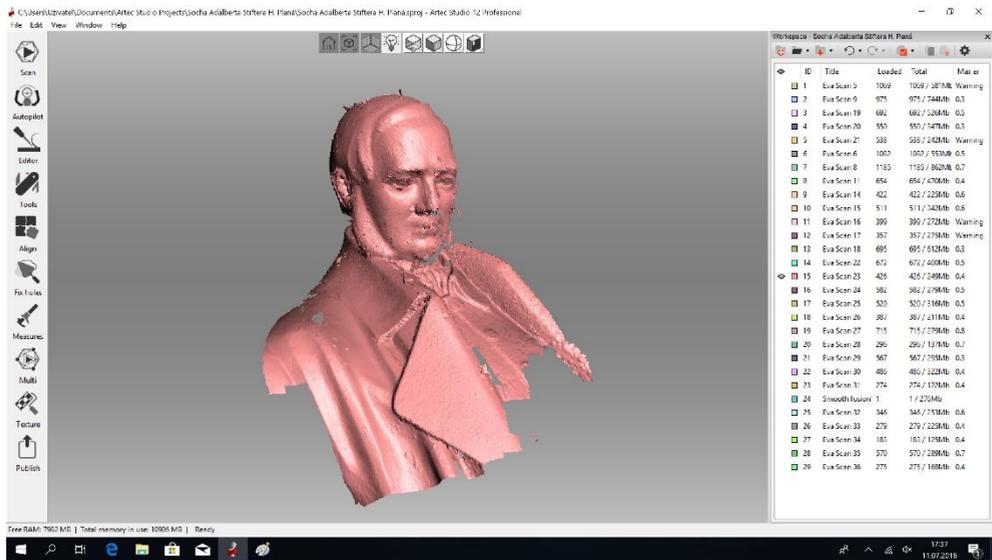


Fig. 2. Scan without modification

3.4 Processing the data

Parts that the software has been able to assign itself were assigned together by function auto-alignment. This was made possible by scanning in the above-mentioned partially overlapping lanes. In this method of cloud point coupling, the method of minimal distance of surfaces in overlapping areas is usually used to determine the transformation key. The algorithm of this method is part of most professional scanning measurement software programs. [3] The guideline is the recurring shapes that make the software orientated and the individual scans together. Some problematic parts have to be assigned manually because the software is not always able to detect where the scan should be moved. Especially if there are parts of smaller dimensions or there are several similar parts on the whole item (eg coats of the same shape, the figure has two very similar boots, etc.). This method is done by selecting at least 6 appropriately selected points, which should overlap after pairing of two scans. A suitable point is a place that is shape different from its surroundings and can be easily found and marked on both scans (in this case, for example, the center of the button, the corner of the book, etc.).

In the next step, all scans can be joined together using the global registration function. To do this, just select this feature and the program can handle the connection without any help from the user. Regarding the scanning accuracy, one of the main problems is the noise.[2] Then it is advisable to remove points that are too deflected from others and delete ambient noise. Both can be done using two more outlier removal software functions and then a small object filter. After all the steps mentioned above, it is necessary to check and eventually to scan the missing parts, which was needed, for example, in the aforementioned problematic sites.

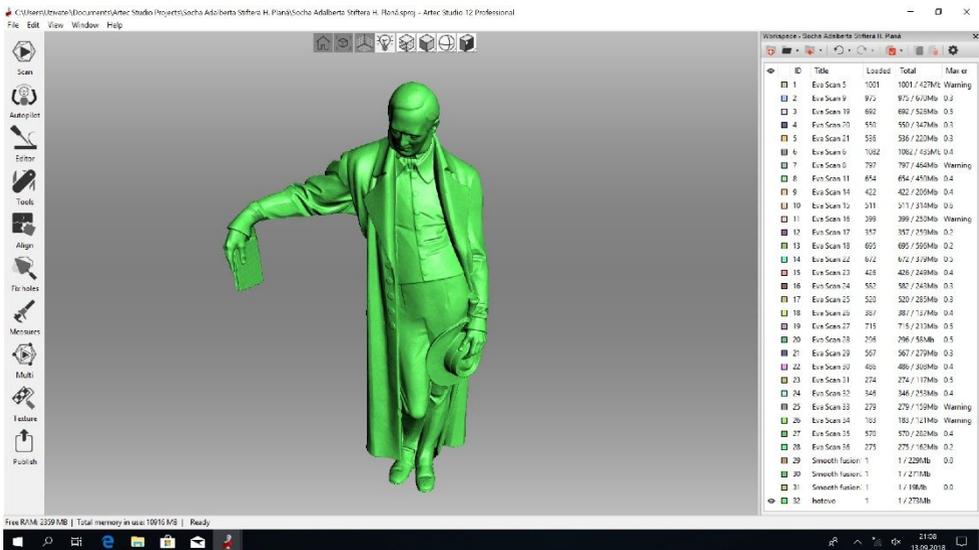


Fig. 3. Final 3D model

Consequently, it is necessary to fuse the merged scans into one and smooth it. We have two features: sharp fusion and smooth fusion. They differ from each other mainly by drawing detail. When selecting the first option, the resulting model will be more detailed, or even smooth with smoothing. In the case of statue of such size, it was sufficient to use smooth fusion. If a part is not drawn in the final model, it is necessary to rewrite it and then edit the new scan (just like the ones previously edited) and join it. Smaller holes can be

filled with function hole filling, either all at once or separately. In this way, even larger parts that could not be scanned, both the back and the lower part of the statue, were filled.

The final model Fig. 3 was exported in STL format and connected to stone blocks in Archicad 21 and printed on a 3D printer.

4 Conclusion

Choosing the right scanner and the level of difficulty of processing the acquired data depends on the properties of the particular object. In the case of the Artec Eva Lite light scanner, shape, material and dimensions play an important role. If there are points that are substantially spaced apart from the scanner, it will be very difficult to scan some parts. Such places are depressions or, on the contrary, very protruding and thin areas. The opposite is also the case where there are almost no clues on the subject, which could be artificially created in some cases. The obtained 3D digital data provide a convenient data set, which can be used to quantitatively analyze and calculate the characteristic indices for the natural joint, such as the roughness, magnitude and angularity.[4]

From the point of view of the material, any matte surfaces are suitable. In the case of shiny surface, it can be treated with a chalk spray for the purpose of scanning, which can be easily washed after completion of the work. The sculpted statue of Adalbert Stifter is made of bronze - this is not a suitable material for scanning because of its gloss. The sculpture is already covered with patina because of its age and therefore it was not necessary to use a chalk spray. The final model is in very good condition when no further editing is needed before 3D printing.

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