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SMARTPHONE-BASED PHOTOGRAMMETRY ASSESSMENT IN INDUSTRIAL ENGINEERING

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Abstract: *This paper presents an innovative way to assess smartphone-based photogrammetry's precision in an industrial environment using 3D printed gauges. The proposed methodology is based on 3D printing technology to create the gauges, which were modeled using CAD software. The resulted gauges were measured using a CMM to obtain the real nominal value, and are compared with the resulted photogrammetry models in order to assess their precision. In the case study only angles were measured, because these are not affected by scaling, thus the errors during measurements are considerably reduced.*
Key words: *photogrammetry, 3D printing, gauges, industrial engineering, geometrical accuracy.*

1. INTRODUCTION

According to [1] 83.32% of the world's population owns a smartphone in the year 2022. As it is known, there are many makes and models of smartphones for every budget, equipped with higher or lower-end cameras. Since smartphones are within reach, many use smartphone cameras to create photogrammetry projects. Photogrammetry is a measurement technique, which is used to extract the geometry, displacement, and deformation of an object using digital images [2]. Photogrammetry is used in various domains such as in bridge measurement in the field of civil engineering [3], aerospace applications [4], 3D shape measurement [5] and so many more. Some research has been done in the field of industrial photogrammetry using SLR cameras [6]. Researchers W. Saif and A. Alshibani compare smartphone-based photogrammetry to compact camera photogrammetry in construction management applications [7], using concrete molds to use as a test subject for the two sets of data.

A very cost effective fabrication method to create test subjects for assessing the precision of photogrammetry is 3D printing.

3D printing or Additive Manufacturing (AM) has been available commercially in the last three decades [8]. 3D printers create actual replicas of computer generated designs, which can be from toys to medical implants [9].

2. RELATED WORKS

The authors of this paper are part of a research collective that utilizes photogrammetry for a long time in domains such as furniture industry [10]. Since photogrammetry is an accessible method to generate complex 3D models, the authors have started to evaluate the accuracy of photogrammetry using DSLR cameras by comparing it to 3D scanning and measurement using custom designed gauges [11], which are medium to smaller sized objects. The authors compare photogrammetry to terrestrial laser scanning [12] in the case of a water treatment plant, which corresponds to a large scale object. The authors are also conducting research in the domain of 3D printing, they developed a linear delta 3D printer [13].

3. MATERIALS AND METHOD

The proposed workflow in this article for assessment of photogrammetry starts with the 3D modeling of the gauges, which contain various shapes and angles, which helps in the assessment process. The 3D modelling was done

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in Autodesk Inventor computer aided design (CAD) software, the gauges have a modular design, which facilitates their assembly in various combinations to increase the number of subjects for the assessment process. In the figure below is presented the design of a gauge, rendered in Autodesk Inventor, which also highlights the angles on the surface of the model that are measured on the resulted 3D models from photogrammetry in the assessment process.

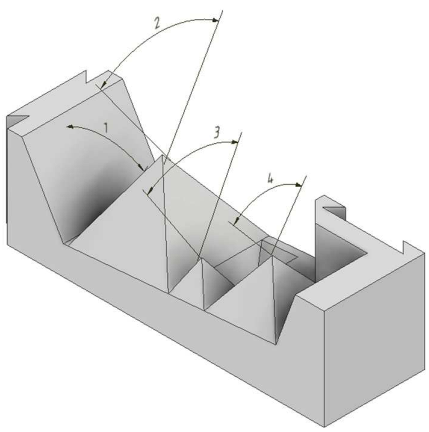

Fig. 1. The design of Gauge no. 1

The resulted CAD models then were needed to be transposed in reality, by using a cost and time efficient method. The best manufacturing method in this case was 3D printing, because considering the costs, it is a cheaper method than machining the gauges from blocks of Aluminum.

The resulted CAD 3D models were exported as *.STL file format in order to create the 3D prints using a Prusa i3 MK3S+ 3D printer. The gauges were 3D printed using PLA TerraPlast material with a 0.4 mm nozzle, a 30% of infill and a 0.15 mm thickness per layer. Since the gauges are not used in any mechanical work, there is no need to have a greater infill, thus 30% is a good compromise between exterior surface quality and material usage.

The next critical step was to measure with a CMM the resulted 3D printed gauges. In this step, a CimCore Stinger II robotic arm CMM was used with a 2 mm sapphire probe. In this case, planar surfaces were generated in order to extract the angle information between the desired surfaces. This step is important, because in the process of 3D printing, as in any other fabrication process, the resulted surface finish differs from the actual CAD models, thus the recording of the resulted shape of the physical gauges is necessary in the comparison stage.

The photogrammetry process is the next stage, where the first step is the creation of the digital photographs, in this case with two different smartphones. The two smartphones in this case were Samsung Galaxy S22 Ultra and Huawei P20 Pro, their main camera specifications are presented in the table below.

Camera specifications for the selected smartphones

Specification	**Samsung S22 Ultra**	**Huawei P20 Pro**
Main camera Megapixels	108	40
F-stop	f/1.8	f/1.8
Field of view	23 mm	27 mm

In the process of picture taking an industrial environment was simulated, without the use of controlled lightning, but some positioning targets were used, which were printed on paper, and positioned randomly near the 3D printed gauges. These positioning targets are useful in the processing step, where a software, in this case Agisoft, is run on a powerful desktop or on a cloud-computing server. The software analyzes the digital images and searches for similarities within these images, thus using targets, this process is faster and can create a more accurate 3D object. In the figure below is presented one of the images taken with a phone, which is part of the image sets for Gauge no. 1.

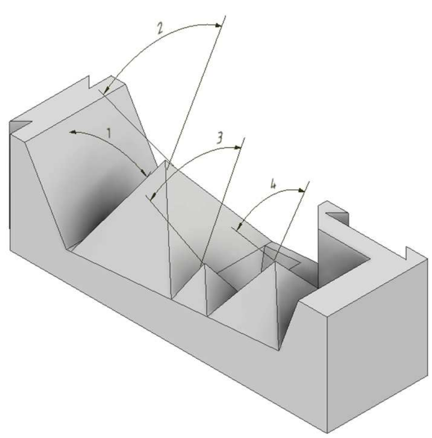

Fig. 2. One image of Gauge no. 1 from the photogrammetry set

After the photogrammetric process the resulted 3D models are not in the real scale, this why in the process of precision assessment only the angles are measured, reducing the errors that could appear if the models were scaled to their real sizes.
Using CATIA V5 with the help of Surface recognition commands, planes were generated on the surface of the resulted 3D meshes of the gauges, where the angles were extracted using the Measure tool. The resulted surfaces are shown in the figure below.

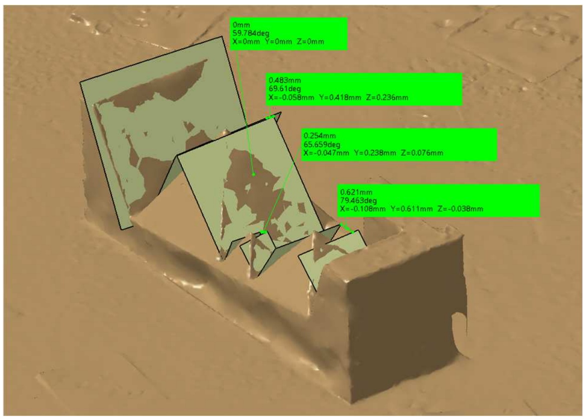

Fig. 3. Planes generated on the surface of Gauge no. 1 in CATIA V5 software

The results were centralized in the table below, where is presented the data for Gauge no. 1.

The resulted data for gauge no. 1

Angle	CAD		3D Measurement	Photogrammetry	
				Huawei	Samsung
1	60	°	59.85	59.83	59.784
2	70	°	69.963	70.017	69.61
3	64	°	64.101	64.286	65.659
4	80	°	79.985	80.601	79.463

4. CONCLUSION

3D printing can be a viable solution to create cost effective physical replicas of CAD modeled 3D objects. In the case of photogrammetry, 3D measuring the resulted 3D prints, the accuracy of 3D printing is virtually insignificant, thus is not affecting the assessment process of photogrammetry, because the comparison is done between the 3D printed surface and the 3D surface resulted from the photogrammetry process.

5. FUTURE WORK

The authors would like to create larger 3D prints with larger 3D printers, to replicate bigger objects from different industries, also trying out different cost effective materials or even techniques that can be applied to 3D printed objects, which resembles objects found in the industry, to be able to create a larger study, incorporating other smartphone brands and models.

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EVALUAREA FOTOGRAMETRIEI BAZATE PE SMARTPHONE ÎN INGINERIA INDUSTRIALĂ

Rezumat: Această lucrare prezintă o modalitate inovatoare de a evalua precizia fotogrammetriei bazate pe smartphone-uri într-un mediu industrial, folosind instrumente de măsurare imprimate 3D. Metodologia propusă se bazează pe tehnologia de imprimare 3D pentru a crea calibrele, care au fost modelate folosind software-ul CAD. Calibrele rezultate au fost măsurate cu ajutorul unui CMM pentru a obține valoarea nominală reală și sunt comparate cu modelele de fotogrammetrie rezultate pentru a evalua precizia acestora. În studiul de caz au fost măsurate doar unghiurile, deoarece acestea nu sunt afectate de scalare, astfel erorile din timpul măsurătorilor sunt reduse considerabil.

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