CREATING AN INFORMATION EXTENSION FOR THE 3D MODEL OF TOMBSTONE – FINDING THE MOST EFFECTIVE WAY

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Abstract

This article deals with creating a 3D model of a stone tombstone created with the terrestrial photogrammetry method and creating an information extension of this 3D model. Information extension is understood a 3D model classification considering different criteria, followed by classified 3D model visualisation. The paper mainly deals with testing the usefulness of different types of programs that can be used to create the information extension and based on this testing defines the most effective way of work.

Keywords

Photogrammetry, classification, visualisation, mesh, dense cloud

1 INTRODUCTION

Preservation of monuments – protection of various types of monuments and studying them – is one of the fields, where photogrammetric methods are often used can be seen for example in [1], [2] or [3]. Correctly created dense cloud or 3D model can make this work easier, it can simplify sharing the representation of the objects or manipulation of this representation.

All the work described in this article was carried out in cooperation with preservation experts and it deals with creating 3D models and dense clouds with photogrammetry method considering following classification, visualisation and information extension.

3D model and dense cloud themselves were created using Agisoft Metashape Professional software. The classification was tested using Agisoft Metashape Professional, CloudCompare, Bentley MicroStation, ArcGIS Pro and Geomagic Wrap software, visualisation was tested using ArcGIS Online, Sketchfab, CopperCube and 3D PDF software.

All mentioned programs were tested for their usability for creating a 3D model or a dense cloud with information extension and the optimal way to create proper output was defined based on these tests.

LITERARY OVERVIEW/DESCRIPTION OF THE PRESENT STATE

Some of the defined levels reflect the surface treatment of the tombstone, so the possibilities of using photogrammetry for a detailed study of the surface were tested, some possibilities are mentioned in [1], [2] too. Some ways of visualisation are listed in [3] or [4]. An important part of this article is finding a way of visualisation suitable for cooperation between experts in photogrammetry and preservation, as in [5] or [6].

2 METHODOLOGY

All the work is described using an example of the stone tombstone of St. Vintíř, located in Břevnov Monastery in Prague (Fig. 1).

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Fig. 1 St. Vintíř tombstone.

Primary data collection

Images were created using a digital Nikon D7100 reflex camera with a Sigma 17–50 mm f/2,8 EX DC OS HSM lens attached.

Six black and white paper targets were placed around the tombstone as control points. Distances between these targets were measured by tape measure. Due to the plasticity of the object, the distances across the object could not be measured, so just eight distances around the object were measured, and all of them were measured twice.

A total of 750 images were made in three sets. The first set was taken at a distance of 0.5 m from the object and 514 images were taken, the second set was taken from a distance of 1 m and 232 images were taken and the third set was taken from a distance of 2 m and 4 images were taken. Taking images was done in a dim environment, so two reflectors put on a tripod were used to light up the tombstone and one hand reflector was used when necessary.

Images were taken in *.jpg format and aperture priority mode, which means that the exposure time was changed according to the light conditions. The specific parameters were – aperture f/11, ISO 1000, zoom 50 mm and exposure time from 1/20 to 1/800 sec.

Primary data processing

Images were processed using Agisoft Metashape Professional software, version 2.0.1.

Cameras were aligned, the accuracy of alignment was set as high and generic preselection was used too. The key point limit was set as 40,000, the tie point limit was set as 10,000 and stationary tie points were excluded. Though adaptive camera model fitting is recommended for non-calibrated cameras, it was not used in this case, because of low alignment quality around Vintíř's hands when used.

Markers were created on every image where paper targets were visible and they were used to create scale bars. After scale bars creation images were optimized.

Gradual selection was done afterwards and points with low quality were deleted. Image count criterion was not processed in this case, projection accuracy limit was set as 10, reconstruction uncertainty was set at 10 too and

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reprojection error was set as 0,5 pix. After every point deletion images were optimized. The achieved final reprojection error was 0.671 pix and the scale bars error was 2.6 mm.

Dense cloud was built with high quality and mild depth filtering set and point colours were calculated. The average distance between points in a dense cloud created this way was 0.072 mm, so the dense point cloud was filtered to a distance of 0.5 mm. Agisoft Metashape window and dense cloud can be seen in Fig. 2.

Mesh was built reusing depth maps created when building a dense cloud. Surface type was set as arbitrary (3D) which is recommended for indented objects, vertex colours were calculated and interpolation was enabled. Face count was set as 7.500,000, which is a pre-calculated rounded average between medium and low face count.

Texture was built as a last step. Diffuse map was set as texture type, images were used as a source type, mapping mode was generic and blending mode mosaic. Hole-filling and ghosting filters were both enabled.

It was necessary to export the dense cloud and textured mesh to formats usable with other software.

Dense cloud was exported as *.las, which is a format that can be opened by almost every software where testing was intended with the exception of Geomagic Wrap, so export in *.ply format was made for this purpose. Mesh was exported as *.obj, which can be opened by every type of software.

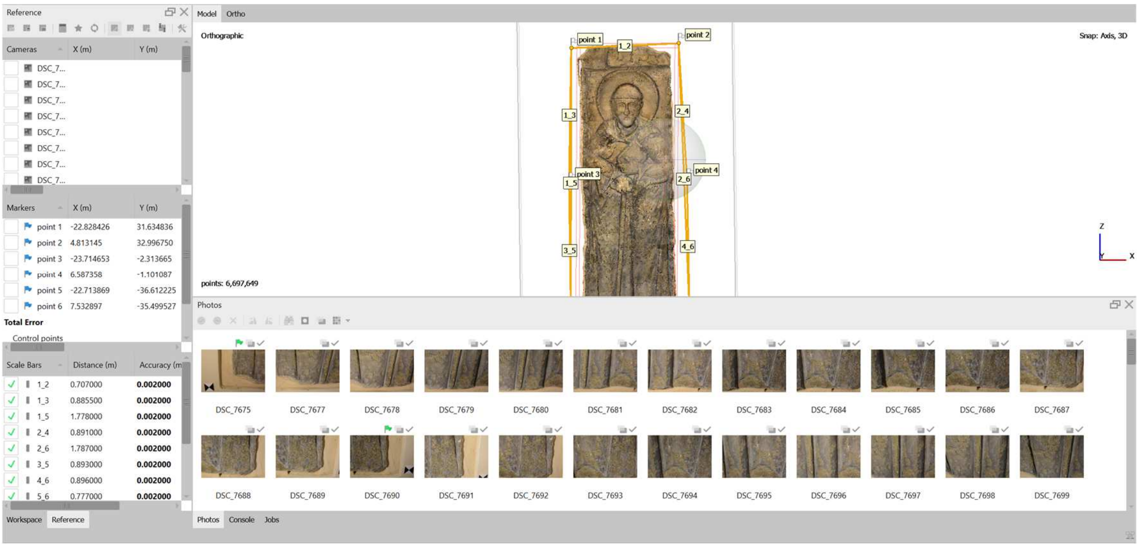

Fig. 2 An Agisoft Metashape Window with a dense cloud.

Definition of levels

Levels were defined in cooperation with preservation experts and should be applicable for tombstones in general, an overview of levels is listed in Tab. 1. According to the fact, that tombstones can be variable, the levels are variable too.

Tab. 1 Definition of levels.

Level category	Level (divisible)	Note
Preservation	*Dating, preservation quality*	
Restoration	*Restoration quality, restoration extent*	
Surface treatment	*Rough modelling, mild modelling, finite adjustment*	
Polychromy	*Colour application, colour structure, colour preservation*	
Geology	*Rock names*	
Special parts	*Text*	
Mass changes	*Place of separation, the presumed shape of the separated part*	
To be solved		

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Evolution	*Milestones (timeline)*	*Text level, it is possible to refer to parts of the model/dense cloud*
Location changes	*Documented previous locations*	*GIS level, in combination with the evolution possibility of complex application*

Classification

Possibilities of manual classification were tested throughout the work. This type of classification was chosen due to the object and level character. The automatic classification works on the principle of morphological characteristics, so it is not appropriate to use it for stone tombstone classification.

Because the testing started before the final definition of levels, tentative levels were defined and used for testing. In the end, the four main levels were defined – stick, book, tonsure and hair – and the additional level – other. All levels differed in shape and size. It could be assumed that levels defined by preservation experts would overlap, and the tonsure and hair would overlap as well.

There was an effort to separate the stick, the book, the tonsure and the hair in separate levels, the level "other" did not have to be necessarily separated, depending on specific software possibilities.

The classification in original meaning was tested, i.e., assignment of specific attribute to specific face in case of 3D model or point in case of dense cloud, but the classification in meaning of segmentation was tested too, i. e., creating specific segments of a 3D model or a dense cloud.

Both the simplicity of classification and the possibility to colourize segmented parts of a 3D model/dense cloud was tested, because it can simplify the orientation in a visualised 3D model/dense cloud.

Software that was used, was Agisoft Metashape Professional, CloudCompare, MicroStation, ArcGIS Pro and Geomagic Wrap software. This is software that is or is not specialized for working with 3D models and dense clouds, in order to cover the widest possible spectrum of possibilities because the classification does not have to be done by an expert in photogrammetry, but by an expert in preservation.

Visualisation

It is good to choose the way of visualisation, that does not depend on the ownership of software that was used for the classification. The appropriate way of arranging this is to visualise a classified 3D model or dense cloud with some web tool, so the visualisation could be added to the web page of the preservation institution, or at least it can be linked to it. Another possibility is to visualise the object by creating some independent application.

The visualisation should enable interactive viewing of defined levels and the option to supplement the visualization with photos, explanatory text is also appropriate. There are many options to visualise classified objects, but only four were chosen for testing – ArcGIS Online, Sketchfab, 3D PDF, and CopperCube, this software and platforms differ.

3 RESULTS

Classification

During the work, it was proven that each type of software is usable for some part of the work or its modification. At the same time, it was proved that it would be more practical to perform classification by segmentation. Due to the large number of defined levels that overlap each other, the segmentation would lead to better orientation in the classified model and save memory.

The most suitable way of classification seems to use complete and unclassified 3D models or dense clouds, together with segments that represent specific levels. These segments can be single-coloured which leads to their better visibility over unclassified models that are left in true colour.

The main advantage of classification in Agisoft Metashape Professional software is that it is a program in which photogrammetric outputs are created. If the classification was performed by the author of the 3D model/dense cloud, it is not necessary to use another software.

In CloudCompare software, the segmentation can be done easily and segments can be colourized additionally and these coloured segments can be exported in a correct format. Since it is an open-source program, it is suitable for classification done by preservation experts, who do not have to own photogrammetric software.

MicroStation is CAD software uploaded 3D models and dense clouds were added as a reference, so they cannot be modified. Dense clouds can be vectorized which can be sufficient in some cases. Importing a modifiable point cloud was only possible in *.dxf, which was unsuitable due to the monochromacy.

In the case of ArcGIS Pro software, there were problems with importing the objects into the project. The count of faces of the 3D model had to be significantly reduced so the import could be done and the texture failed to import at all. Working with a 3D model and a dense cloud was influenced by ArcGIS Pro software specialisation in working with a representation of large terrestrial areas, so with much larger extents than the tombstone. The classification itself was not easy in this software, but it can be used for visualisation in ArcGIS Online which is connected to ArcGIS Pro software.

Geomagic Wrap software is intended for advanced surface analysis, it can be senseless to use it for simple segmentation of a dense cloud or a 3D model, though the segmentation can be done easily. However, the software allows the registration of point clouds taken by a laser scanner, so if the documentation was done this way, the main advantage of this software would be the possibility of processing and classification by the same software.

Based on the testing results, it is not possible to clearly say, which software is the most suitable for classification. All of them differ in ways of work and specialisations, so the suitability is determined by the person who processes the data (expert in photogrammetry/preservation) and the combination with the software used for visualisation. However, if the segmentation was carried out by a processor of a 3D model, it would be suitable to be done by the same software where the 3D model was created. However, if the segmentation was done by someone else, then one of the most functional and universal types of software is CloudCompare.

Whether it is better to use a 3D model or a dense cloud depends on the characteristics of classified segments. In the case of dense cloud segmentation, the boundaries are accurate and smooth. On the other hand, if it is necessary to create segments with a size in the order of millimetres, there can be problems with their visibility if the cloud is not dense enough. However, files with very dense clouds have a large size, which can complicate their loading, manipulation etc. and even a large density does not guarantee high-quality details. 3D models are visually better even with a lower face amount, but as the face amount decreases, the quality of the segment boundaries does too. However even here appliers, the more detailed the 3D model is, the smoother are the boundaries, however, the file size grows at the same time and the loading and manipulation are more complicated.

Visualisation

The main advantage of visualisation in ArcGIS software is the possibility of connecting the desktop application and online tools. In the case of creating the visualisation using one of the ArcGIS Online templates, the process is quite simple, multimedia content can be added to the application created using StoryMaps.

The basic version of Sketchfab doesn't allow users to upload multiple 3D models or dense clouds at the same time, so this version is unsuitable for visualisation. It can be used more for cooperation between workers because 3D models and dense clouds can be displayed without necessity to be sent in another way.

Classified models can be exported to single a 3D PDF file. In this case, the file was created using MicroStation software, but there are many more ways to create it. This way of presentation is quite easy and it can be sufficient in some cases, so it can be recommended.

In the CopperCube software it is possible to create interactive visualisation and multimedia content can be added too. It is possible to export the visualisation as an executable application or as a WebGL (Web Graphics Library), i.e,. file that can be published on the Internet. Everything can be created without the knowledge of programming and the basic and fully sufficient version is free. The software cannot load the dense cloud, but despite this, CopperCube software is suitable for creating a visualisation.

From the tested types of software, CopperCube software seems the most suitable for creating visualisation. The software allows work only with 3D models, but this is the only major disadvantage that was found during testing, other tested programs had more of them, especially the inaccessibility to the public or impossibility of displaying multiple models at the same time. The 3D PDF file software stays a little bit aside from the tested types of software, but it is suitable for visualisation too.

Summary

This article dealt with finding the most efficient way of classification and visualisation of a computer representation of a tombstone. The work aimed to asses, whether it is better to use a dense cloud or a 3D model and to find an optimal software solution with regard to specific circumstances of the creation.

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Since many categories of levels can be defined on a stone tombstone and they overlap and differ in their extent, it is suitable to segment the representation for the purpose of classification. Segmentation means cutting the parts that define the classified level and deleting the unnecessary parts.

It was proved during creation, that it is more suitable to use a 3D model with a high-quality texture. The main reason for using the 3D model is its appearance because the 3D model does not have holes and the high-quality texture displays good details even on models with a lower number of faces. However, the number of faces have to be taken into account. The comparison of the 3D models with different numbers of faces proved that reducing the number of faces does not have to degrade morphological details, but a lower number of faces leads to their bigger size which leads to inaccurate boundaries. So, it seems to be suitable to use 3D models with different numbers of faces, use them according to the character of the classified part and combine them in visualisation.

In the case of a dense cloud, the appearance of boundaries is not a problem, on the other hand, when the dense cloud is zoomed, the details are worse to be recognized and the dense cloud has holes, that can be filled by appropriate interpolation when creating a 3D model.

The software solution of classification depends on the possibilities of the output author. If the classification is done by a 3D model by the author, it is suitable to use the same software for both steps of work. This eliminates the need for other software just for the purpose of classification. In the case of this research, the 3D model was created in Agisoft Metashape Professional software, in which segments can be done quite easily. If the data were collected using laser scanning, there is a possibility to create the 3D model and segment uses Geomagic Wrap software. However, the classification can be done by a preservation worker who can only create a 3D model. In this case, it is suitable to use for example CloudCompare software, which is also very easy to work with and is an open-source program.

There are also many visualisation possibilities, for which it is suitable to use WebGL software. This way is the most adaptable to user's requirements and in addition, it is possible to create WebGL visualisation without programming knowledge. In this article, CopperCube software was tested and it proved to be a simple and effective solution. The software provides a free version and though it is just a basic version, all important functions useful for the tombstone visualisation are included.

During all steps of processing, the hardware equipment has to be taken into account both on the side of an author and the potential viewer user – it is necessary to find the balance between output quality and easy manipulation and loading.

The final application displayed in Fig. 3 was created using CloudCompare software for classification and CopperCube software for visualisation.

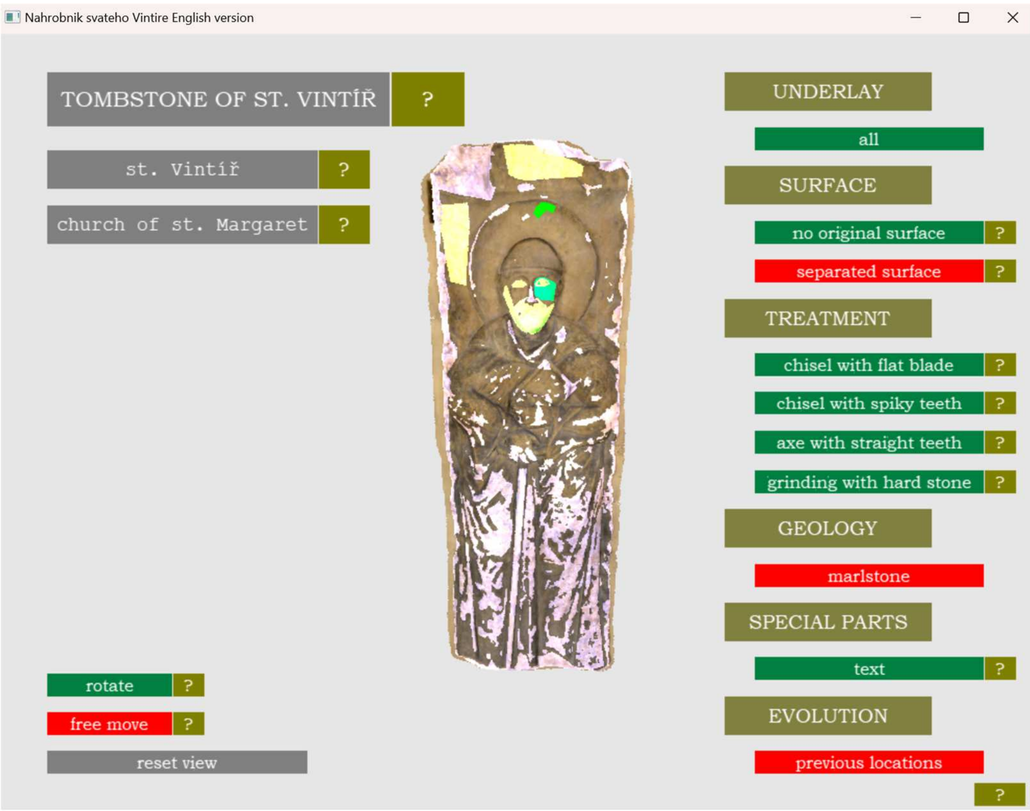

Fig. 3 Final application.

4 DISCUSSION

In this case, only a passive viewer was created, on the other hand in [5] or [6] updatable database was made. A suitable progress for future work would be to change the visualisation into the database and adapted to monuments of similar types.

Nevertheless, if it were to remain with a passive viewer, there is no need to create personalised code like in [4], especially if that viewer was created by a preservation expert.

This article brings compromise between the work of an expert in photogrammetry and an expert in preservation and assumes that preservation workers would participate more in it than in previous cases.

5 CONCLUSIONS

This article dealt with creating the interactive model of a tombstone with information extension. As a part of the work, various types of software were tested as tools to create classification and visualisation of 3D models and dense clouds created by terrestrial photogrammetry methods. The optimal way of classification and following visualisation was defined based on this testing, considering that work can be done by a preservation expert, not a photogrammetry one.

Using open-source CloudCompare software, which is easy to work with, to classify and open-source CopperCube software to visualise the result seems to be the optimal way.

Though an effective way of classification and visualisation was found, there are many possibilities for improvement and development, one of which is to convert the passive viewer to an updatable database. This article can serve as an outline of the possibilities and the direction in which the presentation of stone tombstones can develop.

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