DOI azonosító: https://doi.org/10.53304/PS.2025.1-2.01

PETR BENDL

Use of 3D scanning and modelling in forensic practice

Introduction

The development of computing and software has created a new field - 3D modelling. This is a three-dimensional display of a specific space or object using a computer. In particular, the development of computer games revolutionised both modelling and cinematography. It is interesting what the impact of a commercial field like the manufacture of computer games is. Consistent tools and products (computer programmes) can help the practitioner create a virtual space with realistic visualisation of the documented space.

A three-dimensional view, can also be called 3D modelling, has been widely used in many fields for several years. Spatial models of sites, in particular criminal events and objects created using a computer, provide diverse and comprehensive information of a visually informative type. In recent years, renowned European forensic laboratories have been intensively developing and applying technologies to help investigate and present the crime scene and related evidence in a 3D display.[1]

History

In general, one milestone in using 3D technology is developing imaging technology - whether different glasses or other visualisation devices, and

---

[1] Dolanský, T.: Lidar and airborne laser scanning. J. E. Purkyně University in Ústí nad Labem. 2004.
Source: http://wvc.pf.jcu.cz/ki/data/files/160lidaryweb.pdf.
Accessed: 13.05.2024 Acta Universitatis Purkynianae 99. University of J. E. Purkyně in Ústí nad Labem

not just for virtual reality. Another crucial factor influencing the development of this method is the development of imaging devices which, in different modes (automatically or manually) can capture the necessary scene or object for further display or analysis.

Morton Heilig (22.12.1928 - 14.5.1997) is considered to be the father of virtual reality. Around 1958, he started to create its first virtual reality machine, the so-called Senzorama (Figure 1). The instrument included various technical elements which gave the viewer a complete atmosphere of the projected event. The Senzorama used 3D stereoscopic displays. The first movie that could be seen was a recording of a motorcycle ride on Brooklyn Road. The viewer also blew the wind from the fan, giving him a sense of riding on the motorcycle. Of course, the use of technology and technical means appropriate to the time of the 1950's was obvious.

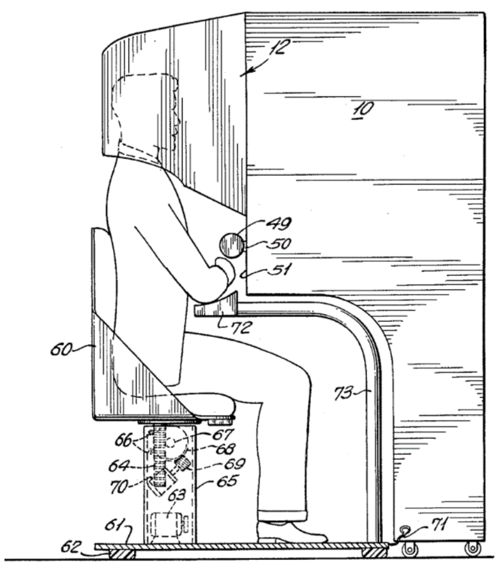

Figure 1
Sensorama (source: Internet)

Thomas Furness and his team continued to develop other visualisation devices. In the 1980's, they developed VR spectacles for the US military and launched the redeployment of US military training to a world of virtual reality (Figure 3).

At the same time, Atari started offering various virtual computer games on the market, which began to fundamentally change the situation on the commercial market, increasing the possibility of using virtual reality for various non-commercial sectors.

In describing historical developments, the origins of developing 3D imaging technologies cannot be ignored. Around 1960, the first attempts were made to capture the plasticity of space using a combination of light, camera, and projector. It is only in the 1980s that some companies are starting to test their laser applications. Around 1985, structured light technologies known as LiDAR were developed. It is an acronym from the English term *„Light Detection and Ranging"*, which is freely translated to mean a light-measuring and detection device.

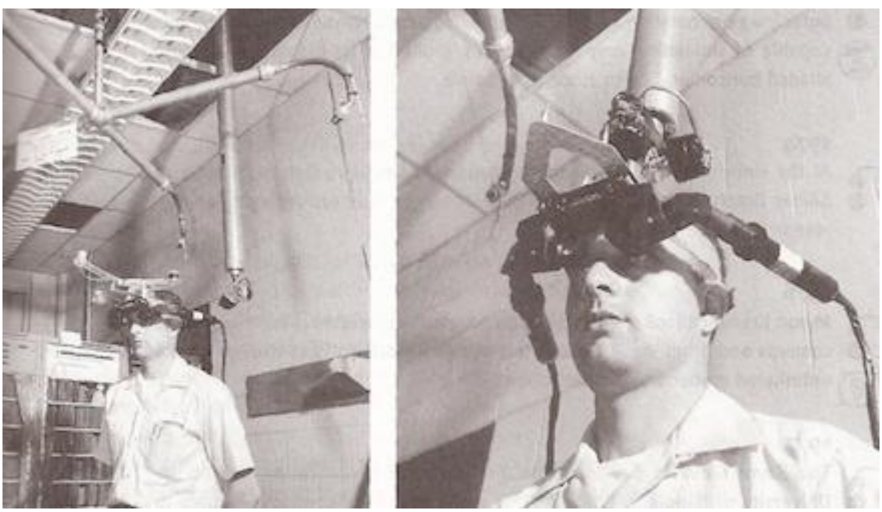

Figure 2
The first VR spectacles of Ivan Sutherland and Bob Sproulla

Figure 3
Furness's virtual reality glasses (source: Internet)

Basic concepts and description of the method

By understanding basic concepts, you can also understand the basics and description of the 3D modelling and sensing method. Basic terms and nomenclature:

- Model area - interest place or part of it (crime scene, scene of event, etc.) to be documented using 3D technologies.
- 3D scanner - a device that allows the user to create a 3D model of a model space or other object using different technology depending on their properties. It should be emphasized that scanners produce so-called dot clouds, which is a cluster of points of the known coordinate (XYZ) and its colour. In addition to the technologies used, scanners can be divided by types. The following scanners appear to

be most appropriate for documenting the location of the event and for scanning different objects (e.g., for expert examination):

- Touch scanners - the probe „grabs" the object and transmits its properties over the mechanical arm to the sensor. This type of scanner is useful for scanning small objects. The advantage of this is that a good scan of the subjects can be created while laser scanners have a problem (glossy surfaces, translucent objects - glass, etc.). Sometimes these types are referred to as CMM scanners (Coordinate Measuring Machine).
- Optical scanners - they operate on the principle of photogrammetry. Any camera can also be used for scanning. The 'Light Pattern Projection'[2] method uses a stereo camera model for 3D scanning, which is firmly installed (either in a compact device or freely, but in a known relative position). The object is projected with light patterns (typically in an invisible radiation spectrum) that provide their own structure on the object's surface. Cameras record pattern distortions on objects. The points of the model are then recalculated based on the known location of the cameras and the information from the light pattern falling on the object. Structured light scanning is used e.g., in facial recognition technologies.[3]

---

[2] Structured Light Scanning

[3] Jena Karl Zeiss: 3D Scanning with Blue LED Fringe Projection. ZEISS COMET. Dostupné z. 2020.
Source: https://www.zeiss.com/metrology/products/systems/optical-systems/3d-scanning/zeiss-comet.html#technicaldata
Accessed: 04.08.2023

- Laser scanners - this type of scanner works on a similar principle to optical scanners, but with the difference that no structure needs to be projected on the object. This is actively illuminating a scanned object (space) with a laser beam, and the light reflected from the object is taken by the camera. Subsequently, the instrumentation shall calculate the flight path of the beam, which shall be reflected on the surface of the object. These devices are not dependent on the illumination of the scene or object. However, they are affected by the surface material of the object. Some reflect a beam very poorly (e.g., glass, mirror). This type includes a camera that collects colour information about areas in its field of view. First, the captured information describes the distance to the surface at each point of the image, which allows identification of the three-dimensional position of each point in the image but also includes information about the object's property (colour).

– 3D scanning— scanning a space or object using a 3D scanner, where the real image is converted to a raster format (e.g., „Point-Cloud"). The captured points (so-called point cloud) carry certain properties (XYZ coordinates and point colour). In general, multiple scans from many different directions are needed to display the scene in an effective way. These scans need to be transferred to the common reference system, a process commonly called registration. It is then merged to form a complete 3D model.

Use of the method in forensic practice

The use of 3D technologies, especially 3D scanners, and the subsequent modelling of the focus space is broad. All available procedures and methods can be applied in forensic practice as in other fields (e.g., reverse engineering, geodesic, forensic archaeology). These can be used to simply document the model space (of varying size) or further analysis and comparison with other available information will be carried out.

Figure 4
Artec Leo scanner (photo: Artec)

Figure 5
FARO Focus S150

Two kinds of usage are applied in the Czech Republic. The permanent group of the Regional Police Directorate of the Zlín Region conducts a scan at all visits to crime scenes which are requested by the police authority. The result is a simple export to html format in a FARO scene environment or a defined-pass video. In contrast to this, the Institute of Criminalistics is developing comprehensive documentation in case of special requests from the police, the Military Police or other state authorities. As in Zlín, the Institute's department is processing basic documentation. Further analysis is conducted based on further requests from the police authorities.

Practical examples of the use of the method in forensic practice

Some possibilities for using 3D technologies for criminal proceedings can be presented using several cases worked out.

Shooting at a bar in western Bohemia: one of the guests began to threaten visitors and the bar with a firearm, from which he fired. The police requested, on the one hand, an expert opinion from the ballistics field and an analysis of three security cameras were presented for the comparison, which was combined with the model of the bar. Using universal models of the character of the human body, every person on the record, including the shooter, was positioned within space. The basis for the ballistic expert's opinion was distances measured between individuals and the range of projectiles. Essential information not only for ballistics was the renewed position of the barkeeper and the track of the projectile that ended up in a mirror on the wall at an exceedingly small distance from the barkeeper's head, but video recordings of security cameras in the shooting area. Another requirement was to compare video records with a 3D scan of the bar space subsequently created. A complete scan of the area was made at the crime scene. It was about 15 x 15 meters in size, but very subtle, with many chairs and tables spaced unevenly. A total of nine scans were performed on site. A record of 3 security cameras were presented for the comparison, which was combined with the model of the bar. Using universal models of the character of the human body, every person on the record, including the shooter, was placed in the space. The basis for the ballistic expert's opinion were distances measured between individuals and the range of projectiles. Essential information not only for ballistics was the renewed position of the barkeeper and the track of the projectile that ended up in a mirror on the wall at a very small distance from the barkeeper's head.

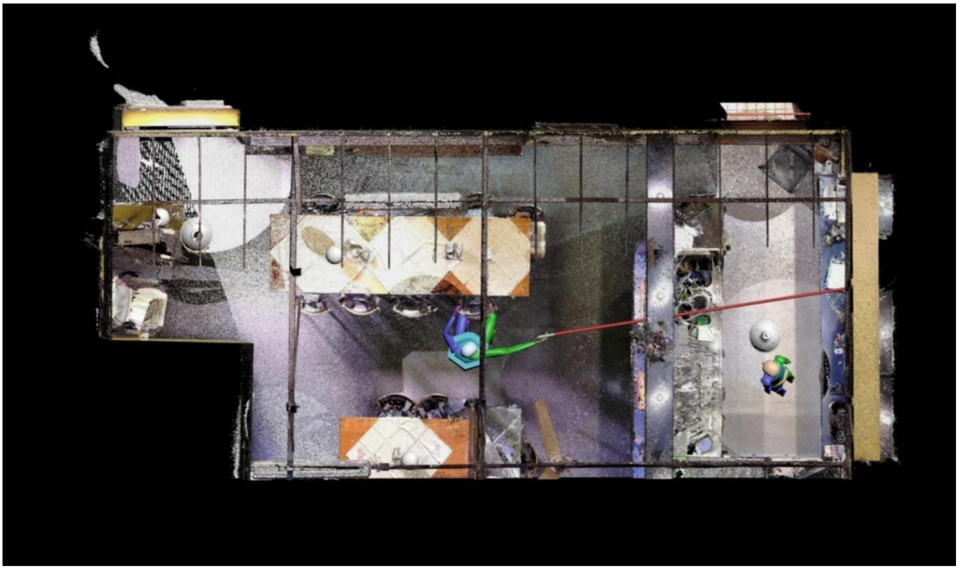

Figure 6
Plan of the model space showing the position of the shooter and the operator and the track of the projectile — without others

Some negative circumstances have been identified which may affect the processing of the 3D documentation and the subsequent comparison with the security camera records. The effect is primarily the security camera using its resolution, and the lens used. Cheaper cameras use both low resolutions, thereby degrading the stored footage, but they are equipped with lenses with short focal distance, the so-called fisheye. This type of lens is distorted by the lens' curvature. This has a negative impact on the final image and its application to the exact 3D model. The operator must either edit the image in another digital image data processing programme (such as Adobe Photoshop) or count on it.

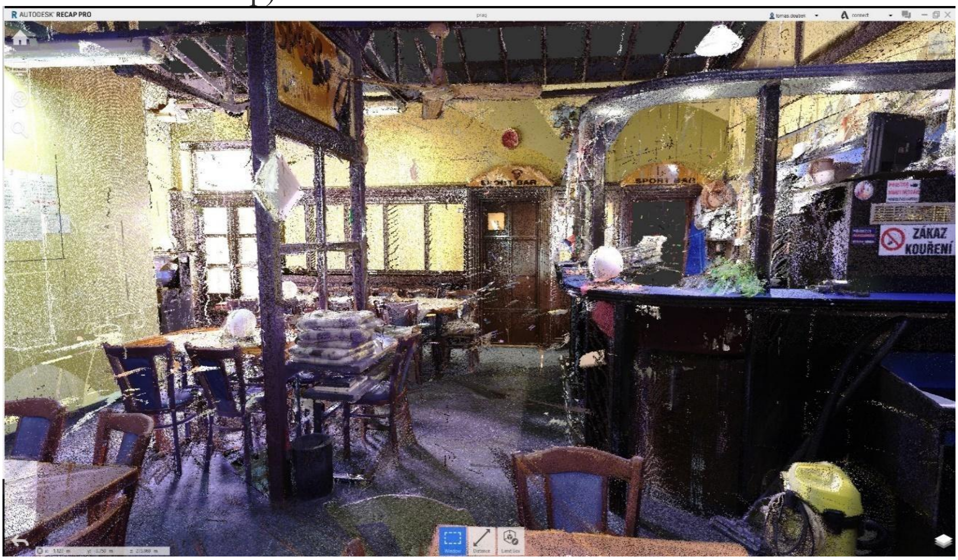

Figure 7
Crime scene view - Scanner exit - Combination of a cloud of points and photos in Recap (f. Autodesk)

Shooting into the window of the flat house: an unknown perpetrator fired into a window in an elevated floor of the flat house in a densely populated part of the city. The projectile passed through the window and stopped in the living room's ceiling. The task was again to prepare an expert opinion in the ballistics field to report all available findings and to determine the position of the shooter. The interest area had been taken by 3D scanner, the space in front of the house and, consequently, the area of the flat affected by the shooting.

After scanning the entire model space, the trajectory points of the projectile track were marked. The ballistics expert, based on this information, created several possible versions of the scenario for how the shooting could have occurred. After a thorough analysis, it was concluded that there were only two options. The first option was that the gunman standing in front of the house fired an unnamed shot toward the affected window. The second option, less likely, was that the shooter was sitting in an unidentified motor vehicle, shooting from him toward the window. The 3D model's practitioner made a focus and identified possible trajectories of the projectile. Everything was done on the 3DsMax programme. As a result, it was very unlikely that the shooter was sitting in a motor vehicle, given the height of his arm where he would hold the gun.

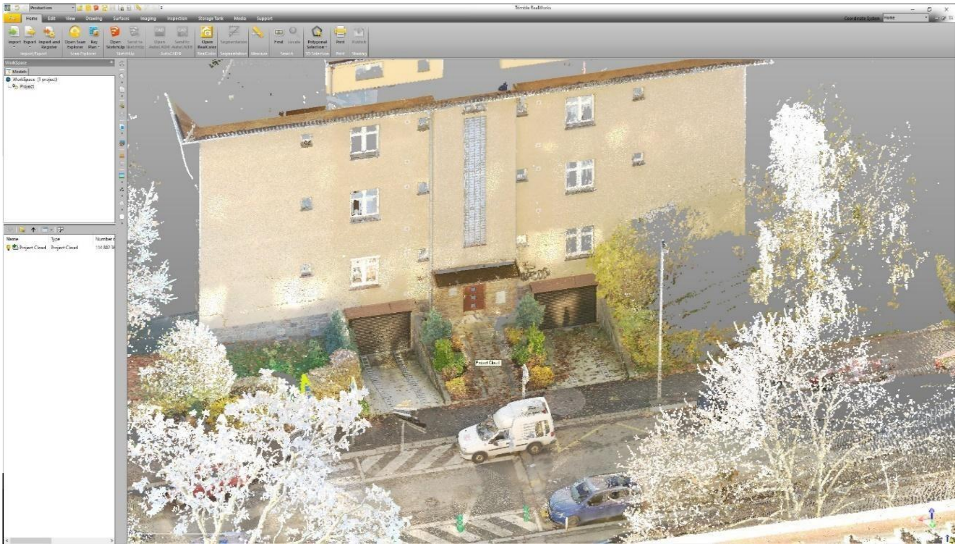

Figure 8
A cloud of points from the scene of the shooting - a general view of the crime scene after exporting the data from the scanner and its basic processing

The first option was confirmed after the figure had been incorporated into the front of the house. Based on general information on the attitude of the shooters, ballistics experts determined the height of the figure to be about 170 cm. As a result, an exceedingly small space was demarcated and shot. The area was limited by the width of the sidewalk, where one edge was embossed by the curb of the road and the other end by the garage in the basement of the house. From the shots in the window and in the roof of the flat, the trajectory was defined precisely, which together gave a specific definition of the shooter's space. The mere variability of the height of the shooter, which was exceedingly small in size, with a maximum of 5 cm in standard shooting skills (height of gun possession, etc.), remained.

Figure 9
Shooting trajectory — provided the shooter was in a motor vehicle

Another option that allows 3D documentation technologies is to determine the height of the person, dimensions, or position of different objects. The essence is to analyze image (dynamic or static) records on which the object being examined is well captured. Good visibility is essential, if possible, without any cover. Abroad, analysis of image records and subsequent evaluation using 3D applications are commonly used.

Figure 10
Trajectory of the projectile track and position of the shooter — provided that the shooter was standing on the sidewalk in front of the house and he was 170 cm high

Figure 11
Trajectory of the projectile track and position of the shooter — provided that the shooter was standing on the sidewalk in front of the house and was about 170 cm high

The death of Jan Masaryk: in 2020, the investigative bodies demanded that the body position of Czechoslovak politicians should be determined after its fall out of the window using 3D technologies. Photos of the crime scene were available. 3D scanning was done at the scene of the disaster's fall. Then a comparison of the wireframe of the crime scene with the scan of photographs from the crime scene was made. A large number of environmental reference points that had not been changed significantly since the event, have been used for comparison, A human body model has been placed in the formed wireframe of the site of the finding and has been modified and directed to the compressed photographs of the body lying on the pavement. A follow-up examination and comparison with the autopsy protocol found that the measured height of the person in the 3D Studio Max and the information obtained from the autopsy report varied by only 1 cm, which is less than 1%. For example, the Dutch NFI (Netherland Forensic Institute) Imaging Analyses Site is working with an error of around 3%, provided that images or other image records of the person or other object are in an ideal state[4], which means that:

- the person is clearly visible and is not bent or in any other unnatural position,
- the person is large enough in the pictures (video),
- the resolution of the recording is of sufficient quality to produce a person's detail without the impact of the image noise or resolution (individual pixels),
- the shot is taken by a camera with a lens without distortion,
- without any other significant effects on the quality of processing.

[4] Edelman, G., Hoogeboom, B. Albering, I.: Comparison of the Performance of Two Methods for Height Estimation. Journal of Forensic Sciences, 55(2), 2010. p. 358-365 DOI: 1556-4029.2009.01296

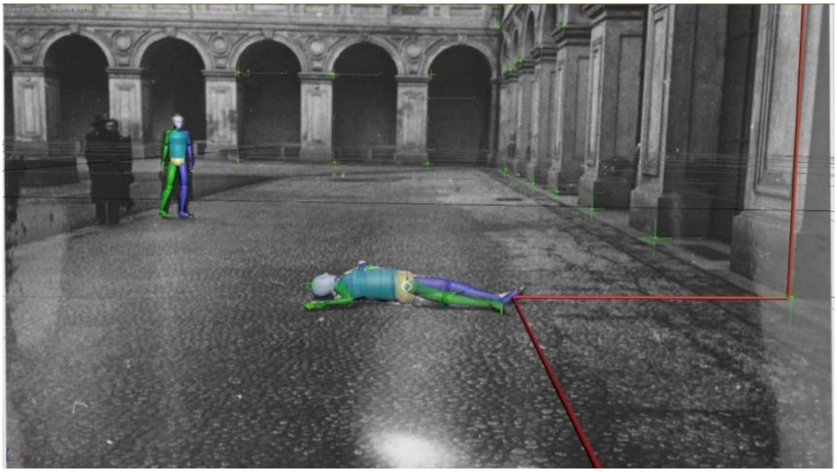

Figure 12
Photo comparisons from the crime scene scan (10.3.1948) and crime scene scan (10.3.2020)

Figure 13
Resultant model produced by photo-composting and crime scene scan

Figure 14
Resultant model produced by photo-comparisons and crime scene scan

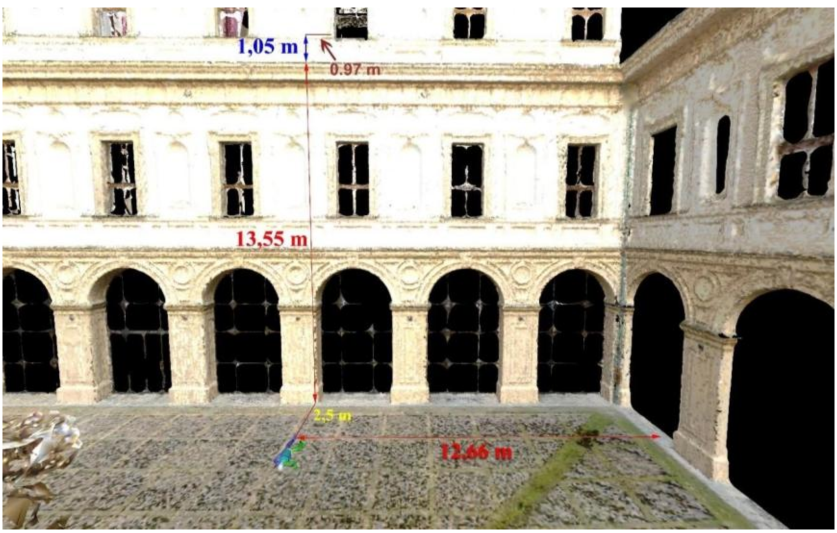

Figure 15
Resulting model created by the combination of photographs and scan of the crime scene, including the fundamental dimensions of Jan Masaryk's position

Analysis using 3D technologies is one of the applicable methods. It is widely used abroad. At the beginning of this century, the method of photogrammetry was used to create a 3D model of the site. In practice, analogue methods may be encountered to determine the physical characteristics of persons or objects.

Further application of 3D scanning and modelling can be found in anthropology or forensic archaeology. Foreign institutions (Switzerland, the Netherlands, etc.) routinely analyze the emergence of various injuries for forensic biomechanics. The cooperation of the forensic doctors of the Zurich Institute of Medical Medicine at the Zurich University Hospital and 3D Zentrum Zurich uses each other's knowledge and uses the possibilities of 3D modelling and scanning. The workplace routinely scans damaged parts of the human body for forensic medicine or collaborates closely on a project called virtual autopsy (virtual autopsy).

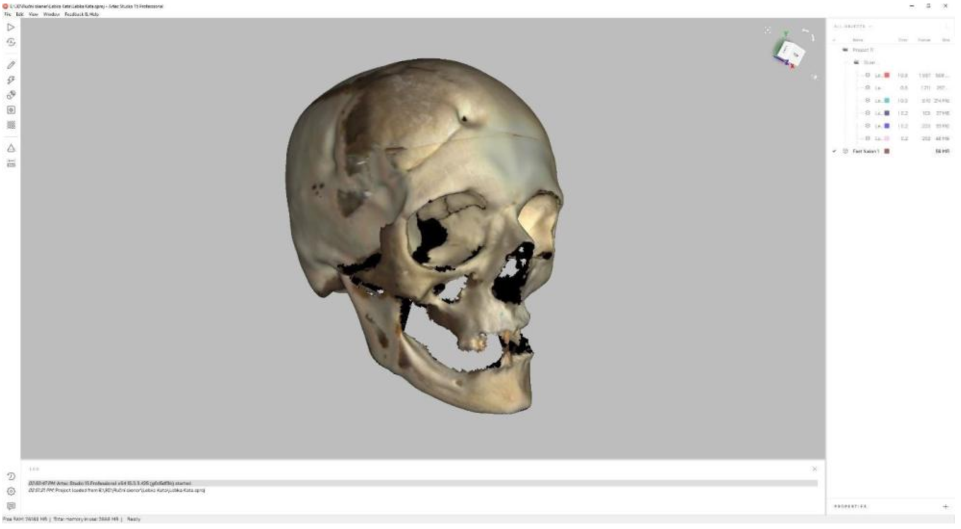

Figure 16
Human skull scanned at the Institute of Criminalistics using the Artec Leo hand scanner

Benefits of using the method in forensic practice

As with previous methods described, the 3D documentation is characterized by the objectivity of the data presented in the location, applying the recommended procedure. Objectivity is reviewable for the method described, which ensures that the results of the police authorities' activities are protected against any doubts when using this method forensic documentation.

The operator of the sensing apparatus shall not be able to intervene in the process of sensing and subsequently basic processing of the data If an operator wants to intervene in a process in some way, it can do it, but with the result of unprocessed final data. This will be reflected in the impossibility of presenting the results of the scan. Therefore, in this method, the rule is that either everything is processed correctly, and the result can be published, or the result is incorrect and unpublishable. The operator may be able to influence the accuracy of the processing (e.g., poor configuration of the scanner) by its approach, but this can simply be detected either in the final visual output or in the report produced by the processing programme. It can therefore be concluded that this method of forensic documentation is objective and safe.

Another great advantage is the high accuracy of the scan. The principle of the method and the technical parameters of the scanners can derive high processing accuracy. If the correct procedure is followed, the adjustment is correct and, above all, without negative interference, the accuracy of the scan can be achieved below 1 mm for stationary scanners. As with photometry, forensic documentation can be created with high precision. Very precise results and outcomes are essential for analysis or outcomes for further expert examination (e.g., ballistics, anthropology).

Stationary scanners can be seen as having a major advantage in the scope of scanning. These are fixed to the tripod, and can scan within a 50 m radius to achieve high accuracy depending on the type of instrument.

The three-dimensional documentation brings spatial sensation to classical documentation, which increases understanding of the scene and possibilities for the presentation of the scanned space, objects, and forensic evidence. The 3D documentation allows the observer to move around the virtual location - the scene taken, when using means for display (e.g., VR spectacles). A person who had never been to the scene of a scan can thus see the area as if it were real. In a virtual scene created in this way, it can move freely, viewing all the objects you have captured. Unlike spherical frames, the 3D view is enriched with additional added value.

Disadvantages of using the method in forensic practice

The deployment of 3D technologies in forensic practice, for crime scene documentation, events or as a means of documenting an expert's investigation, does not involve any significant negative aspects in case it is conducted in accordance with good practice and with objective documentation processing. The operator shall avoid modifying the acquired data, in particular, at higher stages of processing, and shall be appropriately trained to use all available technologies and processes.

A negative factor may be the high cost of purchase of the necessary technology and, where appropriate, additional mandatory costs for maintaining the serviceable equipment (in particular, the SW licensing policy is currently set to rent out the SW for a limited period). Here is the need to acquire 3D technologies and then use them. After reading the previous text, it should be clear to readers that these methods cannot be used to document scenes of volume crime. In some cases, only documenting using a 3D scanner can be done without further processing, if necessary.

Conclusion

The use of 3D technologies in modern forensics has its position and is only a matter of time to what extent, and how long it will take to use all its available functions and strengths.

Development in Europe makes the case for using 3D imaging and imaging technologies clear. As well as the demands of the various Czech Police stations, which are interested in good quality and, above all, precise documentation of the location of the event (whether it is a crime or a traffic accident or other events).

In this article authors provide information that can be further used by readers. Especially for those seeking information on the possibilities of 3D systems, not only those used for documentation (3D scanners), but on the way forward in processing (so-called postprocessing). When acquiring the necessary technology, it is important to consider the timescale, and particularly the minimum technical facilities. You cannot expect immediate results with a simple 3D scanner. In the case of 3D modelling, and in particular visualisation with the possibility of good quality telling output, you should be aware of everything described in the previous text. Without being aware of both the technical and the time-consuming nature of the results required, the results cannot be achieved.