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Image-based 3D Scanning: System Setup and Operations for Two Different Model Approaches

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Abstract: 3D models are required for design studies carried on in many sectors such as automotive, machinery, aeronautics and industrial design. 3D models frequently used in Computer Aided Engineering (CAE) applications are obtained by drawing with a Computer Aided Design (CAD) software. Moreover, when it is desired to improve the design of an existing part or to make its computerized analyzes, it is necessary to transferred to the electronic environment. Today, 3D scanning methods are used especially in reverse engineering applications, patient-specific designs, cases that parts need to be redrawn and obtaining free-form models. The use of different 3D scanning methods, such as laser scanning and optical scanning, is increasing in scientific studies and industrial applications. In addition to these methods, the image-based 3D scanning method known as a low-cost photogrammetry method has started to be used in many different areas such as engineering, biomedical, forensic medicine and archeology. It is possible to carry out the digitization process with this method which basically needs a photographic machine and a computer software which allows the creation of the 3D model from the obtained images. During this process, some problems arise from the operator and external factors, and as a result, the scanned models cannot be digitized as desired. In this study, image-based 3D scanning process is explained in detail and two different approaches which can work manually and reduce errors caused by operator and external factors that may occur in the scanning process are discussed. In addition, image-based 3D scanning applications for both systems were carried out and merits and shortcomings of these systems were evaluated and compared the methods used in these systems with other scanning methods.

Keywords: 3D scanning, Photogrammetry, 3D Photo scan, Image based 3D scanning, Digitization

Introduction

3D scanning is a technique to capture the shape of an object using various scanning equipment depend on different technologies. Nowadays, there are 3D scanning technologies such as laser triangulation (Franca, Gazziro, Ide & Saito, 2005), structured light (Geng, 2011), touch-probe (Persson, Andersson, Oden, & Sandborgh, 2006), and laser pulse (Rocheuse, & De Données, 2013). Another 3D scanning technology that requires lower cost than others is image-based 3D scanning technology (Surmen, Ortes, & Arslan, 2016). This technology, also known as 3D photo-scan, is a photogrammetry technique that relies on the measurement of objects over photographs and the dimensional interpretation of image data. In recent years, 3D scan, which has gained momentum in its development, has become even more popular with the advancement of 3D printing technologies. This is because 3D printers, which are very successful in printing free-form objects, are able to directly print the models obtained from the 3D scan. Today, 3D scanning is used in several industries, such as medical (Grazioso, Selvaggio, & Di Gironimo, 2018), forensic (Buck, Buße, Campana, & Schyma, 2018), automotive, aeronautics (Allard, Lavoıe, & Fraser, 2013), reverse engineering (Buonamici et al., 2018), jewelry, movies and video games.

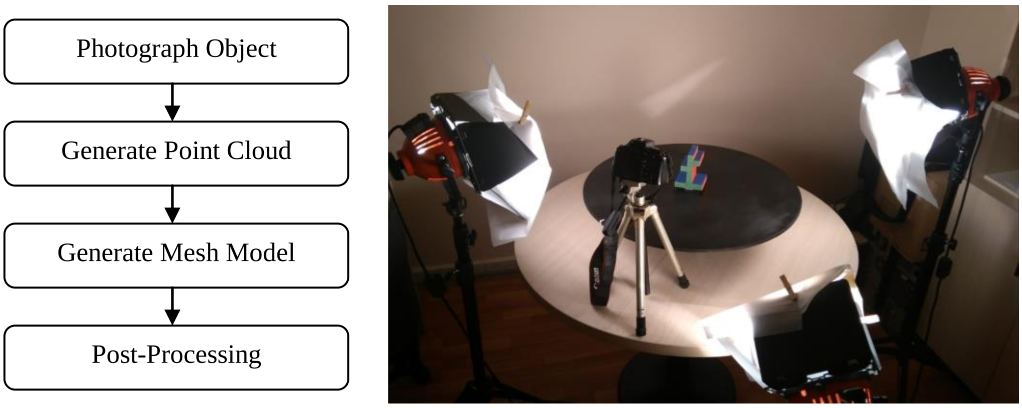
3D scanning is used to capture the physical measurements and digitized model of an existing object. So it is a powerful tool for engineering optimization studies such as modifying the design or performing finite element analysis and other engineering analysis of an existing manufactured part.

The cost of the 3D scanning process is one of the reasons restricting the use of this technology. With the image-based 3D scanning method, the cost could be reduced considerably. This method basically requires a camera and a 3D scan software. In image-based 3D scan operation some problems arising from user and external factors affect the scan result. In this study, two different approaches are considered that reduce errors caused by operator and external factors. Scanning processes were performed according to these approaches using small objects and both methods were compared with each other to evaluate the results.

Method

Image-based 3D scan (3D photo-scan) can be performed with a camera and a 3D scan software. This process consists of four basic stages (Figure 1a). The first step is to take photos of the object. Then the photos are transferred to a 3D photo-scan software. The software basically creates a point cloud model by combining photographs taken from different angles and then transforms this model into a mesh model. After the mesh model is obtained, post-processing consisting of a series of surface smoothing and repair operations can be applied. This process requires a sufficient number of photos in 360 ° circles at 2 or more different heights to describe a 3D object in all viewpoints. The photos should overlap with each other. The number of photos depends on the complexity of the object geometry.

In this study, two approaches that could be used to scan small objects and reduce the problems caused by operator and external factors are discussed. First a manually rotatable table was fabricated to facilitate photographing. This table is placed on a circular stand marked with 360 degree angles. In addition, an object stand is designed for the placement of objects. The object stand rotates with the table when it is in the first position, and remains constant independently of the table when in the second position. Before the scanning process, suitable ambient conditions were provided and appropriate lighting equipment was positioned for photographing (Figure 1b).



a) b)

Figure 1. a) Workflow of image-based 3D scan, b) System setup

In the first approach, 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. The table can 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 2a). If the photos aren't enough to show the top or bottom surfaces of the object, the camera should adjust at a different height and a new shot loop should be added to previous photos.

In the second approach, the object stand was in the second position and the object placed on the stand was stationary regardless of the rotating part of the table. In this approach the camera was placed on the table and turns with the table. The table was rotated to adjust the angle of the camera and shooting operations were performed (Figure 2b).

PhotoScan software of AgiSoft and ReCap Photo software of Autodesk were used in 3D scanning process. Cannon EOS 550D camera and 18-135 mm lens were used for photographing.

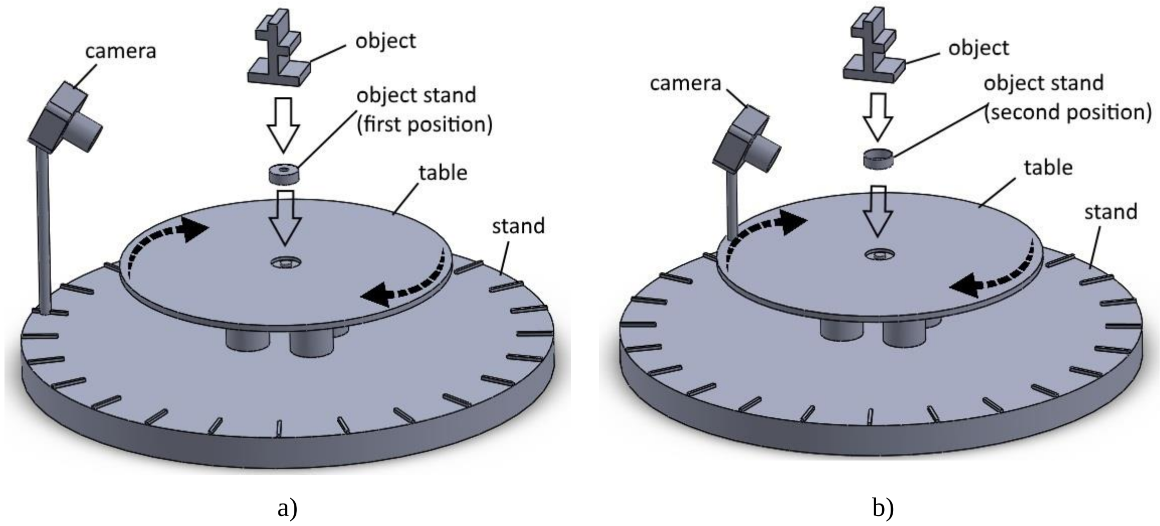


Figure 2. a) First approach, b) Second approach

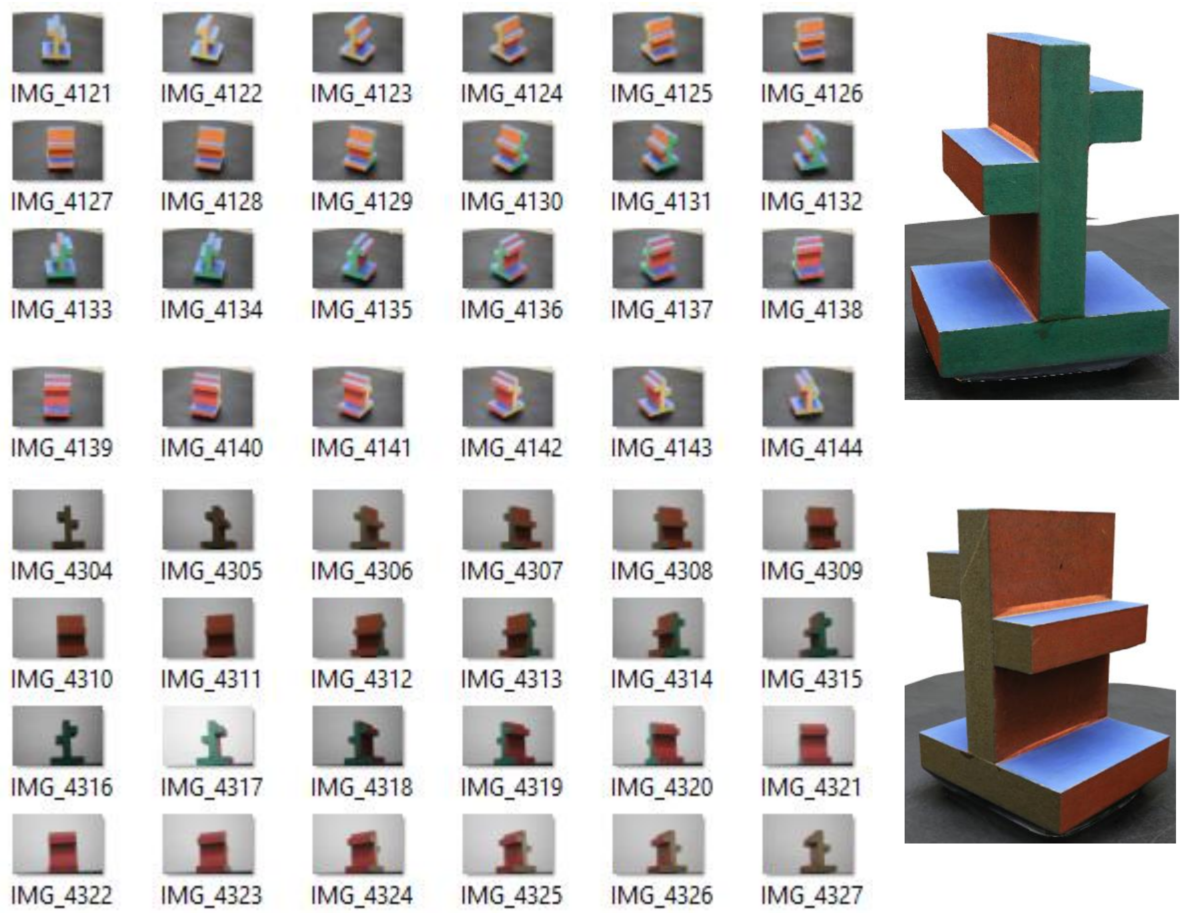
Results and Discussion

The 3D photo-scan process for both approaches was successfully completed and 3D models were obtained. For each scan, 24 photos were taken and over 80% overlapping was provided. The photos were taken with the help of the fabricated mechanism and they were transferred to the 3D scan software.

As a result of the first scan operations, some surface defects caused by the shaded areas on the lower surfaces of the part were observed and therefore, 24 more photos taken at a different height were added to the scanning process. Agiosoft 3D PhotoScan software and ReCap Photo software were used for 3D photo scanning process. Agiosoft 3D PhotoScan which is a desktop software could be preferred in terms of detailed scan settings and scan speed. However, the software is very selective about photographic suitability. Therefore, the focus and lighting should be adjusted precisely during the image capture phase. ReCap Photo is a web based software. The scanning process using ReCap Photo software took a long time but satisfactory results were obtained (Figure 3). Moreover, ReCap Photo software was highly tolerant of accepting photos.

Considering the simplicity of process and the arrangement of the background and lighting, more satisfactory results were obtained in the scanning using the first approach. In the first approach, the camera angle was fixed and the object was rotated at certain angles to take photographs. Thus the background was unchanged, the illumination quality remained almost the same. In the second approach, the camera was rotated around the object while the object was stable. At each shot, the background changed constantly, and reflections or shadows from the objects in the background affected the quality of the photographs negatively.

The mechanism fabricated for the 3D scanning process facilitated shooting for both approaches and played an important role in avoiding shooting mistakes. However, it could be necessary to take free shots for fixed or heavy objects that cannot be placed on the platform. In this case, as in the second approach, the camera should turn around the fixed object.



a) b)

Figure 3. a) 48 photos taken at two different heights using the first approach, b) Digitized 3D model.

No post-processing was applied to the digitized 3D model in the study. Post-processing can be applied at the end of the scan. At this stage, some possible topological issues such as bulges, holes and damaged surfaces can be resolved by using a mesh-repairing software. However, if any error occurs during the scanning process, the operations should start over.

Conclusion

Two approaches were considered to implement the process efficiently in this study. A mechanism was fabricated to avoid errors due to operator and external factors, and 3D scanning operations were successfully accomplished through this mechanism. The mechanism was also very useful to ensure the same overlap ratio for each shot. The first approach, in which the camera, light and background are fixed, and the object rotates around its own axis, is more useful and reliable than the second approach.

Image-based 3D scanning process seems to be an effective method of digitizing 3D objects. This scanning method, also known as a close-range photogrammetry method, has some advantages such as low cost, suitability for outdoor use compared to other 3D scanning methods. Furthermore, in this method models can be created together with their texture and color properties which are important for some areas such as medical, forensic medicine, architectural, archaeology, video game and film animation.

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