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Reverse engineering technology for forensic use

Summary

The paper presents the possibility of using reverse engineering in forensic science. Available *reverse engineering* technologies and examples of their use as a helpful forensic research tool are reviewed. A method of reconstruction of objects using computed tomography technology was described, as well as an example of the application of this method to the analysis of the geometry of ignited 7.62 mm calibre model 30 pistol cartridge shells (7.62 mm calibre projectile).

Keywords reverse engineering, forensic examination, computed tomography

Introduction

Reverse engineering (*Reverse Engineering*) is a measurement technology for obtaining the information on the operating principles as well as the method of reconstructing an object. [1]. Reverse engineering technologies are often used with the intention of producing the counterpart of an object. Appropriate to the application, a few basic aims for the implementation of the operations can be singled out. In the case of industrial applications, the aim is to obtain a computer model of the existing object in order to reproduce technical documentation. In medical applications, performed analysis is used to ensure the anatomical fit of prostheses or implants. The continuous development of equipment used in the process of *reverse engineering* has allowed the extension to various areas of interests, which has resulted in digitization also in the arts, archaeology, building construction and forensics [2].

Distribution of reverse engineering techniques

The distribution criterion largely depends on the method of database collection, which affects the design of measuring device [3]. The first, and most important group, includes contact methods which, because of the necessity of contacting the device with the object during acquisition, are mainly suitable for the analysis of small objects of simple geometry. The second group, which has found a wider application, involves non-contact methods. A variety of systems allows scanning objects of sizes ranging from a few millimetres to tens of metres [4]. This group incorporates the devices used, among others, in forensic science. Within the group of non-contact devices, one can distinguish devices allowing the evaluation of the outer surface of an object with such methods as the application of a laser beam or optical light analysis. Additionally, this group contains the devices which utilise gamma radiation (MSCT – Multi Slice Computer Tomography), X-ray (CT – Computed Tomography) or magnetic resonance (MRI – Magnetic Resonance Imaging).

Reverse Engineering in forensic examination

Crime scene investigation is a complex process involving a number of different sciences. One of the first and probably the most critical steps is the “walk through” the scene. The main objective of this activity is to collect as much evidence as possible to reconstruct the course of events. Additionally, during this action, appropriate measurement techniques [5] should be applied, which will enable generation of objective documentation required for subsequent investigative steps. Conventional methods of collecting the evidence, such as photos, sketches and notes are two-dimensional, the measuring tapes, according to the the measurement method, may interfere with the environment and influence the measurement [6]. While performing 3D documentation in the form of castings of footprints, tyres and so on, there is a risk of damage to the replicated trace evidence, especially in the case of making plaster casts [7]. Due to the technique of combined images and virtual reality, there is the possibility of supplementing the investigation by 3D digitization. One of the techniques used to perform spatial photographic documentation is photogrammetry. It is a technique of replicating the shape, size and relative position of objects outdoors based on photogrammetric images (photograms) taken from different perspectives. This technique is one of the simplest methods of replicating the geometry of an object, so in order to perform it, one needs to have a standard camera, markers (tags), and a computer with appropriate software [7].

In order to record an entire room, for example sole prints, devices are used taking advantage of a camera and a light source casting shadows of a specific shape (e.g. stripes) on the object, which allows observation and replication of the spatial structure [8]. More details can be seen from such digitization than in the photograph. The last tool used to conduct the site inspection and secure trace evidence is computed tomography (ICT – Industrial Computed Tomography), described in detail later in this paper. This method allows looking inside an object, therefore, besides getting the surface image, it is possible to observe e.g. the damage caused by a gunshot. Additionally, there is the chance of combination of various digitization methods during a digital reconstruction of the object using specialized software [8].

Industrial computed tomography technology

Computed tomography is a non-invasive imaging method based on the principle of registration changes in the absorption of radiation in an examined object. Due to the chance of mapping internal and external geometries by means of the described technology, analysis of the dimensions, porosity, density and structure of objects, both, of natural origin and man-made is possible. [9]

During measurement using computed tomography, the object is placed on a turntable between a lamp and a detector. The object is illuminated with a conical beam of X-rays generated in the X-ray tube, and the intensity changes resulting from the absorption of radiation passing through the examined object are registered by the detector.

The result of recording is an X-ray picture of high contrast and brightness saved in greyscale. The registration of serial X-ray projections of the object being rotated by 360° at a predetermined angle allows the three-dimensional reconstruction of its structure. Accomplishing a projection of high contrast and brightness is possible only in the case of adequate penetration of the object by a beam of X-rays. Therefore, the radiated energy, determined by voltage and current of the X-ray tube, must be chosen so that the object is sufficiently exposed to the radiation beam at each position. The ICT reconstruction is performed by means of dedicated software that allows reduction of noise and measurement of artefacts on the basis of serial projection. As a result, a reconstruction of a series tomographic cross sections is performed. Each cross-section is composed of spatial pixels called voxels (Fig. 1 Diagram of voxel modeling based on a series of CT images; see Polish version).

Each voxel is assigned to an ICT grayscale value, corresponding to the density, atomic number and thickness of the examined material at a certain point of the reconstructed volume. The voxel size, which means the measurement resolution, depends on the magnification and size of the examined object. The larger the sample, the smaller the measurement resolution can be achieved.

The ICT scan time depends on the shape and material of the object and typically takes between 1 to 2 hours. Limitations on using the ICT method are based on the size of tomographic measurement chamber, which depending on the model, ranges from several to tens of centimetres. The possibility of reconstruction is also limited by the X-ray tube voltage which determines the penetration ability of the radiation through an object. Normally in technical tomography the lamps of a voltage up to 225 kV are used, which allows the penetration of steel up to a thickness of 1.5 cm, aluminium of above 10 cm and plastic parts above 20 cm [10].

Use of computed tomography in forensic science

Identification of three-dimensional structure of examined objects offers more possibilities for forensic research. One of primary uses of computed tomography is the ability to accurately determine the trajectory of a projectile inside an obstacle, e.g. the human body. Another area of the application of ICT technology is shell and bullet testing. Due to a high density of lead commonly used in bullets, their reconstruction requires the use of tomography equipped with an X-ray tube of high voltage, above 250 kV. An example analysis of a 9 mm calibre bullet can be found in the literature [11].

The authors [11] analysed the quality, geometry and thickness of the bullet jacket before and after it has been fired, as well as its deformation. The analysis of deformation of the bullets upon impact with the surface of the obstacle enables determining the value of their impact energy.

Figure 2 shows an example of the CT cartridge shell analysis of a fired 7.62 mm cal. 30 mod. pistol cartridge (visualization of a 7.62 mm calibre pistol cartridge shell: real object (a), three-dimensional reconstruction by ICT (b) 2D sections of the analysed cartridge (c); see Polish version).

The reconstruction was carried out with a voxel size of 37 μm, which allowed registration of the characteristics present on the surface of the shell, such as embossing number, scratches on the surface, and traces of the firing pin.

In addition, the visualization of internal structure of the shell allows analysis of the primer chamber with the fire-channels. It is also possible to analyse the characteristic structural changes in the cartridge resulting from the impact of high pressure on the walls of the shell during firing, such as cracks or deformations.

The three-dimensional volume model, obtained by the ICT reconstruction, allows performing dimensional analysis of the examined object, which gives the opportunity of evaluating an internal damage of the shell (Fig. 3 3D view of the shell dimensions (a) 2D cross-section of the internal dimensions of the primer chamber (b); see Polish version). Mutual distribution of the traces left by the firing pin tip, ejector and claw extractor on the surface of the shell allows determination of the model and design of the weapon, which the projectile was taken from.

Figure 4 shows the analysis of the shell wall thickness with, marked in colour map, changes in its structure. A reduced thickness of the cylinder wall, which constitutes the shell, in its upper part (formed during the shell manufacturing process) can be clearly seen.

The above examples of the ICT analysis of cartridges and shells can greatly support the procedure of forensic identification of trace evidence secured at the crime scene. The studies of shells and cartridges tested by means of ICT technology carry information about the internal structure of elements inaccessible by other methods of measurement. Therefore, they may help identify both the group and individual weapon where the bullet was fired from.

Figure 5 shows analysis of the shell walls thickness and the cross-section showing changes inside its structure.

Summary

The paper presents the technology of *reverse engineering* and its potential use in forensic science technology. The possibility of three-dimensional digitization of a crime scene or registration of trace evidence secured on the spot can significantly increase the capability of collecting and securing evidence. In addition, the digital processing of data collected in this manner makes it possible to reconstruct the course of events, such as determining the trajectory of the projectile inside an obstacle, including the human body. The registration of internal and external physical structure of the evidence in the form of shells and cartridges allows the comparison and identification of forensic traces mapped on their surfaces. The above methods of registration and spatial documentation of physical objects make it possible to significantly support the evidence secured during the investigation.

Source

Figures 1–6: the authors

Translation *Ronald Scott Henderson*