INNOVATIVE INVESTIGATIONS OF THE CRIME SCENE USING 3D SCANNERS

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Abstract: *Innovative solutions that can be applied in contemporary forensic science, including the examination of the place of the incident or crime, are still being sought. One of them is the preservation of evidence by means of 3D scanners. In Europe, 3D scanners have got, among others, Police services of the following countries: Switzerland, Germany, France, Spain and Italy In the paper, the results of research on the preservation of the crime scene using 3D scanning techniques have been presented. The research used Creaform hand scanners, both laser and structural light, Smarttech3D portable 1.3MPix, a scanner on the measuring arm - FARO Laser ScanArm AND TERRESTIAL scanners (Faro, Leica, Z + F). The accuracy and precision of scanners were carried out on a certified measurement pattern. The obtained accuracy results for the tested scanners are within the accuracy range given by the manufacturers in the technical specifications of the devices. To examine the scanners' resolution, an object with a complicated shape and many small elements was used. It was examined how the tested scanners behave when attempting to scan surfaces generally considered as hard to scan surfaces. Attempts have also been made to use a 3D structural light scanner to scan snow tracks. The possibilities of combining scans from a portable scanner (Go! SCAN50, Smarttech) and a scanner on a measuring arm (Faro), with scans obtained from long-range were examined. It has been found that it is possible to supplement clouds of points acquired in 3D scanning technology with photos from digital cameras, detailed scans of selected traces and precise geographical locations.*

Keywords: 3D SCANNING, CRIME SCENE, LASER SCANNERS, STRUCTURED-LIGHT SCANNERS

1. Introduction

Preservation of the crime scene and the discovered forensic evidence is the first and very important stage in the investigation process. It is important to document the crime scene, possibly without any changes, so that it is a reliable material in further investigations, reconstructions or trial experiments. The results of the Research Project, implemented by the authors as part of the "Polish State Security and Defense Research Program", have allowed the development of innovative solutions supporting the preservation of the crime scene and the detection process based on evidence recorded using 3D scanning techniques. The developed methodology assumes that both the terrestrial and portable scanners will be used at the crime scene (terrestrial scanners to scan the entire scene of the event, usually often hundreds of meters in size). The presented article discusses only chosen test results.

The world is constantly looking for modern solutions that can be applied in contemporary forensic science, including the examination of the crime scene. 3D scanning technology is such a solution. The most common 3D scanning techniques are used by the US police services, primarily in the forensic examination of traffic incidents and on the spot of the most serious criminal events, most often with the use of weapons. In Europe, 3D scanners have, among others, Police services of the following countries: Switzerland, Germany, the Netherlands, Luxemburg, Italy, and Spain. Danish and British Polices assume that in the near future they will introduce 3D scanning into routine forensic work. Currently, the Police use the help of external companies in the field of 3D scanning, handling complex and extensive incident scenes. In Poland, so-far, 3D scanning technology applied to the investigation of the crime scene has been used only incidentally. The main goal of the research and development project carried out by the authors, was the implementation of 3D scanning for the Police practice.

2. Testing portable 3D scanners

The research used Creaform [Creaform 2017] portable scanners, both laser (HandyScan, MetraScan), KonicaMinolta Range 7 and structured-light (Go!Scan), Smarttech3D, and a scanner on the measuring arm - FARO Laser ScanArm.

2.1 Testing scanners' precision

The accuracy test was carried out on a certified measurement pattern (determined with an accuracy of one micrometer). Due to the fact that scanners use different methods of positioning, the measured pattern was placed on a specially prepared pad with markers (Fig.1). Thanks to this solution, each of the scanners will be able to position themselves appropriately and the obtained results can be compared with each other. The diameter of the bullets is 38.107 mm (left ball) and 38.111 mm (right ball). In addition, the distance between the ball centers, which is 648.413 mm, was determined. Each scanner was tested with 6 pattern scans each time placing them in a different position on the pad. Measurements on scans were made using the manufacturer's software - VXelements.

Fig. 1 *The pattern for testing scanners' precision.*

The results of the measurements are presented in the table 1. For each measurement, precision was determined and the average value was calculated.

Table 1: *Results of portable scanners' precision testing [CaspSystem 2016]*

Scanner type	Handy SCAN	Metra SCAN210	Go!Scan50
Average value - left ball [mm]	38,117	38,159	38,159
Average error - left ball [μm]	19	52	52
Average value - right ball [mm]	38,110	38,156	38,147
Average error - right ball [μm]	23	45	36
Average value – between balls [mm]	648,371	648,512	648,621
Average error – between balls [μm]	49	107	322
Average scanner's precision [μm]	30	68	137

2.2 Testing scanners' resolution

To examine the scanners' resolution, an object with a complicated shape and many small elements was used. Thanks to the use of such model, it was possible to check the accuracy of grid mapping. During the examination, the object was scanned four times each time with different resolution of: 0.5mm; 1.0mm; 1.5mm; 2,0mm.

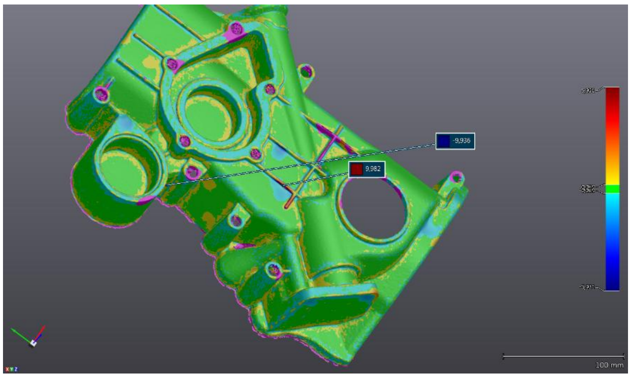

Fig. 2 *The map of deviations compared models scanned with 0,5 and 2mm.*

The change in scanning resolution for all examined scanners achieved similar effects. In the case of scans made with high resolution, the model had more clearly visible edges and better mapped smaller elements. In the case of smaller resolutions, however, the scans were smoother, and in some cases the reproduction of small elements was impossible. The figure 2 shows a colorful map of deviations resulting from a comparison of averaged models scanned with a resolution of 0.5mm and 2.0mm (green color, practically no errors). The maximum errors are marked in the figure (blue color negative deviation, red positive). The biggest deviations can be observed at the edges of the model. Certain fragments (purple) are off the scale. They represent fragments that could not be measured at all, while scanning at a resolution of 2mm.

Another aspect of resolution changing is the scan time and the size of the resulting scan files. Higher resolution scans have a larger number of triangles. Please note that the mesh of the tested element (about 240x320x80mm) when scanning with a resolution of 0.5mm has got more than 800,000 triangles. The highest resolution, this number can reach tens of millions, which of course also affects the scanning time, strongly enlarging it. That’s why, it is so important to find the right compromise between the resolutions, the size of the files and the time of scanning.

2.3 Scanning of different surfaces

The tested portable scanners are based on optical systems, therefore the optical parameters of the object being scanned are very important to them. In order for the scanners to be able to correctly acquire the data, the light beam displayed by them (whether it be a laser beam or a structural pattern) must be properly visible on the scanned surface. Therefore, surfaces that are highly reflective, transparent, strongly absorbing light or causing its dissipation are difficult materials to scan.

The tests were carried out on six samples of materials. It was a black polyurethane foam, a piece of fabric with a weave, a nickel element with a high degree of reflexivity, an acrylic glass plate, a steel plate and a white sponge with a small bubble structure filled with air.

Surfaces with high reflectivity are very difficult for 3D scanners. They cause so-called mirror effect. To investigate this effect, a polished nickel-plated component and a steel plate were used. Both the laser scanner and the structural light scanner had very big problems with scanning the nickel element (fig.3). The correct surface could not be scanned. As a result, an uneven and jagged surface was obtained. The solution to the problem with scanning highly reflective surfaces may be the use of surface matting powders. But in the case of crime scene, the method cannot be used because of traces contamination. Similar materials with a high reflectivity (steel plate) were tested. For such elements, both laser scanners and structural light were able to create a very good surface model.

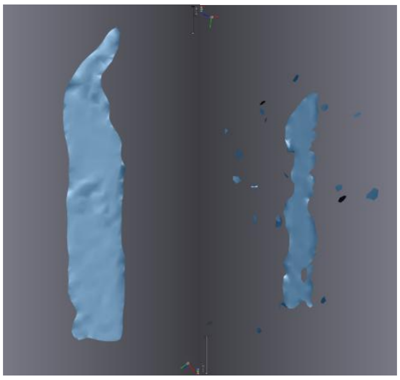

Fig. 3 *Results of a nickel element scanning: laser and structured-light scanners.*

Attempts have also been made to use a 3D structured-light scanner to scan snow tracks [Smarttech 2017]. The MICRON3Dgreen 10Mpix scanner, manufactured by Smarttech3D, with the accuracy of 0.041mm was used for the measurements. Six scans of the snow track were carried out, moving the scanner around the object being scanned. The resulted cloud of points has been transformed into a grid of triangles, becoming the model of the tested track. In order to confirm the high accuracy of the scan, a computer model of the shoe was made, and then both models were compared. The results are presented in a colorful deviation map (Fig.4). The green color means a practical lack of errors, which is fulfilled for almost the entire print.

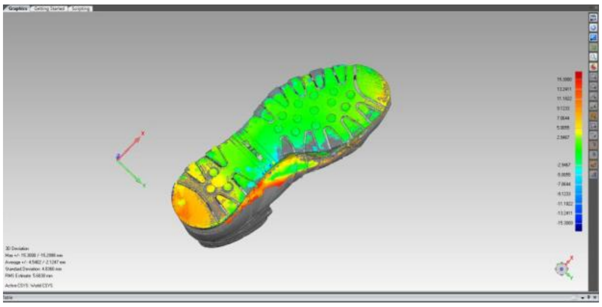

Fig. 4 *Results of a shoe print in snow scanning - a map of deviations (source [Smarttech 2017]).*

Transparent materials are virtually invisible for scanners. If the pattern emitted by the scanner is not reflected and the registered creation of the model is impossible. This is exactly what happens with all transparent materials, i.e. glass or plexiglass. The transparent surface was not registered for both the laser scanner and the structured-light scanner (fig.5). On the other hand, the effects of light passing through the transparent plate are visible. The edges of the scanned plate are clearly visible. The scanners captured all the elements of the environment, i.e. the base with markers, on which the plate was placed and the protective foil glued on the bottom of the half of the plate.

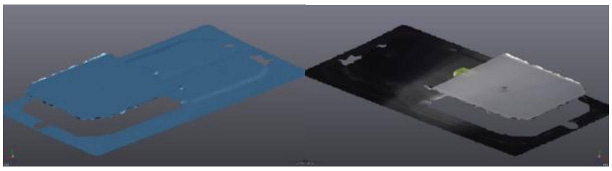

Fig. 5 *Results of a plexiglass element scanning: structured-light and laser scanners.*

A sample, which absorbed light very much, was a white sponge made of bubbles filled with air. The structure of this material causes very strong penetration of the light inside without the possibility of leaving it. In addition, the white color makes it difficult to recognize the pattern especially for structured-light scanners, due to the very low contrast between the pattern and the surface. In the case of laser scanners, the result is correct, whereas the structured light scanner had problems with surface acquisition. The structure of the material caused a very large loss of pattern visibility on the scanned surface. The obtained surface had discontinuities (fig.6).

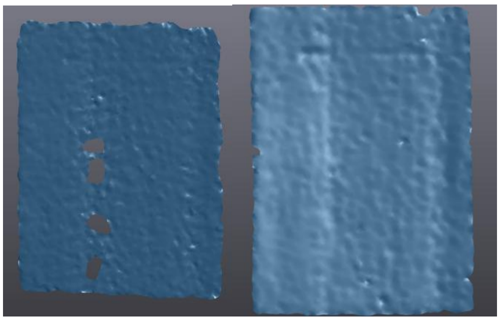

Fig. 6 *Results of scanning of a white sponge made of bubbles filled with air: structured-light and laser scanners.*

3. Testing terrestrial scanners accuracy

An important issue is to determine the distance between two selected points on the scan (e.g. the position of the object and the assumed reference point of measurements in the scene). The precision of determining the distance consists of two factors - the first is the precision of the scanner itself, the second is the precision of pointing of the measuring points on the scan. Accuracy tests of measurements making on the scan were carried out for scanners: Faro, Trimble, Z + F, Leica. Many testing measurements have been taken on different scans made either inside buildings, like at the simulated "scene of crime" - fig.7 or outside. In tab. 2 example results have been presented.

Fig. 7 *Simulated "scene of crime" for scanners accuracy testing.*

To test the accuracy of measurements on 3D scans a series of measurements was made on the real scene (for long distances with accuracy ±1 cm, for small elements ±1mm), and then the same measurements were made on 3D scans. Considering accuracy of measurements taken on scans we should notice that the data acquired by the scanners are useless unless they are processed using specialized software (we tested Faro Scene, Leica Cyclone, Z+F Laser Control).

Table 2*: Results of terrestrial scanners' precision testing*

Description	**RD [mm]**	**DMS [mm]**
Left drawer handle – left leg of the chair	2270	2286
Washing machine-cabinet: corner-corner	195	198
Corner to corner of higher cupboards	2875	2860
Floor – top of the wall cabinet	1999	1961
Width of the beam	135	137
Table in the room	500x1500	498x1488
Heel - the corner of the table	960	911
Drawer handle – cupboard's top corner	7085	7098
Thickness of the table top	18	20
The width of the door	940	949
Lath-threshold	1955	1952
The width of the lamp	1265	1249

RD – real distance; DMS – distance measured on the scan

Some of obtained errors could be considered as too big (i.e. 16 – 38 mm). But the problem was to properly determine equivalent point in the scan e.g.: drawer handle – reflective, shining surface, corner of cabinets - overlapping edges in the scan, rounded edges of the washing machine, lamp housings made of transparent plastic etc. The most important causes of errors and difficulties occurring while dimensioning objects on the scan:

- surfaces difficult to scan (e.g. reflective),
- carefully choose the perspective to mark the measurement point because often the edges overlap,
- for small objects (e.g. table top thickness) problems occur due to the scanner's resolution (at a further distance from the scanner the resolution is a few mm),
- errors done by measurements in the real scene.

Accuracy of measurements taken on the scan strongly dependent on the software and an operator's skills. Z+F Laser Control software supports distance measurements by introducing the so-called "spatial grabs", i.e. characteristic elements - planes, edges and corners, so that the measurement is better suited to the characteristics of the object being measured. This solution is very useful, because it allows to reduce the error resulting from the imprecise indication of the measurement point.

4. Integration of 3D models

An important aspect for the documentation of the crime scene is the integration of data from various types of devices. It is possible to supplement the cloud of points obtained in the technology of scanning 3D by photos from digital cameras, detailed scans of selected traces and precise geographical locations. Therefore, the possibilities of combining scans from a portable scanner (Go! SCAN50, SmartTech) and a scanner on a measuring arm (Faro) with scans obtained from terrestial scanners (Faro, Leica, Z + F) were tested. Attempts to integrate scans were carried out using the following programs: VXelements - Go! SCAN scanner software, SCENE - Focus 3D X130 scanner software, Leica Cyclone - P40 scanner software, 3D Systems Geomagic Design X, CloudCompare (Open Source Project). Each of the tested software has various possibilities of importing and exporting files in given formats. Terrestial scanners operate on point clouds, while portable scanners (in particular the Go! SCAN scanner and measuring arm scanner), as a result of the scan, immediately generate a grid of triangles. In all cases, therefore, format conversions were carried out. All scans were made in one room in similar time intervals and the individual elements of the scene are in the same position in relation to each other on each of the scans performed. The study locations were simulated crime scenes with many key elements. Using terrestial scanners, a general overview of the scene was made, and scans of key elements of the scene of traces discovered at the scene were made using portable scanners. In all attempts, the resulting files have a total size of GB and work with them is extremely time-consuming and cumbersome, requiring the highest-class computer equipment. For example, in the case of a simulated crime scene with 7 detailed evidences, the editing of the joint model was possible only on a computer with an i7, 2.6GHz processor and with 16GB RAM memory. That is why the Project was proposed as final solution to create a full documentation of the crime scene in the form of a set of files, linked together with hyperlinks. Since all native programs of the examined scanners allow to attach a label and assign a link to an external file or application, the resulting set can be protected as a whole (folder).

Preparation of documentation of the crime scene (in the form of a set of files) using 3D scanning requires adaptation of the methodology to secure the integrity of the registered space to current Police standards [Wieczorek T. at all. 2017]. Applicable standards include the need to calculate checksums (hash functions) of data recorded at the scene (results of the process of image or sound recording for process purposes) and attach them in the form of a certificate to a record prepared for each medium on which the image was registered. The certificate must be made obligatorily and the check sums should be calculated and attached to the record. The following applications were tested, mainly in terms of their functions and capabilities: SHA256 Checksum Calculator, #hashing, HashTab, HashMyFiles, Febooti fileTweak Hash & CRC, WinMD5Free, Microsoft File Checksum Integrity Verifier, HashCalc, Md5sum, ComputeHash 2.0, MD5 & SHA-1 Checksum Utility 1.1, File checksum integrity verifier, Md5 checker 0.9, Checksum control 2.0, MultiHasher. In the course of the research, it was found that only the application SHA256 checksum calculator v.1.2 meets the main criteria set (in particular the criterion of the ability to calculate checksums for many files at once). Therefore, the program was selected for further testing. Next, the software license of the program was analyzed, in terms of the possibility of its use to secure the integrity of the documentation of the crime scene inspection. It was stated that the license terms of the program allow its use in order to safeguard the integrity of the documentation of the crime scene. Finally, as the suggested application to secure the integrity of the inspection documentation of the crime scene, the application "SHA256 checksum calculator v.1.2" is indicated. This application has met all the requirements. The results of the research have allowed the development of a methodology in the application of methods of securing the documentation of the crime scene in investigative practice. This methodology is currently being tested under real conditions of crimes and road accidents.

5. Summary

Analysis of devices for spatial scanning in the form of commercially available systems was carried out. An analysis was also carried out in the field of forensic technology used in the world in investigating of crime scenes, stating that in many EU and other countries 3D scans are used by the Police of these countries, also to inspect the crime scenes and places of incidents.

It was stated that the precision of devices declared by manufacturers corresponds to the requirements set in the project (i.e. for long-range scanners: 3 mm for 50 m and 6 mm for 100 meters, and 35 μm for the scanning head mounted on the measuring arm) - [Wieczorek T. and Górawska A. 2017]. The use of the measuring arm is associated with numerous limitations regarding the scanning conditions, and the precision of the measuring arm itself used for positioning the scanning head. The work of the measuring arm can easily be disturbed (in experiments in the case of an unstable floor there are disturbances resulting from the trembling of the floor caused by cars passing the nearby street), which means that they can only be used in laboratory conditions.

Series of 3D measurements were made using various 3D scanners in terms of construction and technology. Terrestrial 3D scanners, portable scanners with dynamic positioning in relation to the scanned object and measuring arms with 3D scanning heads were tested. The tests carried out in laboratory conditions allowed to check devices using various 3D scanning techniques and various techniques of light projection and scanner positioning. Further tests were carried out at measurement stations that mapped real conditions. These tests were aimed at determining the limitations of the use of individual devices in real conditions. Both in laboratory measurements and measuring in conditions close to real, accuracy measurements and analysis of the influence of changing environmental conditions on measurement accuracy. For this were used measurement patterns and markers provided by equipment manufacturers. The conducted research allowed to select devices that meet certain technical parameters and to determine the functional properties of these devices, which will affect their functionality during the inspection of the crime scene. As a result of the research, a technology for performing spatial scans, their processing, combining and matching was developed, taking into account the diversity of devices used.

In the investigative practice of the methods of securing the documentation of the inspection of the crime scene, it is necessary to calculate checksums for "each file included in the record" and attach them to the media record. During the research, the procedure of securing the documentation (using a 3D scanner) of the inspection of the crime scene was carried out. The procedure presents step by step how to calculate checksums (using program SHA256) for a 3D scanner result files and finally execute and attach the checksum printout to the media record.

6. References

1. Casp System: Badania dotyczące określenia parametrów i charakterystyk skaningu 3D w zastosowaniu do zinwentaryzowania miejsca zdarzenia – skanery ręczne. Raport z badań, Casp System, 2016 mat. niepubl.
2. Creaform: http://www.creaform3d.com/en (31.08.2017)
3. SmartTech: Możliwości wykorzystania skenera 3d do skanowania śladów w śniegu, raport z badań. http://skaner3d.pl/wp-content/uploads/2017/04/SMARTTECH (31.08.2017)
4. Wieczorek T., Górawska A.: Portable 3d scanners for crime scene investigations. Studia Informatica, vol.8, no.3, 2017, 132-141.
5. Wieczorek T., Zubańska M., Wiciak K., Szymczak M.: Techniczne i prawne aspekty oględzin miejsca zdarzenia z wykorzystaniem skaningu 3D. [In] Przestępczość teleinformatyczna, pr. zb. pod. red. J. Kosińskiego. Wydawnictwo Wyższej Szkoły Policji w Szczytnie, 2015.