

Digital Documentation of Cultural Heritage Objects using hybrid recording techniques

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Abstract

Using hybrid recording techniques is a well established procedure in the documentation of cultural heritage objects. Due to changes in the technological process, to choose the appropriate techniques and systems may be difficult and has to be adopted for every single project. The potential of new technologies sometimes tends to be overestimated whereas the need for especially adopted usage and processing may be underestimated. In combination with the needs of the appropriate and concerned historians or humanists the special requirements for the investigation and documentation of the objects have to be checked. The paper shows concepts and present results for several example sites in Germany e.g. the documentation of Porta Nigra, a roman city gate in Trier, and the Herkules-Monument in Kassel. Used techniques in the projects are 3D laser scanning, high resolution textured-light scanning, total stations, digital and analytical photogrammetry and high resolution digital surface images - all of them in combination with the conventional manual inspection and evaluation of the objects themselves by the particular experts from other disciplines.

3D-Scanning, Archaeology, Cultural Heritage, Documentation, Hybrid Sensor, Laser Scanning, Photogrammetry, Visualisation,

1. Introduction

For the documentation of extended or complex cultural heritage objects usually different aspects have to be fulfilled in data recording. One of them is the measurement of geometry data, another is the recording of image data to describe the surface and texture of the object. Due to different technologies and limitations of available hardware these data sets are often independent from each other and not freely combinable. Additionally the customers needs in certain aspects of the data sets differ in such a way, that a full integration of the data sets is not required or desired in all projects. For architectural projects geometry information is often sufficient for particular structures like e.g. edges or joints of blocks to generate plans of sections. A complete 3D surface model is often not needed, whereas high resolution texture data may be absolutely necessary.

Taking stereo images with non-metric consumer digital equipment allows to record situations with high resolution for further inspection in three dimensions with low additional operation expenditure. 3D-viewers and tools supporting the non-technician operators in orientation and

basic measurement functionality can extend the usability of this data source widely.

Currently available technologies often still have limitations in hybrid sensor hardware and/or processing software for the generation of hybrid data sets. These systems cannot be optimum solutions for all problems, but adopted use and processing is essential.

2. Motivation

The documentation of cultural heritage objects in many cases comprises a more or less large number of challenging tasks. First of all, a detailed and carefully elaborated requirement specification is a must to achieve a sufficient quality of the results. Quality standards have to be formulated, which are needed as the base for the selection of feasible equipment and for the definition of well suited data interpretation procedures, as well. The specification which is of utmost importance for the subsequent steps typically has to be developed in close co-operation between persons with different professional background. Persons

who are familiar with all kind of relevant state-of-the-art technology jointly have to work together with persons who are able to formulate the requirements from the users point of view. The requirement specification task is far from being trivial. Overestimation as well as underestimation of the potential of, particularly, new technologies has to be avoided, the same holds for the trend to misstate the needed quality of the results, the combination of different technologies has to be designed in an appropriate way, financial and human resource factors have to be observed, and so forth.

In this context the paper particularly discusses the use of hybrid recording techniques for the documentation of cultural heritage objects. Credit is given to the progress of technology as well as to the selection of feasible measuring equipment depending on the requirements of specific documentation tasks. Special attention is given to the use of high resolution images, particularly in the context of digital stereo models within photogrammetric processing procedures. This technology in many cases is a cost effective alternative as compared to complete 3D model generation of complex shaped objects.

Best practice case studies are dealing with several locations in Germany like the city of Trier with its Porta Nigra, a roman city gate, and the city of Kassel with its Herkules monument. The described methods cover the wide field of many techniques which are nowadays available, like 3D laser scanning, high resolution textured-light scanning, use of total stations, application of digital and analytical photogrammetric methods and high resolution digital surface image processing - all of them in combination with the conventional manual inspection and evaluation methods of the objects themselves.

3. Technologies

The catchwords surrounding the term of metrology at the preservation of historical monuments can be described by manual inspection, tacheometry, 3D laser scanning and stereo photogrammetry. With regard to the requirements of an expert for the preservation of monuments, but being not familiar with the field of metrology, the most common demands are aiming at a simplification of the measuring techniques. The millions of 3D laser scanner points of a recorded object are often described by an overcharge of information. Thereby, it has to be paid attention, that the desired simplification of data capturing and proceeding does not lead to a loss of critical object information and an apparent uselessness of the data as well as the applied metrology.

Nevertheless, at the view of stereo photogrammetric proceeding, a simplified strategy of data ascertainment and proceeding is thinkable and often demanded from the operator's view. Helpful in the task of recording stereo models by non-experts could be the development of an object oriented observation and capturing instruction

followed by an analytic proceeding at digital workstations with the help of special developed software tools.

Even though, in case of possible error sources at measurements and a demanded enhanced resolution of the object as well as an increased accuracy in geometrical and morphological ways, geodetic know-how is indispensable.

4. Geometric and visual Documentation of the Herkules Monument in Kassel

4.1 Projects purpose

The Herkules Monument, located at the Wilhelmshöhe in Kassel/Germany, was built in the early years of the 18th century in the care of earl Karl von Hessen-Kassel following the design of master builder Francesco Guerniero.

The memorials eye-catcher is the more than 8 meters high copper statue of the antique hero Herkules, reposing on a pyramid on top of the octagon shaped castle. The basalt-tuff, which was used as building material, was descended from regional quarries and has suffered from weather conditions through out the years. Owing to this, a basic remediation was decided by the responsible administration department.



Figure 1: View of the Herkules monument

To find suitable means of documentation for the different parts of the building, an exemplarily axis of the monument was picked out to get a formative impression of proceeding in view of the whole Herkules. These investigations are building the base for extensive analysis of the monument and the call for proposals for the monument's restoration. The i3mainz, the Institute for Spatial Information and Surveying Technology of the University of Applied Sciences at Mainz, is carrying out the task of the metrological documentation of the instancing sample.

4.2 Initial situation

The i3mainz has worked several days on site and a large bandwidth of measuring techniques have been used. To get a solid documentation of the building in geometrical and image based ways, analogue and digital close-range photogrammetry, tacheometer measurements as well as 3D laser scanning have been applied.

4.3 Geodetic observations

Whenever geometrical contexts needs to be explained, geodetic networks are building a solid groundwork of an adjusted coordinate system. Even if high precision is not the point of view in case of the projects purpose, it is still of importance that all measurements and observations can take place in the same environment. To achieve this aim, direction observations and distance measurements to signalised an natural marked points were done by tacheometers. With regard to the clients claim and the following evaluation of the achieved precision, those measurements were done with over determination where at least each point was constituted by three rays. On the whole, a precision of ± 3 mm (1 sigma) was reached for all datum points.



Figure 2: Geodetic observations at the monument

Signalising for the different methods mentioned before is the arising data and the consequential workflow. Where pre-selected single points are associated with total station measurements, close-range photogrammetry and 3D laser scanning come up with lots more of information of the recorded object. Besides a lot of 3D points, texture and intensity values are describing the recorded object more likely.

This additional information has to be carved out and can be orientated to the customers questions. In case of the Herkules project, the formulated requirement by the client has been the geometric documentation. Other important tasks have been the mapping of defects, the determination of mass for remediation purposes and the presentation of the possibilities for visualisation of the collected point data and the images. Still, the project's working environment

demanded for a presentation of the evaluated data in 2D and as a matter of fact, a lossless reduction of the data's third dimension had to be done.

4.4 Stereo photogrammetry



Figure 3: Photogrammetric work at the monument

In case of the Herkules monument, on hand, the most common proceeding of close-range stereo photogrammetry has been the digitalisation of joints, for which metric analogue medium format images have been building the data basis for the stereoscopy. Especially with regards to the monument's domes, the captured stereo models were utilised in analytic plotters and after the step of digitalisation, the high resolution images were interpreted in digital stereo tools, too. Due to good accessibility of the wall areas and the floor space, other measuring and documentation techniques got into action. On those parts it was worked conventionally by manual inspection and evaluation at the objects surface.

Only natural and not signalised points were used as photogrammetric control points. They were coordinated by tacheometer measurements, too.

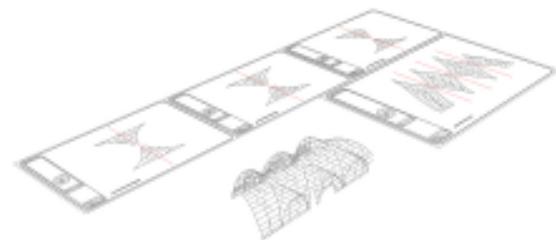


Figure 4: Collage of a 3D CAD model and the associated 2D joint graphics

The maps of the curved domes (of the monument) are presented in 2D. To achieve a lossless graphical representation, a cylindrically projection to the plane was done and as a result the displayed joints appear with effective length. The plans are used for mapping the defects of the building's material by experts and are the

base for length evaluation of joints, which was an important task in the course of restoration.

Another aspect has been the photographic documentation of some interesting parts of the monument. The images were made in view of stereo photogrammetric means and shall serve for evaluation purposes on the part of historians and architects. With the help of the middle format images and a suitable stereoscopes, those gainful observations can be done in a common and easy way.

4.5 3D laser scanning

Another part of the project's work is focussed on 3D laser scanning. This technique was brought into the project to show the possible abilities and it was applied to a few grottos and facades. The clients questions around this measuring technique have been of same nature as in case of the applied stereo photogrammetry – finding an adopted way of generating 2D plots of the building's joints for evaluation purposes.

The digitalisation of some interesting parts of the monument was done. This was made possible by treating the point cloud data, which was including intensity values, in usual CAD systems. The digitalisation depends on many object and observation parameters and the evaluation is mainly relied on intensity values which are resulting of surface colour and structure. In case of the monument's facades, the available third dimension of the laser scanner points eclipsed by increasing the model's density. A proper result could only be achieved by evaluating the intensity values of the joints. As the case arises, the effect of outliers and noise of measurements still is an important issue, which has to be reviewed and estimated correctly.



Figure 5: Basic 3D surface model of a grotto

In addition, surface modelling of the laser scanner data was done and the possibilities of registration and point cloud treatment with regard to outliers and noise were shown to the client. The modelled closed surfaces can serve for mass and inspection purposes but do not achieve the

projects main goal. Never the less, the created models are intended to be applied at public exhibitions and presentations due to the projects public agenda.

4.6 Hybrid solutions

With the advantages of both the stereo photogrammetry and 3D laser scanning the combination is supposable and surely productive. The arrangement of high resolution images and digital elevation models was performed in the course of the project and was commented feasible for evaluation and public relation.



Figure 6: Image textured 3D facade model

Nevertheless, the creation of hybrid data sets does not provide a seamless workflow. Still noisy and outlying measurements occur moreover geometric and radiometric improvements have to be done which requires the use of several software tools. This aggravation complicates the data handling and builds a great barrier for non-experts. To achieve this, the choice was to present the results in common viewers and data formats like DXF and VRML.

5. The Porta Nigra / Trier



Figure 7: Overview of the Porta Nigra, World Heritage Site at Trier/Germany

Another motivation of detailed analysis can be found at the Porta Nigra at Trier/Germany where strictly defined, partially commercial aims of civil works do not stand in foreground. In fact, the allocation of digital data for the use of historians and architects for means of construction research is taking place and it was found out, that a determined object documentation can only be achieved by using several, hybrid used measuring techniques.



Figure 8: Hybrid data model of parts of the Porta Nigra – 3D laser scanning combined with high resolution images

The Roman city gate has obtained an enormous variety of construction phases from its surely inducing history where a lot of conversions took place. From the original use as a roman city gate, to the transformation to a mediaeval church, over to the Napoleonic deprivation of building materials to the point of today's monument, a lot of surveys can be done. Accordingly, a large spectrum of measuring techniques were used so that geodetic measurements, 3D laser scanning, digital stereo photogrammetry, structured light based scanning and manual inspections on site were executed.



Figure 9: High resolution 3D surface model of a relief

The measurement's results are intended to be presented with the help of suitable and easy to use software tools for further processing by experts. Therefore, the dialog between the involved faculties and the surveying department as a data provider is playing an important role within the project since the interpretation of the construction phases and the mapping of mortar and joint defects can only be done by colleagues of other professions. As a result, suitable software tools in view of the needs of the involved departments mentioned before are specified and developed at which a defined workflow particularly with regard to the Porta Nigra is intending the object's studies.

6. Conclusions

The main concern of the paper was to describe how to combine different measuring techniques in order to guarantee maximum efficiency in the appropriate process of cultural heritage object recording. The recording tasks were performed by using currently available state-of-the-art technology while observing carefully the specific properties of all methods in use. Technology may, and most probably will change in future in the same way as it did in the past. In the same way it can be expected that the tasks of appropriate method selection will persist in the foreseeable future, as well.

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