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Application of 3D Scanning Technology for Evaluation of Virtual Model of Gun Geometry

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Abstract. The paper presents the results of reconstruction of selected gun elements with application of 3D scanning technology. Algorithm of under investigation process, the way of preparing object for scanning and measuring process were also presented. This article discusses also data acquisition of clouds of points and methods of some activities with measured geometry data (i.e. solving some imperfections caused by the preparation or by the measurement process). Geometry was remeshed by the creating a new mesh of polygons to unify shapes defined after previous steps. On the basis of cloud of points measurements, the solid geometry of the whole object was prepared. The effect proved satisfactory accuracy of the estimated parts' characteristics and allowed for recommendation of the mentioned approach in the described process.
Keywords: construction and operation of machines, 3D scanning, geometry reconstruction, gun parts geometry

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1. INTRODUCTION

Reliable evaluation of virtual models of various mechanisms has very applicable meaning for the modern engineering activity. It has very close relation to the rapid prototyping techniques (RPT) that are used in the a wide range of technical issues.

The process of renovation of damaged mechanisms' parts and the reconstruction process in the medical area (e.g. computerized tomography CT, magnetic resonance imaging MRI) are examples of its applications.

Coupling of RPT with another inverse techniques [1, 2] can be very useful for validation of various theoretical methods of modelling physical phenomena. Recently, one of the most interesting methods of geometry reconstruction is 3D scanning technology.

Authors of [3] showed a possible application of this technique for reconstruction of selected anthropometric characteristics of human body. In [4], results of validation of bone models using 3D surface scanning were presented. The authors of [5] provided a wide review of literature, regarding applications of scanning technology for analysis of animal skeletons, and applied this approach to specimens which are not always available to faunal analysts for use in identifying archaeofaunal remains. The results of the mentioned researches revealed usefulness and accuracy of RP approach.

The aim of the presented work is to demonstrate the application of 3D scanning technology in another branch of engineering area – reconstruction of crucial gun parts, which strongly influence kinematics of the whole launching system. Basing on available literature [6, 7], there is a growing interest in accurate modelling of gun parts kinematics.

2. DESCRIPTION OF 3D SCANNING METHOD

In the presented investigations, non – contact, active scanning, triangulation – based method was applied. Generally, there are two types of 3D scanners basing on this method: laser and structural light ones. In the first group, the measurement is based on directing a laser beam onto a model, then sensor equipped with CCD camera detects angles of reflection and distances. Three-dimensional map (cloud) of model points is generated. In the second group of scanners, incoherent light is projected in the model area, displaying patterns (lines, stripes) on the model surface. Detector, at least one camera, observes the displacement of every pattern, and calculates the position (X,Y,Z) of a model surface. There are some applications of scanners using white, green, and blue light – wavelength should be considered, because of accuracy and interferencies with daylight. The scheme of this approach was depicted in Figure 1.

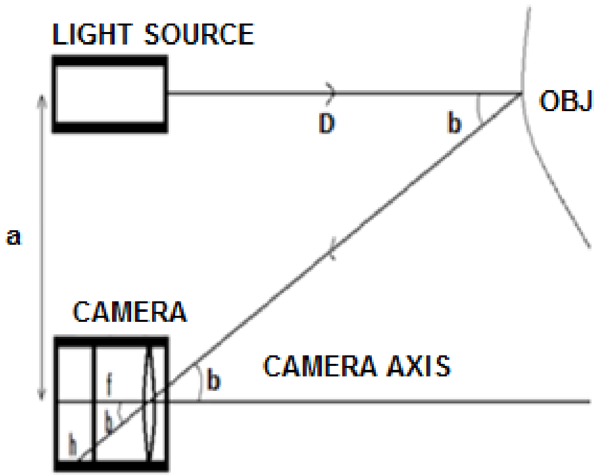

Fig. 1. Scheme of 3D scanning process [8]

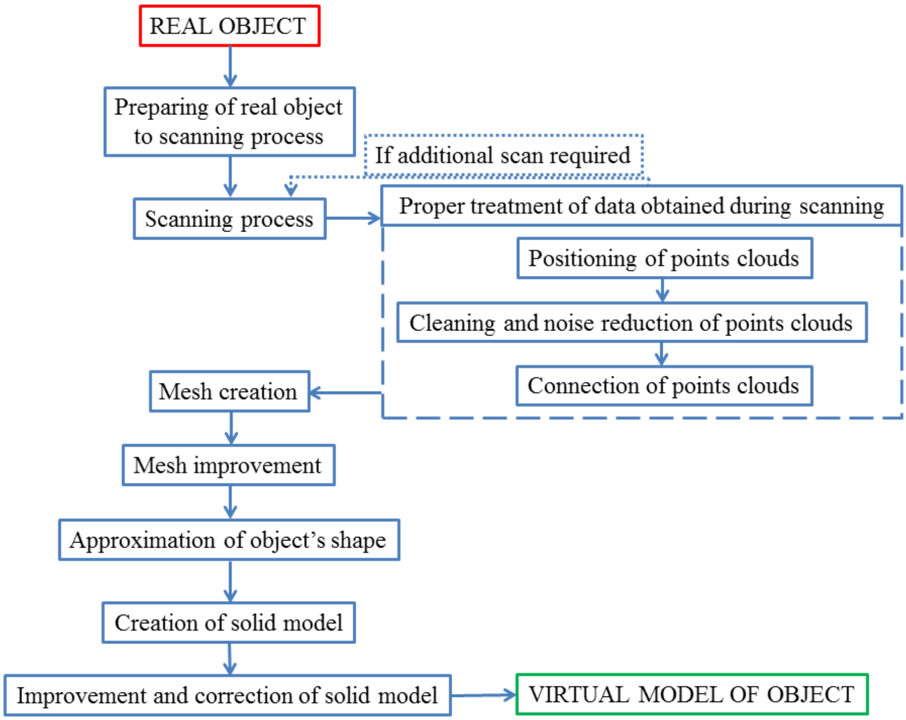

Fig. 2. Scheme of virtual model creation process

In the authors' opinion, the main disadvantage of the applied approach is requirement of proper object preparation, providing appropriate "visibility" of the investigated object by the camera. This stage was described in further part of the article. Moreover, the considered approach is unfortunately characterized by seriously limited working area (up to single meters).

Algorithm of the whole geometry reconstruction process is presented in Fig. 2. Detailed description of the presented steps, will be conducted in the next paragraphs.

3. EXPERIMENTAL SET-UP AND MEASUREMENTS

3.1. Object preparation

In order to obtain reliable results of measurements, the investigated object was carefully cleaned and coated with a quick-drying, solvent-based wet developer for colour contrast (PFINDER 871). This step is necessary to make the investigated object well-visible for scanner. The effect was shown in Fig. 3.

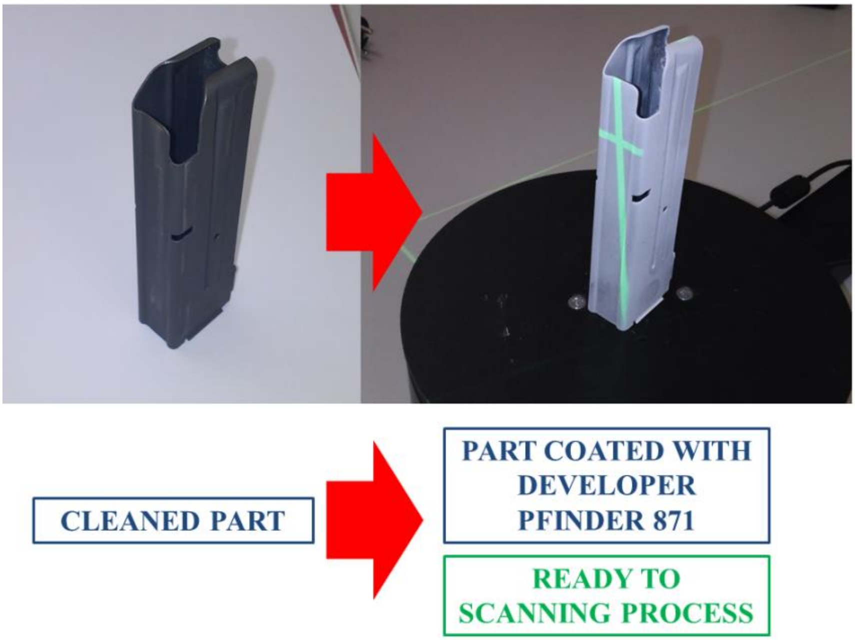

Fig. 3. Effect of coating process of selected part

3.2. Measurement unit and measurement process

In order to reconstruct the shape of analyzed parts, the “SmartTech Micron 3D green 5 Mpix” scanner was applied. Its technical data were summarized in Table. 1. Moreover, general view of a measurement set is presented in Fig. 4. In this case, a measurement process is based on green LED light which ensures relatively effective reduction of influence of white daylight.

Table 1. Technical data of Smarttech Micron 3D green scanners [9]

Technical specifications	5 Mpix	10Mpix
Scanning technology	Green LED light	Green LED light
Detector’s resolution	5 Mpix	10 Mpix
Measurement area [mm^2]	150x200 to 600x800	150x200 to 1200x1600
Distance between points	0.07 ÷ 0.30	0.05 ÷ 0.20
Sampling [points / mm^2]	164 ÷ 10	369 ÷ 23
Accuracy [μm]	18 ÷ 70 (depends on volume)	18 ÷ 280 (depends on volume)

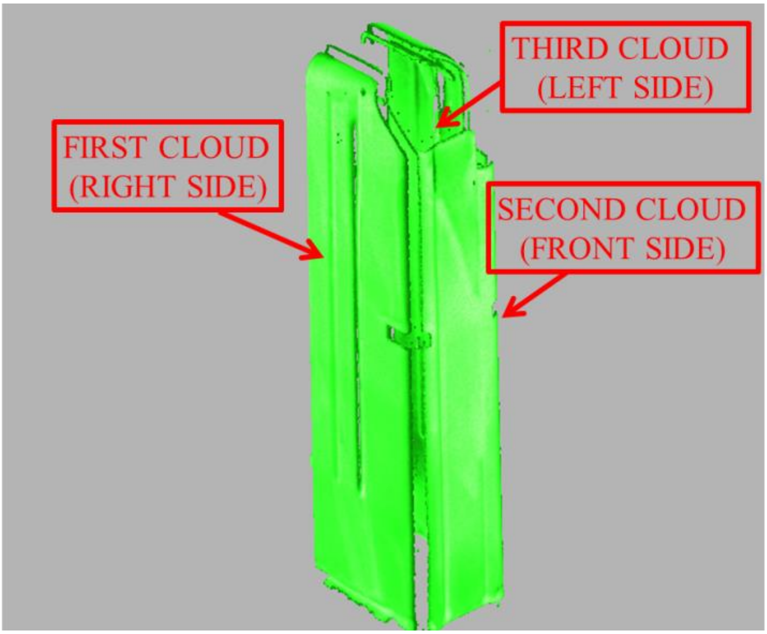

Fig. 4. Assembly of three point clouds obtained for selected part

The measurements were carried out with a rotary table, which facilitates further points' clouds relative positioning (clouds are preliminarily aligned). Its application ensures regular measurements with a constant angular step. In our investigations, a step of 15 degrees was adopted in a range up to 360 degrees.

Each scanning process provided 24 clouds of points. Several of them were presented in Fig. 4. In order to improve reliability of a reconstruction process, additional scanning process has been conducted (selected parts have been scanned in several positions).

4. GEOMETRY RECONSTRUCTION

Geometry reconstruction was performed with application of Geomagic Design X software. First step of geometry reconstruction was combining several sets of points into one-layer, merged set (cloud) of measurement data.

Each set represents data acquisition from one exposition of an object. Preliminary combination of clouds can be generally realized in two ways – the first one is based on the application of a rotary table, the second one is based on application of characteristic points of each cloud. Unfortunately, imported data can be significantly noised. Due to noises, there are artifacts of 3D representation of a model: unnecessary, redundant points. So, it seems to be obvious that before next step of reconstruction, these noises should be reduced with application of appropriate algorithm included into software. These pre – aligned clouds can be accurately combined with application of small relative movements of each cloud. The combined clouds can be used to create appropriate mesh, which can be generated with various fitting properties (fitting of mesh to the cloud). The produced surfaces are usually distorted. There can be holes, surfaces with a gap. These errors can be effectively corrected. Surface discontinuity can be eliminated with some tools like filling, setting "bridges", using curvature of neighbourhood or flat filling.

Another step to solve the observed inaccuracies or imperfections was defeaturing (smoothing) selected areas. Some imperfections were caused by the way of preparation or by the measurement process. Therefore, some selected polygons should be deleted. The next procedure was the remeshing by the creating a new mesh of polygons to unify shapes defined after previous steps. New group of polygons wraps and connects entities of points cloud.

After building a mesh (some authors call that type of meshes: one-layer, waterproof mesh which means that mesh should be without holes and distortions), geometric data of the analyzed shape is ready to generate solid bodies based on the obtained points' cloud. With the support of specialized software it is possible to create solids which represents geometry. Assigning planes to many points gives flat planes with good accuracy and position of edges. Some special shapes can also be found using graphic algorithms.

Mesh constitutes a base for further planar or 3D sketches (Fig. 5) as an origin to extrude solid objects.

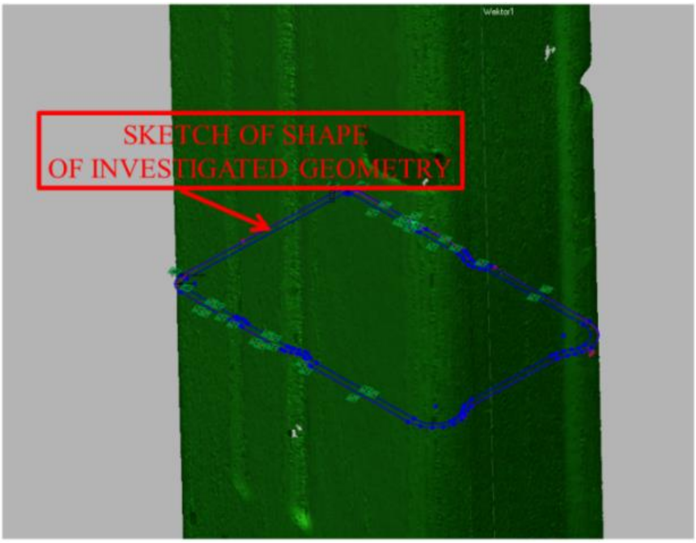

Fig. 5. Creation of sketch based on scanned geometry

For irregular geometries it is desirable to generate more sketches and to extrude the solid object through these sketches. Using available software options, it is possible to ensure satisfactory continuity conditions of generated surfaces.

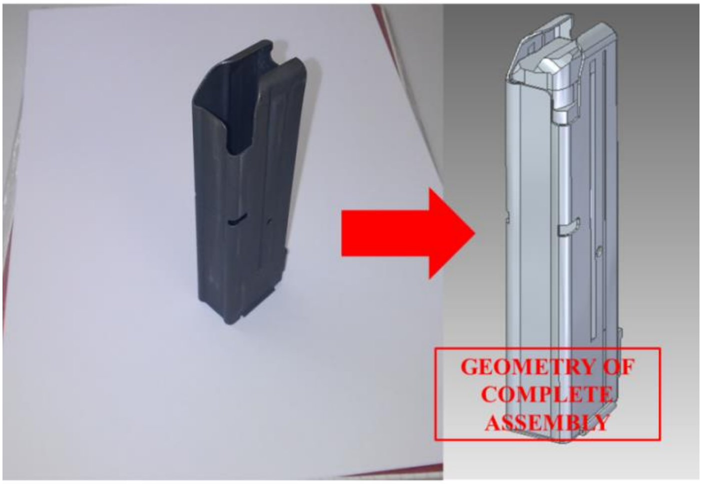

Fig. 6. Effect of reconstruction of a complete part

It is important, that during each step of reconstruction, geometry dimensions should be verified with alternative measurements methods (e.g. microscope, coordinate measuring machine etc.).

In Fig. 6, the effect of reconstruction of Sub Machine Gun (SMG) ammunition magazine was presented. The obtained geometry is characterized by dimensions of a real object and can be effectively applied in numerical simulations of physical phenomena taking place during its exploitation.

5. CONCLUSIONS

The work presents methodology of 3D scanning process and effects obtained with its application in the process of reconstruction of the selected part of a gun. Taking into account experience gained during model investigations, it can be concluded, that application of 3D scanning technology can be useful for analyses of functioning of real objects, including imperfections generated during production technology and wear processes.

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Zastosowanie technologii skanowania trójwymiarowego w procesie odwzorowania geometrii wybranych elementów broni

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Streszczenie. W artykule przedstawiono wyniki rekonstrukcji geometrii wybranych elementów pistoletu z zastosowaniem technologii skanowania 3D. Przedstawiono również algorytm rozważanego procesu oraz sposób przygotowania obiektu do skanowania i pomiaru. Omówiono również pozyskiwanie chmur punktów i metodykę opracowania danych z mierzonej geometrii (tj. rozwiązywanie problemów wynikających z obecności nieciągłości chmur spowodowanych przez błędy przygotowania lub proces pomiaru). Uzyskana geometria została zmodyfikowana przez utworzenie nowej siatki wielokątów w celu połączenia kształtów zdefiniowanych w poprzednich krokach. Na podstawie chmury punktów pomiarowych przygotowano geometrię bryłową całego obiektu. Efekt końcowy pozwolił na oszacowanie charakterystyk geometrycznych części z zadowalającą dokładnością i pozwala na rekomendację wspomnianego podejścia w opisywanym procesie.

Słowa kluczowe: skanowanie 3D, rekonstrukcja geometrii, geometria elementów broni