Faculty of Engineering
University of Kragujevac

Ministry of Science, Technological Development and Innovation

10th International Congress

Motor Vehicles & Motors 2024

ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

Proceedings

University of Kragujevac

Department for Motor Vehicles and Motors

International Journal for Vehicle Mechanics, Engines and Transportation Systems

October 10th - 11th, 2024
Kragujevac, Serbia

10th International Congress
Motor Vehicles & Motors 2024

ECOLOGY - VEHICLE AND ROAD SAFETY - EFFICIENCY

Proceedings

October 10th - 11th, 2024
Kragujevac, Serbia

Publisher: Faculty of Engineering, University of Kragujevac
Sestre Janjić 6, 34000 Kragujevac, Serbia

For Publisher: Prof. Slobodan Savić, Ph.D.
Dean of the Faculty of Engineering

Editors: Prof. Jasna Glišović, Ph.D.
Asst. prof. Ivan Grujić, Ph.D.

Technical preparation: Asst. prof. Nadica Stojanović, Ph.D.
Asst. prof. Ivan Grujić, Ph.D.

Cover: Nemanja Lazarević

USB printing: Faculty of Engineering, University of Kragujevac, Kragujevac

ISBN: 978-86-6335-120-2

Year of publication: 2024.

Number of copies printed: 100

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

CIP - Каталогизација у публикацији Народна библиотека Србије, Београд

629.3(082)(0.034.2)
621.43(082)(0.034.2)

INTERNATIONAL Congress Motor Vehicles and Motors (10 ; 2024 ; Kragujevac)
Ecology - Vehicle and Road Safety - Efficiency [Elektronski izvor] : proceedings / [10th] international congress Motor vehicles & motors 2024, October 10th - 11th, 2024 Kragujevac, Serbia ; [editors Jasna Glišović, Ivan Grujić]. - Kragujevac : University, Faculty of Engineering, 2024 (Kragujevac : University, Faculty of Engineering). - 1 USB fleš memorija ; 1 x 1 x 6 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa nasl. strane dokumenta. - Tiraž 100.
-
Bibliografija uz svaki rad.

ISBN 978-86-6335-120-2

a) Моторна возила -- Зборници b) Мотори са унутрашњим сагоревањем -- Зборници

COBISS.SR-ID 153339657

Publishing of this USB Book of proceedings was supported by
Ministry of Science, Technological Development and Innovation of the Republic of Serbia

SCIENTIFIC BOARD

President: Prof. dr Jasna Glišović, UniKg, FE, Serbia

Secretary: Assoc. Prof. dr Aleksandar Jovanović, UniKg, FE, Serbia

Members:

Prof. dr Giovanni Belingardi, Politecnico di Torino, Italy
Prof. dr Ivan Blagojević, University of Belgrade, FME, Serbia
Prof. dr Murat Ciniviz, Selcuk University, Turkey
Prof. dr Adrian Clenci, University of Pitesti, Romania
Assoc. Prof. dr Aleksandar Davinić, University of Kragujevac, FE, Serbia
Prof. dr Miroslav Demić, University of Kragujevac, FE, Serbia
Prof. dr Jovan Dorić University of Novi Sad, FTS, Serbia
Assoc. Prof. dr Boris Stojić, University of Novi Sad, FTS, Serbia
Prof. dr Jovanka Lukić, University of Kragujevac, FE, Serbia
Prof. dr Valentina Golubović Bugarski University of Banja Luka, FME, Republic of Srpska, Bosnia and Herzegovina
Prof. dr Aleksandra Janković, University of Kragujevac, FE, Serbia
Assoc. Prof. dr Aleksandar Jovanović, University of Kragujevac, FE, Serbia
Prof. dr Emrullah Hakan Kaleli, YTU, Istanbul, Turkey
Prof. dr Dimitrios Koulocheris, NTUA, Athens, Greece
Prof. dr Božidar Krstić, University of Kragujevac, FE, Serbia
Prof. dr Danijela Miloradović, University of Kragujevac, FE, Serbia
Prof. dr Alexander Novikov, OSUni, Orel, Russia
Prof. dr ing Oday Abdulah, TU Ham, Germany
Prof. dr Radivoje Pešić, University of Kragujevac, FE, Serbia
Prof. dr Snežana Petković, University of Banja Luka, FME, Republic of Srpska, Bosnia and Herzegovina
Prof. dr Ralph Puetz, Landshut University UAS, Germany
Prof. dr Dragan Ružić, University of Novi Sad, FTS, Serbia
Assoc. Prof. dr Aleksandar Stevanović, UniPitt, USA
Assist. Prof. dr Slobodan Mišanović, Project Manager GSP Beograd, Serbia
Prof. dr Zoran Lulić, University of Zagreb, FSB, Croatia
Prof. dr Igor Gjurkov, FME, Skopje, Republic of North Macedonia
Prof. dr Sunny Narayan, Instituto Tecnológico y de Estudios Superiores de Monterrey, Mexico
Prof. dr Zbigniew Lozia, WUT, Warsaw, Poland
Prof. dr Breda Kegl, University in Maribor, FME, Slovenia

ORGANIZATIONAL BOARD

President: Asst. prof. dr Ivan Grujić, UniKg, FE, Serbia

Secretaries: Asst. prof. Nadica Stojanović, Ph.D., UniKg, FE, Serbia
Assist. Slavica Mačužić Saveljić, M.Sc., UniKg, FE, Serbia

CONGRESS ORGANIZERS

University of Kragujevac
Faculty of Engineering of the University of Kragujevac
Department for Motor Vehicles and Motors, FE Kragujevac
International Journal “Mobility & Vehicle Mechanics”

CONGRESS PATRONS

Ministry of Science, Technological Development and Innovation
City Council of Kragujevac

International Congress
Motor Vehicles &Motors 2024
Kragujevac, Serbia
October 10th- 11th, 2024
Motor Vehicles & Motors

MVM2024-017

Marko Delić[1]
Vesna Mandić[2]
Dragan Adamović[3]
Dušan Arsić[4]
Đorđe Ivković[5]
Nada Ratković[6]

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

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.

KEYWORDS: 3D scanning, photogrammetry, reverse engineering, point cloud

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.

[1]*Marko Delić, Faculty of Engineering, University of Kragujevac, SestreJanjić 6, marko.delic@kg.ac.rs*
[2]*Vesna Mandić, Faculty of Engineering, University of Kragujevac, SestreJanjić 6, mandic@kg.ac.rs*
[3]*Dragan Adamović, Faculty of Engineering, University of Kragujevac, SestreJanjić 6, adam@kg.ac.rs*
[4]*Dušan Arsić, Faculty of Engineering, University of Kragujevac, SestreJanjić 6, dusan.arsic@fink.rs*
[5]*Đorđe Ivković, Faculty of Engineering, University of Kragujevac, SestreJanjić 6, djordje.ivkovic@fink.rs*
[6]*Nada Ratković, Faculty of Engineering, University of Kragujevac, SestreJanjić 6, nratkovic@kg.ac.rs*

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 eva 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.

DIGITALIZATION OF PARTS

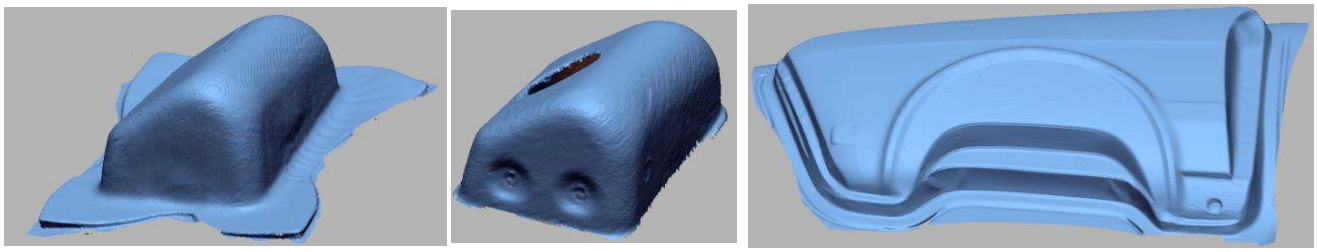
The Artec eva lite scanner according to the manufacturer's specification has a precision of up to 0.1 mm and due to its proven precision this digitization result will be taken as a reference. Photogrammetry was done using a mobile phone camera and then post-processed with appropriate software. Three 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.

a) b) c)

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

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.



a) b) c)

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

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.

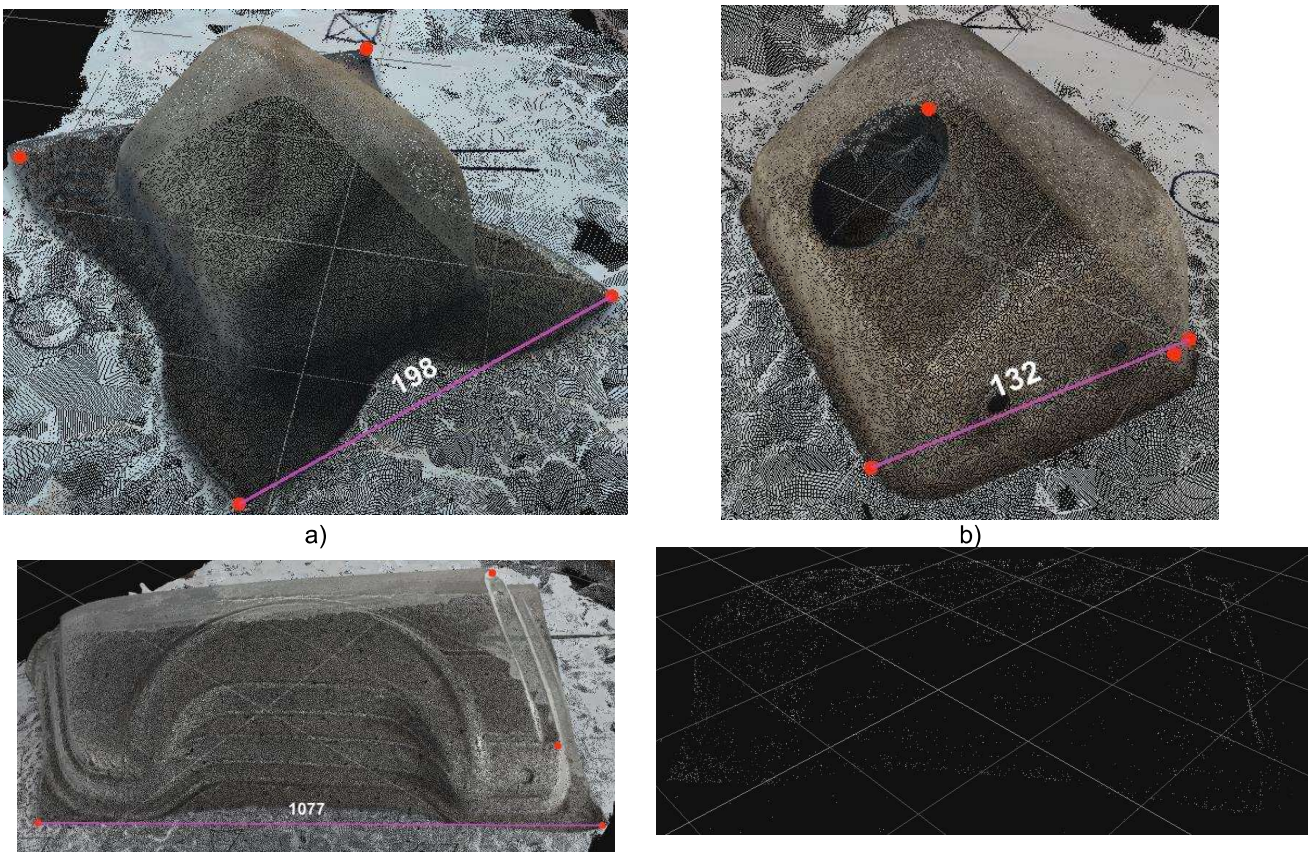


Figure 3. Obtained mesh of a) crankcase with rim b) finished crankcase c) the wing of a vehicle and d) point cloud of the vehicle wing

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.

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.

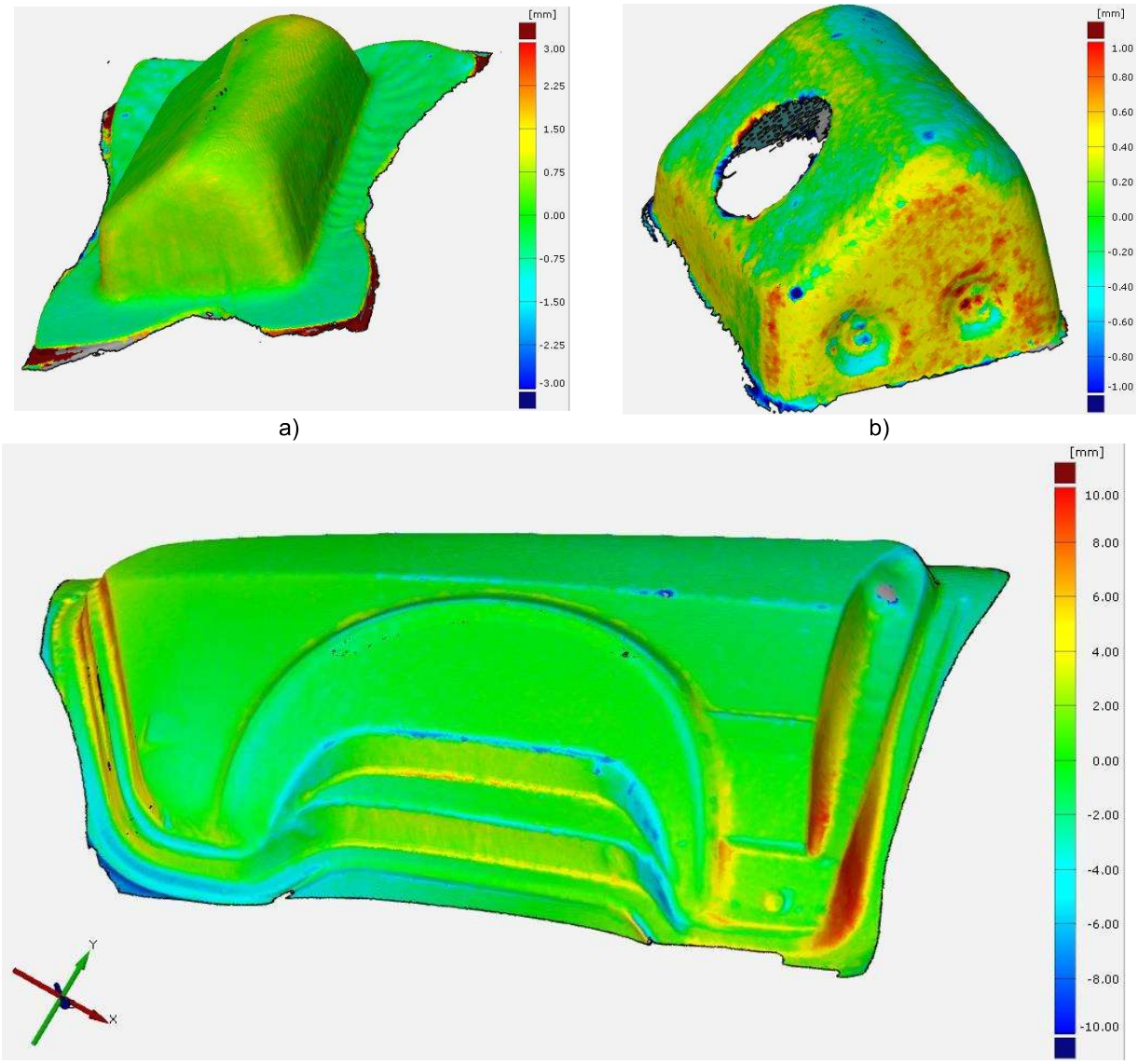


Figure 4. Deviation between obtained point clouds for a) the crankcase with rim b) the final crankcase and c) the vehicle wing

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.

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.

ACKNOWLEDGMENTS

The present work was funded by the Ministry of Science and Technological Development of the Republic of Serbia under the project TR34002.

REFERENCES

[1] Collins, T., Woolley, S. I., Gehlken, E., Ch'ng, E.: "Automated low-cost photogrammetric acquisition of 3D models from small form-factor artefacts", Electronics, Vol. 8, No. 12, 2019, 1441.
[2] Gerbino, S., Martorelli, M., Renno, F., Speranza, D.: "Cheap photogrammetry versus expensive reverse engineering techniques in 3d model acquisition and shape reconstruction", In DS 32: Proceedings of DESIGN 2004, the 8th International Design Conference, Dubrovnik, Croatia, 2004, 749-754.
[3] Kesteven, M.: "Photogrammetry for large structures", [Online] https://www.gb.nrao.edu/MetConf/talks/Wednesday/Kesteven.pdf, 2016.
[4] Prasetyo, Y., Yuwono, B. D., Barus, B. R.: "Comparative Analysis of Accuracy to the Establishment of Three Dimensional Models from Diponegoro Prince Statue Using Close Range Photogrammetry Method in Non Metric Camera and Unmanned Aerial Vehicle (UAV) Technology", In IOP Conference Series: Earth and Environmental Science, Vol. 313, No.1, 2019, 012038.
[5] Shan, J., Hu, Z., Tao, P., Wang, L., Zhang, S., Ji, S.: "Toward a unified theoretical framework for photogrammetry", Geo-spatial Information Science, Vol. 23, No. 1, 2020, 75-86.
[6] Zivanović, S., Tabaković, S., Randjelović, S.: "Rapid prototyping of art sculptural shapes according to the sample", Advanced Technologies and Materials, Vol. 44, No. 1, 2019, 27-32.