USE OF CLOSE-RANGE PHOTOGRAMMETRY IN FORENSIC SCIENCE

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Summary: *This paper outlines two examples of application of close-range photogrammetry, their preliminary results and observations. The first application is identification and measurement of deformations and displacements of the vehicle chassis after a frontal crash-test. This is done by comparison between the pre- and post- crash models and measurements. The second mentioned application is determination of the road pavement macro-texture, where the photogrammetry can serve as an alternative method.*

Keywords: *close-range photogrammetry, vehicle deformations, pavement macro-texture*

1 Introduction

Photogrammetry is already used in the forensic science for a long time, especially in a transportation field. But recent development of digital technologies, particularly of digital cameras and photogrammetric software, opened the door for new photogrammetry applications. Areas, where it was not possible before, can now benefit from using of this measuring method. Because of this reasons, the research of new alternative photogrammetric applications is currently taking place at the Department of Forensic Experts in Transportation. Two examples of application were chosen to show the flexibility and potential of modern digital photogrammetry.

Two software programs are used for the photogrammetric evaluation of given examples. The first is PhotoModeler Scanner (PM). Photogrammetric system developed by Eos Systems Inc. for 2D and 3D noncontact measurements from photographs. The software is using bundle adjustment method to determine the camera position and if necessary even the camera internal parameters to recreate the spatial information. For the purposes of this paper, this software is used mainly to create a highly accurate point based models of the vehicle chassis. Second software, Agisoft PhotoScan (AP), is developed by the AgiSoft LLC. Program performs photo-based 3D scanning and is mainly aimed for an aerial photogrammetry use. Nevertheless, the software is also suitable for the close-range photogrammetry. High amount of overlapping photographs serve as an input for the program. These are aligned and dense point clouds or DSM models are generated. The AP is used, within this paper, mainly for creation of dense 3D point meshes.

2 Vehicle damage documentation

In a first example, there was required to obtain information about the vehicle deformation during full-width frontal crash test of vehicle ŠKODA Rapid, which was followed by crash rescue demonstration. The time between actual impact and rescue demonstration was only few minutes. The rescue process itself involves cutting and massive deformations of the vehicle chassis. Therefore, the actual measurement of vehicle deformations after the crash test itself had to be carried within very narrow time window. This time limitation was the crucial problem for any standard measuring technique such as total station, 3D scanner or hand-on measurements. The photogrammetric measurements offered as the only one the ability to obtain any kind of accurate measurement in given conditions.

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2.1 Used equipment and preparations

The pre-crash vehicle preparation included placing of adhesive paper targets on the exterior surface of the vehicle. Specifically, one hundred and fifty white target dots and thirty-six black and white 10-Bit coded targets were placed around the vehicle sides and frontal part. All coded targets were in approximately regular distances from each other in order to achieve even distribution along the photographs and served for the initial orientation during the processing. The target dots were the actual points on which the damage was measured. These target dots were also used for additional improvement of the orientation and for accuracy checks. Precision was tested by strips of dot targets with known length. These were placed on different parts of the vehicle chassis.

The photographs were taken using a Canon EOS 60D camera body at $5184\text{x}3456\,\mathrm{pixel}$ resolution. The camera was equipped with a Sigma $18-200\,\mathrm{mm}$ F3.5-6.3 DC OS HSM zoom lens. All imaging was done with the lens set to its widest angle ($18\,\mathrm{mm}$) setting. Camera settings were in accordance with the usage of uncalibrated DSL camera for close-range photogrammetric purposes [1]. The camera itself had manual and fixed focus for the whole time of imaging, an aperture of f/8 and an automatic ISO sensitivity (limited by value of 1600). In total fifty-two photographs before the crash and ninety-nine photographs after the crash were taken. The camera was calibrated with the use of multi-sheet calibration generated by the PM and also by the Agisoft Lens software.

2.2 Processing

In the beginning, twenty-six photographs were selected for each project with the necessary coverage and overlapping. The PM allows utilizing of several alternatives for the orientation of photographs or their combination. The most precise alternative is the coded target point method. Another option is smart matching feature, which tries to identify common point between photographs. The last and least accurate option is the point determination by a user. All three options were employed in both projects. The photographs were loaded into the PM and the camera internal parameters from calibration were assigned. Automatic target detection was carried out to establish the initial orientation of images. Subsequently, automatic detection of dot targets together with manual corrections was used to reconstruct the spatial coordinates of targets. The coordination system together with scale and rotation was defined for both resulting models. This was done with the help of preselected targets on the vehicle chassis. Additionally, target dot strips lengths were measured and used as precision checks. The resulting accuracy of the pre- and post-crash projects is shown in Table 1. As can be seen, the actual achieved precision of both projects is very high. Both models were exported in form of .dxf format and putted together with use of AutoCAD Autodesk program. Here, actual deformations were measured and evaluated.

Table 1: Pre- and post-crash project point marking residuals and maximum check distance errors

Project	Overall RMS [px]	Maximal residual [px]	Average check distance error [mm]	Maximal check distance error [mm]
Pre-crash model	0.308	0.868	0.069	0.156
Post-crash model	0.354	0.946	0.154	0.233

2.3 Model creation

Two 3D mesh models were also created for the overall comparison of resulting deformation. In total forty-eight and sixty-four photographs, respectively, were used for the mesh generation. This was done with AP software. The workflow within AP is divided into three main steps. The first step is called alignment and consists of the mutual point detection and matching between all images. Based on this, the photographs are then oriented and the camera internal parameters are estimated. The information from the calibration was imported from the Agisoft Lens program. However, this calibration data served only as initial values and the programme was left with an option to adjust them during the processing. Second step is building of geometry. Point clouds and meshes can be generated with different precision and resolution. More than forty-eight thousand tie points with error of $0.427\,\mathrm{pixels}$ were identified in the alignment step of the pre-crash project. The post-crash project had over one hundred forty- five thousand tie points with error of $0.646\,\mathrm{pixels}$. At first, two digital meshes consisting of four million faces were generated. Mainly due to high computational demands and an unnecessary level of detail, two other meshes consisting from five hundred thousand faces were then generated. This resolution proved to be sufficient for the purposes of forensic analysis. Both models were scaled and oriented again. The last step is the texture mapping. Where the texture information is obtained from the images and mapped on the surface. This step serves more for the representation purposes than for actual measurements.

It is important to note that during the imaging it was a rainy day. This condition had almost no effect on the PM evaluation. On the other hand, for the AP processing it was the significant issue. However, even under these adverse conditions the program was still able to deliver good results.

3 Road pavement macro-texture

One of important characteristics of roads, significantly affecting the safety, is the skid resistance properties of the roadway. Currently, a research to find new alternative ways of the pavement texture and skid resistance properties is taking place at the Department of Forensic Experts in Transportation. One of the potentially suitable methodologies is the photo-based 3D scanning. The pavement surface has ideal properties for this type of measurement. The high contrast changes and random asphalt pattern can potentially increase the amount of tie points.

3.1 Used equipment and methodology

It was created a frame with four circular targets with set distance from each other for the imaging. Main objective of this frame is to ease the image orientation, scale definition and to serve as accuracy check. The size of measured pavement patch was set to $150\text{x}150\,\mathrm{mm}$ for the first round of tests. First tests were done in the form of four imaging series with twenty images for each. The photographs had a high level of overlapping to secure required level of precision. All of the images were taken using a Nikon D600 camera body at $6016\text{x}4016\,\mathrm{pixel}$ resolution. The camera was equipped with a Nikon AF-Nikkor $50\,\mathrm{mm}\ 1:1.4$D prime lens. The camera itself was set to manual and fixed focus ($0.5\,\mathrm{m}$), an aperture of f/8 and an automatic ISO sensitivity(limited by value of 1600). The camera was calibrated by the Agisoft Lens software. Furthermore, photographs were taken in raw format and then processed in Adobe Photoshop CS 6. The adjustment involved only contrast and exposition changes which improved the overall quality of pictures.

The resulting image orientation and produced mesh was showing good representation and precision after processing in the AP. In average sixty thousand tie points were identified in each project. After setting the scale, the average check distance error was less than $0.5\,\mathrm{mm}$. One of resulting meshes from the AP can be seen in Figure 1.

3.2 Further research

To this day, only the first series of photogrammetric measurements of the pavement macro-texture were conducted. The main outcomes of these tests are that this methodology proved to be suitable and have very good results. The generated mesh from the photogrammetric measurement shows low level of noise and the potential resolution is more than sufficient. In the future, it is necessary to further examine the noise and its effect on the resulting pavement macro-texture. Furthermore, an appropriate resolution is necessary to define to be processable and still have a sufficient quality.

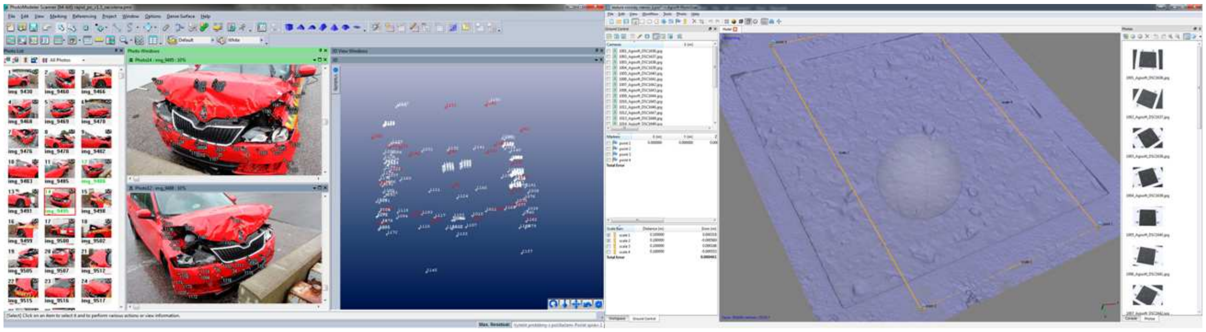

Figure 1: Vehicle deformation measurements in PhotoModeler Scanner and a road pavement model in Agisoft PhotoScan

4 Conclusion

This paper has presented two applications of digital close-range photogrammetry. First example was vehicle deformation measurements. Photogrammetry was able to deliver all necessary information even under unfavourable condition such as rain and time pressure. Second example was an alternative approach for determination of road pavement macro-texture. Here the photo-based 3D scanning showed to have a good potential. Overall, based on the preliminary results it can be concluded that photogrammetry has great potential for wider use in forensic science because of its non-invasive, quick and precise measurements. An in-depth analysis of preliminary results, accuracy and suitability of measurement together with some recommendations for further measurements and potential use should be the objectives of further research.

5 Acknowledgment

This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS13/157/OHK2/2T/16.

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