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Image-Based 3D Scanning: A Study on Surface Topography and Geometric Accuracy

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Abstract: Image-based three dimensional (3D) scanning is a photogrammetry method. Photogrammetry is a scientific discipline used for obtaining dimensional information from photographs taken of objects. This discipline used in the mapping of geographical areas with photographs taken from airplanes at first, began to be used in obtaining the 3D model of objects with the development of the technology. Image-based 3D scanning method which is becoming increasingly widespread in the field of photogrammetry has become important like laser and optical scanning methods in areas of reverse engineering, personalized design, forensics, biomedical, industrial design, virtual reality. This method has some advantages such as low cost, color modeling compared to other 3D scanning methods, and yet is questioned in some aspects such as dimensional accuracy and surface integrity. In this study, as a result of the scanning operations on small size (125-1000 cm3) objects, the digitized models and the actual objects were compared dimensionally. In addition, glossy, transparent and matte surface objects were modeled by image-based 3D scanning method and the differences related to the process were revealed and the precautions to be taken were stated. This article is thought to be useful for researchers who want to use image-based 3D scanning in their study.

Keywords: 3D scan, Photogrammetry, Photo scan, Image based, Recap

Introduction

Image-based 3D scan is a 3D scanning method that involves taking pictures of an object from different angles and combining them with a software to obtain 3D model of the object. This method is also known as photogrammetry and 3D photo scan. Image-based 3D scanning is used in forensic medicine Urbanova, Hejna, & Jurda, 2015), modeling of historical and structures (Kersten, & Lindstaedt, 2012), damage detection (Allard, Lavoıe, & Fraser, 2013), reverse engineering (Hoffmann, Hermanek, Rybka, & Honzik, 2015)., architecture (Baik, & Alitany, 2018) and many other sectors. The models obtained by this method are used for many purposes such as manufacturing, design, digital arts and archiving of objects.

Image-based 3D scan method has some advantages compared to other 3D scanning methods. These are low cost, open area scanning, suitability for large objects and good texture-color properties. However, the method has some disadvantages related to dimensional accuracy and surface topology.

In this study, image-based 3D scanning operations were performed for objects with different characteristics such as matt, glossy and transparent using the ReCap Photo (2019) software. Surface topography and geometric accuracy of the obtained 3D models were investigated and scanning results of 3D models evaluated. In addition, measures to be taken in scanning and shooting phases were specified for efficient 3D scanning applications,

Method

The image-based 3D scan method, which basically requires a camera and a scanning software, consists of 4 main stages. These stages are taking photos of the object, generating the point cloud, obtaining the mesh model and post-processing. In this study ReCap Photo software of Autodesk were used for 3D scanning process and Cannon EOS 550D camera and 18-135 mm lens were used for photographing. ReCap Photo is a cloud-based software to generate point clouds and textured meshes. Point cloud format and high-resolution mesh format of the software are RCS and RCM. ReCap Photo has also some tools for mesh editing, retopologizing and model analysis in the stage of post-processing.

During the shooting phase, a system has been utilized to prevent errors that may arise from user and external factors (Figure 1). In this system the object was placed on the object stand at the center of the table. The reference points for each 15 degrees were marked on the stand where the rotating table was placed. This angle was determined to ensure high overlapping between images. The table could be manually rotated according to these references. In the system, the camera was positioned on the fixed stand and pictures were taken at a certain distance. At the end of each shot, the table was rotated 15 degrees again and the process was completed after a complete rotation of 360 degrees.

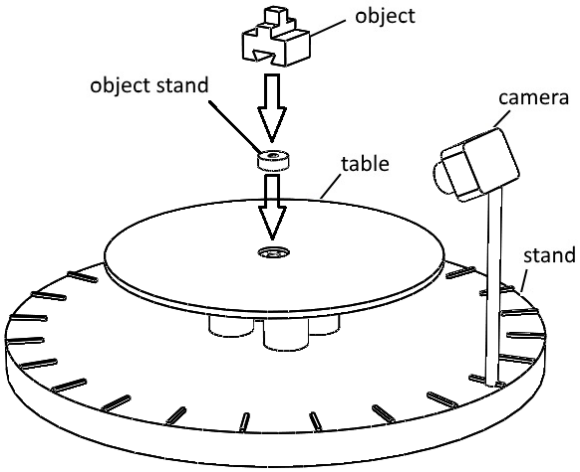


Figure 1. System setup of image-based 3D scan used in this study

24 pictures were taken at a single height for each object. Photos have been transferred to a computer and converted into a 3D model with ReCap Photo software. This process was completed by using the cloud service of Autodesk.

In order to measure the dimensional accuracy, simple geometrical objects with matt surface were used in the study. The objects were measured by means of measuring instruments such as calipers and rulers. The dimensions of the 3D models were measured using the "Measure Distance" tool in the "Analyze" toolbox of the ReCap Photo software. The measurements for the different parts of the objects were averaged and the dimensional accuracy was determined. In addition, objects with glossy surface and transparent objects are also included in the study to observe the results of image-based 3D scanning. A transparent plastic object and an aluminum object were used for this purpose. Moreover, an object with the same color as the background color was scanned for the purpose of observing the results of 3D scan when the background and the object have the same color (Figure 2).

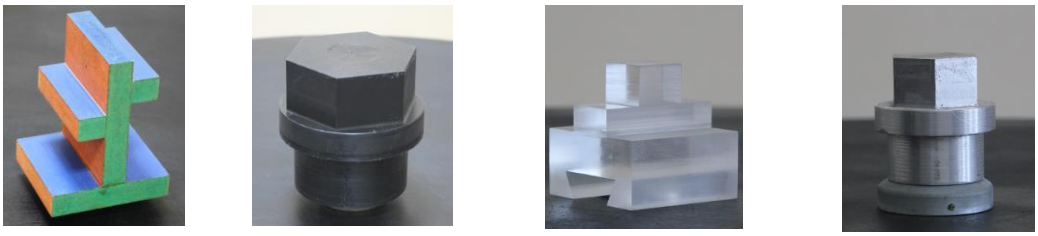


Figure 2. Images of objects used in 3D scanning process

Results and Discussion

The 3D photo-scan process for four objects was performed and 3D models were obtained. For each scan, 24 photos were taken and over 80% overlapping between images was provided. First, the matte object was scanned and the 3D model was successfully obtained. Some defects were observed in the areas outside the camera angle (Figure 3a). This problem could be solved by adding additional photographs.

In order to examine the dimensional accuracy, three more matte objects with different geometry were scanned and evaluated. The scales of the obtained models were measured differently from the real object depending on the shooting distance and angle. The scale of the 3D model can be increased in the ReCap Photo software by determining a magnification ratio between the real object and the model. Comparisons between real objects and 3D models revealed that the dimensional accuracy was altered in the range of 100-98%. If there are surface defects in the model resulting from shooting angle and photo quality, the dimensional accuracy will be negatively affected. In this study, the objects used to investigate dimensional accuracy were small (125-1000 cm^3) and simple geometrical objects. More detailed assessments may be required for objects with complex geometry and free-form surfaces.

The other scan was made for the black object with the same color as the background. A large part of the model was obtained properly, but some holes and bulges were formed in one area (Figure 3b). Instead of editing the model, it might be preferred to repeat the photo shooting phase using a different colored background. As a result of 3D scan of a transparent plastic object, the 3D model of the object was not fully obtained (Figure 3c). The 3D scanning software could not detect the shape of the object due to the light transmittance of the object. When the glossy subjects were scanned using the image-based 3D scanning method, the 3D model was not fully obtained (Figure 3d). Light reflecting surfaces could not be detected by the 3D scanning software. Additional processes or surface coating can be applied to reduce the glossiness of the object. Illumination and shooting angles also affect the results.

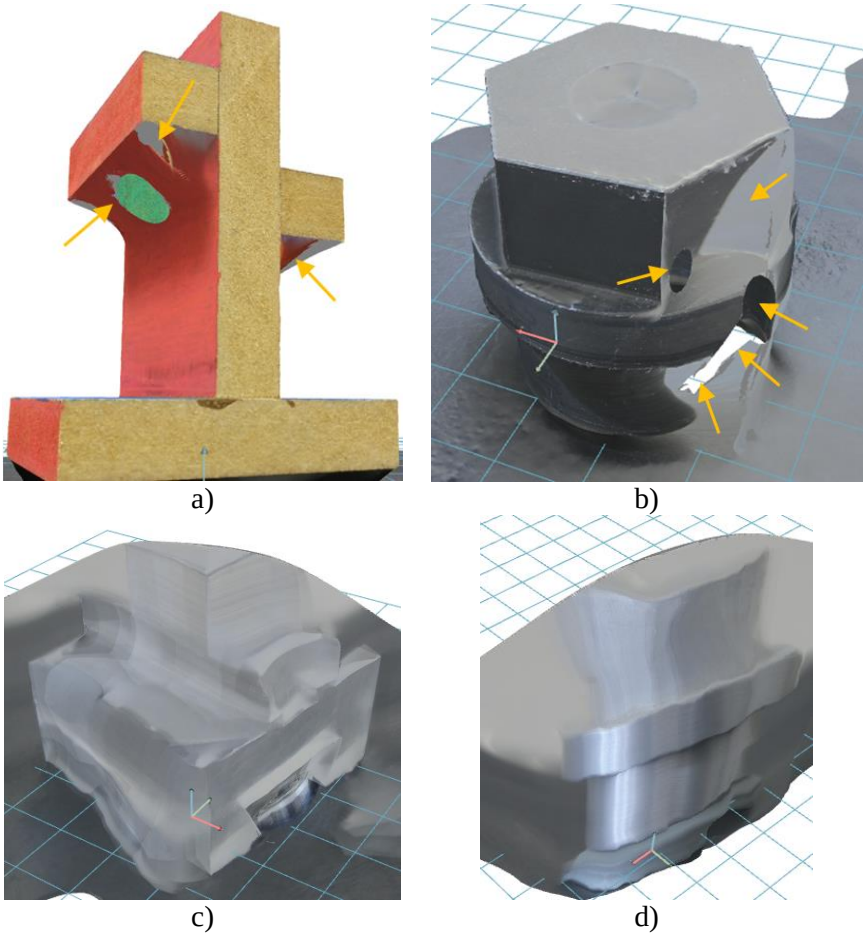
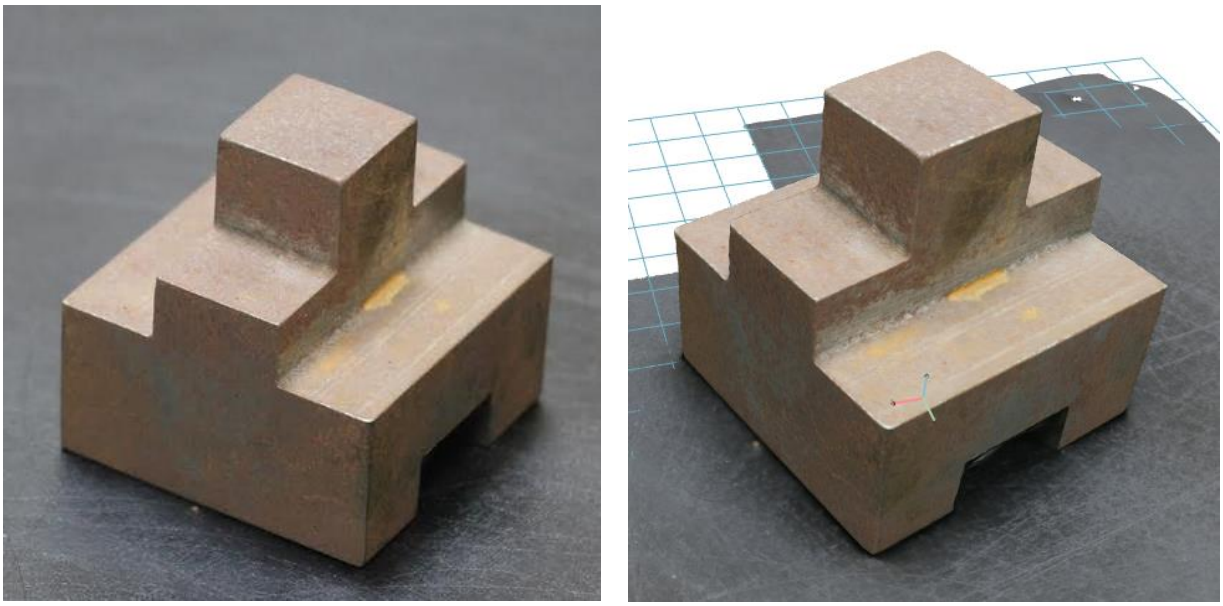


Figure 3. Defects of 3D models obtained from four objects with different characteristics (a-Surfaces out of camera angle, b- Object with the same color as the background color, c-Transparent object, d-Glossy object)

3D scanning steps were applied to a metal object with rusty surfaces. Since the surfaces of this object were largely rusty, no glossiness occurred and the model could be obtained properly (Figure 4). The dimensional accuracy, color and texture properties of the obtained 3D model were quite satisfactory.



a) b)

Figure 4. a) Rusty metal object, b) 3D model of the object

Image-based 3D scan (photogrammetry) that does not require electricity, provides the high resolution color information (Buck, Bußе, Campana, & Schyma, 2018). As a result of the scans performed with the image-based 3D scan method, it was proved that the texture properties of the objects could be obtained in detail. Besides, the colors of the objects were successfully generated by the software in a realistic way. This method was found to be reliable for cases where the object needs to be modeled together with texture and color characteristics.

Conclusion

In this study, matt, glossy and transparent objects were scanned by using image-based 3D scanning method. Dimensional accuracy and surface topography of the 3D models obtained with ReCap Photo software was compared to real objects. In addition, the results of the 3D scan were evaluated when the background and the object have the same color.

According to the results of the comparisons, we note that dimensional accuracy reached in the range of 100-98% for complete 3D models. Holes and bulges were formed on the surfaces not included in the shooting angle. This problem can be solved by adding new photos that overlap with other photos for the invisible parts of the object.
Another aim of the study was to examine how successful the image-based 3D scanning method was for glossy and transparent surfaces. In this context, scanning processes were performed on glossy and transparent objects. As a result of the scans, 3D models were not completely obtained. In order to remove the glossiness and transparency and to detect the surfaces, surface coating operations and matting should be done before the shooting phase. It is possible to remove small surface defects in 3D models by mesh repair software. However, in cases where defects are spread over a wide area, the desired results may not be obtained by post-processing. In case the background color and the color of the object were the same, some surface defects occurred in the 3D model. Therefore, the background should be preferred matt and different from the color of the object.

The suitability of this low-cost 3D scanning method for professional purposes in different areas can be investigated in detail. Specific processes which can be integrated with image-based 3D scan process can be developed for application areas in different sectors.

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