



## ANALYSIS OF PHOTOGRAMMETRY APPLICATION POSSIBILITIES FOR REVERSE ENGINEERING OF COMPONENTS IN THE AUTO INDUSTRY

Marko Delić<sup>1\*</sup>, Vesna Mandić<sup>2</sup>, Dragan Adamović<sup>3</sup>, Dušan Arsić<sup>4</sup>, Đorđe Ivković<sup>5</sup>, Nada Ratković<sup>6</sup>

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**ABSTRACT:** Reverse engineering is a technique that has recently been used in all areas of industry. The application of reverse engineering in the auto industry occupies a very important place. 3D scanners are often used to digitize parts with fine details or large sheet metal, and they can be very expensive. In this paper, the possibility of using photogrammetry for reverse engineering of components in the auto industry will be analyzed. Digitization of the automotive component will be done in two ways, using a mobile phone camera and free photogrammetry software and a suitable professional scanner. The accuracy of the cloud of points obtained and time required for digitization by both methods will be compared. At the end conclusion will be drawn whether it is currently possible to use photogrammetry in industrial conditions.

**KEY WORDS:** 3D scanning, photogrammetry, reverse engineering, point cloud

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<sup>1</sup>Marko Delić, Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, Serbia, [marko.delic@kg.ac.rs](mailto:marko.delic@kg.ac.rs),  <https://orcid.org/0009-0004-0172-3216>, (\*Corresponding author)

<sup>2</sup>Vesna Mandić, Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, Serbia, [mandic@kg.ac.rs](mailto:mandic@kg.ac.rs),  <https://orcid.org/0000-0003-1624-3536>

<sup>3</sup>Dragan Adamović, Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, Serbia,  <https://orcid.org/0000-0003-3459-3011>

<sup>4</sup>Dušan Arsić, Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, Serbia, [dusan.arsic@fink.rs](mailto:dusan.arsic@fink.rs),  <https://orcid.org/0000-0003-0326-0898>

<sup>5</sup>Đorđe Ivković, Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, Serbia, [djordje.ivkovic@fink.rs](mailto:djordje.ivkovic@fink.rs),  <https://orcid.org/0000-0002-5747-7876>

<sup>6</sup>Nada Ratković, Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, Serbia, [nratkovic@kg.ac.rs](mailto:nratkovic@kg.ac.rs),  <https://orcid.org/0000-0003-1446-8678>

## **ANALIZA MOGUĆNOSTI PRIMENE FOTOGRAMETRIJE ZA REVERZNI INŽENJERING KOMONENTI U AUTOMOBILSKOJ INDUSTRIJI**

**REZIME:** Reverzni inženjering je tehnika koja se u poslednje vreme koristi u svim oblastima industrije. Primena reverznog inženjeringa u automobilske industriji zauzima veoma važno mesto. 3D skeneri se često koriste za digitalizaciju delova sa finim detaljima ili velikim limovima, i mogu biti veoma skupi. U ovom radu biće analizirana mogućnost korišćenja fotogrametrije za reverzni inženjering komponenti u automobilske industriji. Digitalizacija automobilske komponente će se vršiti na dva načina, korišćenjem kamere mobilnog telefona i besplatnog softvera za fotogrametiju i odgovarajućeg profesionalnog skenera. Upoređiće se tačnost dobijenog oblaka tačaka i vreme potrebno za digitalizaciju obe metode. Na kraju će biti izveden zaključak da li je trenutno moguće koristiti fotogrametiju u industrijskim uslovima.

**KLJUČNE REČI:** *3D skeniranje, fotogrametrija, reverzni inženjering, oblak tačaka*

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## INTRODUCTION

Photogrammetry is an optical method of 3D digitization. The name comes from the Latin words *fotos* (light), *gramma* (writing, recording) and *meteo* (measurement). The first application of photogrammetry is related to the middle of the 19th century when Aimé Laussedat made topographic maps based on images created from the ground. With the development of the technique, new methods of photogrammetry appeared, first of all analog and analytical and, in modern times, digital photogrammetry. The essence of photogrammetry is that the user receives a model of the object in one of the available formats based on photos of the object using photogrammetry software. Photogrammetry has found application in numerous fields: art, design, engineering. When two images of the same object taken at different angles are projected, a sense of depth is created, that is, the impression of a third dimension is created. The technical prerequisites for a successful photogrammetry process are the recording of high-quality photographs of the object. It is necessary to use a high-quality camera in order to obtain photos of high-quality resolution with depth of field. Objects with high reflectivity and objects without pronounced texture are not suitable for digitization by photogrammetry.

Paper [2] presents a case study where part of a car seat was digitized using photogrammetry and Photomodeler software. The cloud of points obtained by photogrammetry was compared with the CAD model and the largest measured difference of the cloud of points in relation to the model is about 2.2 mm, on the basis of which it was concluded that the photogrammetry method can satisfy the desired accuracy. A unique theoretical framework for the implementation of the photogrammetry process with physical and mathematical formulations is presented in the paper [5]. There are numerous examples of digitization of artistic statues and parts of larger dimensions [4]. Photogrammetry enables the measurement of extremely large structures such as radio telescopes [3]. Researchers are developing semi-automated systems to facilitate the use of photogrammetry for smaller parts [1]. The joint application of photogrammetry and additive manufacturing is shown in [6], a sculpture of an officer digitized by photogrammetry and then made by additive technology.

As presented, there are many examples of the application of photogrammetry, but it is primarily used for the digitization of artistic statues, objects or larger parts such as pieces of furniture. The goal of this paper is to analyze the perspective of the use of photogrammetry in the auto industry, that is, for the reverse engineering of auto components. In this paper, the analysis will be made through three sheet metal parts. The parts will be digitized in two ways, scanned with a 3D scanner Artec evo lite belonging to the middle price range and by photogrammetry using a mobile phone camera. The point cloud obtained by the 3D scanner will be taken as a reference and by overlaying it with the point cloud obtained by photogrammetry and deviation analysis, conclusions will be drawn.

## 1 DIGITALIZATION OF PARTS

The Artec eva lite scanner according to the manufacturer's specification has a precision of up to 0.1 mm and due to its proven precision this digitization result will be taken as a reference. Photogrammetry was done using a mobile phone camera and then post-processed with appropriate software. Three parts were selected: the crankcase after deep drawing with the rim, the finished crankcase and the wing of a vehicle. The layout of the parts is shown in Figure 1.

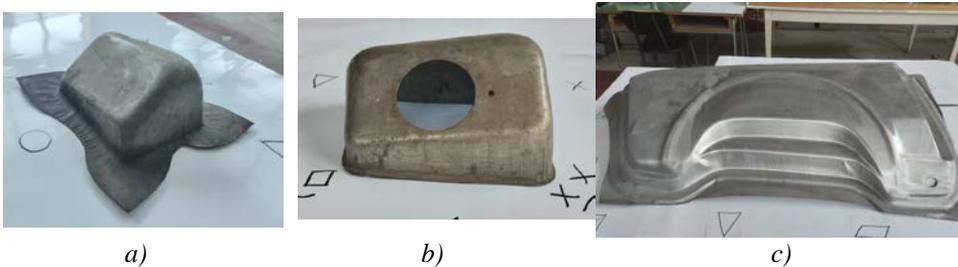


Figure 1. Analyzed parts a) crankcase with rim b) crankcase c) the wing of a vehicle

### 1.1 Scanning parts with a 3D scanner

The parts were scanned and post-processed in Artec studio 13 software. They were exported from the software in stl format. The appearance of the point clouds is shown in Figure 2.

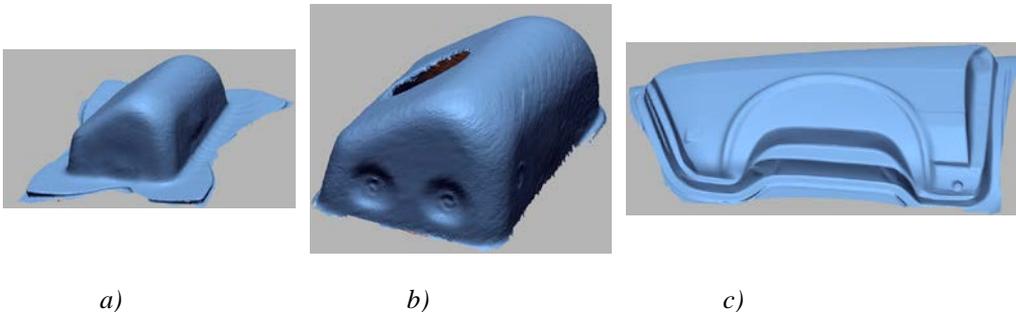


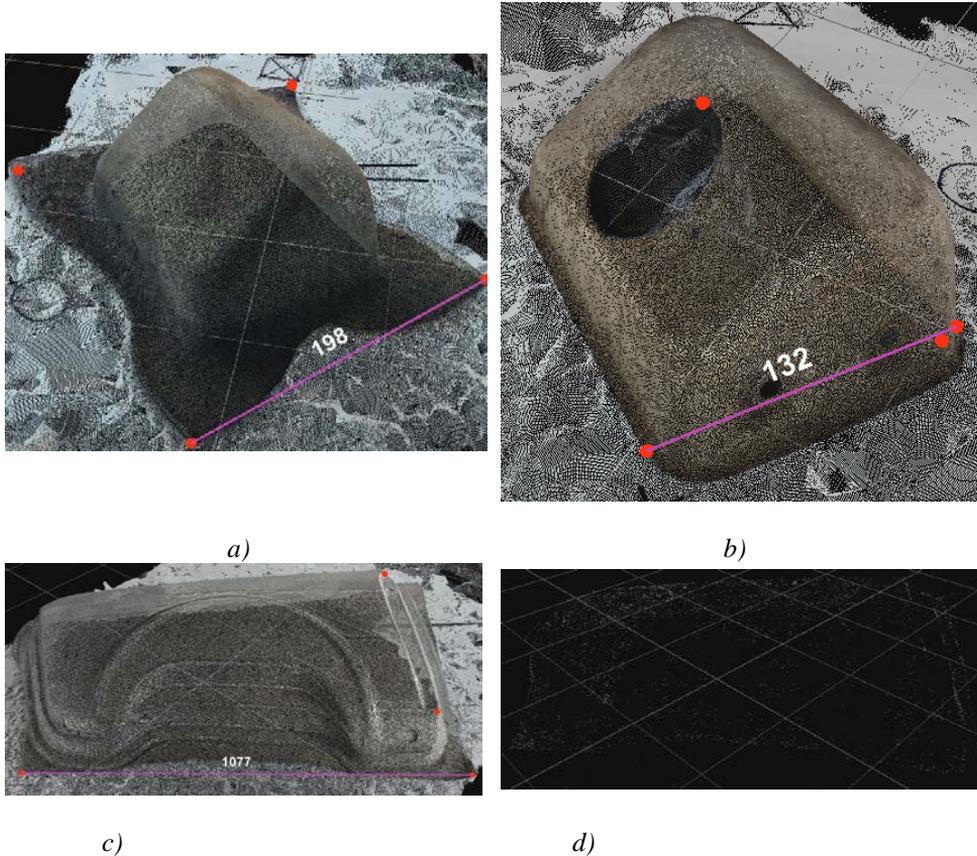
Figure 2. Point clouds of parts scanned by a 3D scanner

### 1.2 Photogrammetry

Zephyr 3D software was used for photogrammetry. There are several versions of the software, and in this paper a trial version was used, which is available to students and researchers. According to the theory of photogrammetry, images were made from three levels. For the first two parts, 34 and 38 photos were taken, which is quite enough due to the size of the parts, while for the third part, 50 photos were taken, which is the limit for the free version of the software. All three parts are suitable for photogrammetry because they have a pronounced texture (measuring grids that already existed on the parts). If there was no texture on the parts, it would be necessary to apply certain shapes so that the software could more easily do the joining. In both cases, hand-drawn markers were used to make the process easier. Each part was photographed from three levels and care was taken to make the photos at approximately the same distances as to make each part visible in the three photos.

According to the theoretical basis of photogrammetry, that it is forbidden to crop, modify photos, all photos were imported into photogrammetry software, and after the initial checks, the initial calibration of the cameras was made.

The first result of photogrammetry is to obtain a certain number of points to determine if the reconstruction is well done. After that, the complete model is obtained, which includes the texture, as shown in Figure 3.



*Figure 3. Obtained mesh of a) crankcase with rim b) finished crankcase c) the wing of a vehicle and d) point cloud of the vehicle wing*

In Figure 3, where the results of photogrammetry are shown, certain control points can be seen. The result of photogrammetry is a cloud of points where the shape of the part is defined but the dimensions do not correspond to the actual dimensions. In order for the dimensions of the cloud of points obtained by photogrammetry to be accurate, it is necessary to calibrate the results. This is achieved by defining control points. It is necessary to find two points that are easy to mark on the mesh and that it is possible to measure the distance between those two points on the model that is the subject of digitization. The selection of these points and accurate measurement are a challenge because any measurement error leads to a difference in the results. After calibration, the point cloud is exported in stl format. Given that as a result of photogrammetry, the environment is also obtained, it is necessary to process the obtained stl in the software. Autodesk meshmixer, which is free and available to researchers, was used in this research.

## 2 ANALYSIS OF RESULTS

The analysis of the results of the photogrammetry process will actually be a comparison of two point clouds where the stl obtained by a 3D scanner will be selected as a reference. Overlapping two point clouds can be done in numerous software such as Geomagic control, Cloud control, Gom inspect, etc. Gom inspect software was used in this research. It is necessary to first overlap two models by defining one stl as cad body and the other as mesh. The layout of the superimposed stl files and deviations is given in Figure 4.

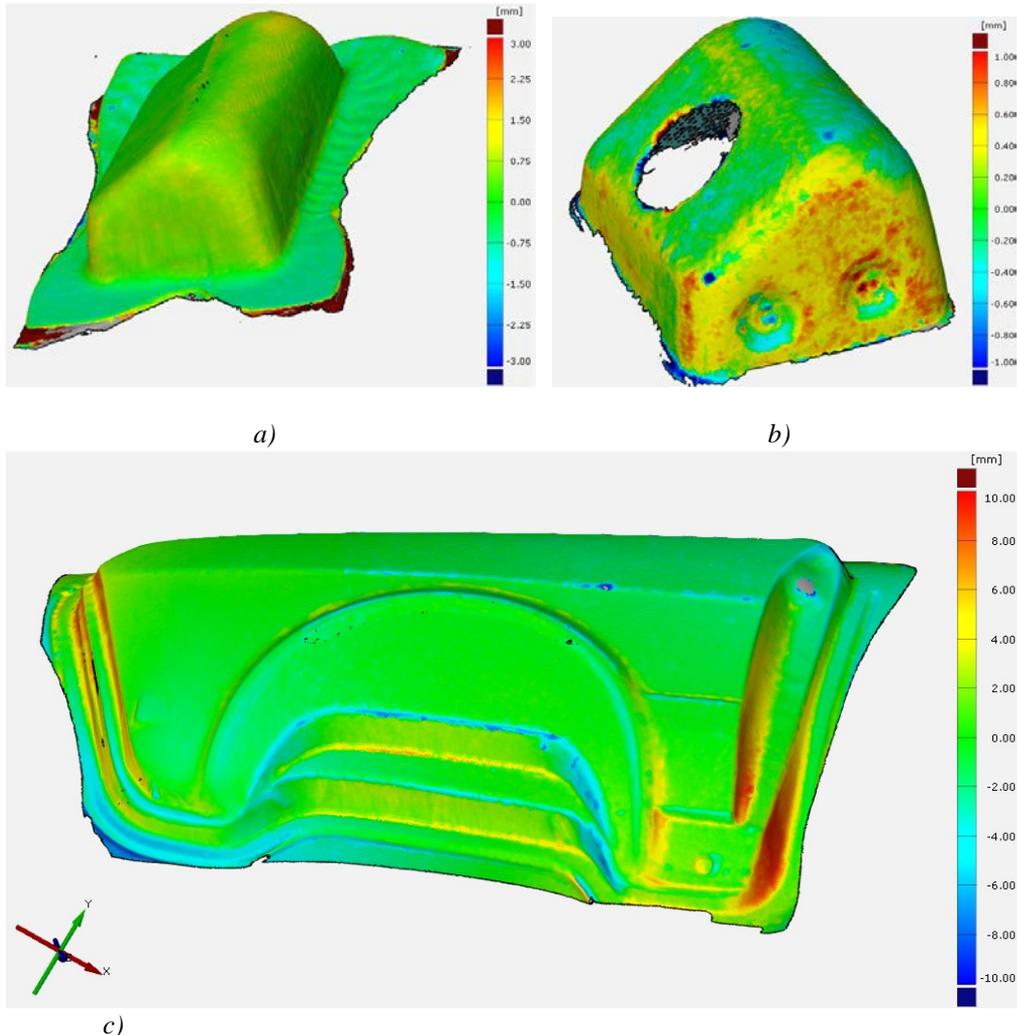


Figure 4. Deviation between obtained point clouds for a) the crankcase with rim b) the final crankcase and c) the vehicle wing

The deviations shown in Figure 4 are satisfactory. Deviations on the smaller parts shown in Figure 4 a and b are less than 1 mm. Deviations in the largest part are significantly larger and the highest value is around 8 mm, while in the rest of the part the deviation is less than 2 mm, on average around 1.8 mm. The explanation for such a large deviation is an error in

calibrating the accuracy of the cloud of points, that is, in measuring the physical model and matching that measurement with the control points.

### 3 CONCLUSIONS

The analysis of the results showed that the application of photogrammetry has a perspective for application in the auto industry. Given that the deviations are significant, the conclusion is that photogrammetry at this moment cannot be used to control the accuracy of parts, but that the point cloud or the resulting model can be a good basis for reverse engineering or the reconstruction of parts.

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