A comparative study about some application packages used in Photogrammetry

D Nedelcu1,*, G-R Gillich1 and C Malin-Tatian1
1“Eftimie Murgu” University of Resita, “Traian Vuia” Square, No. 1-4, 320085, Resita, Romania
E-mail: d.nedelcu@uem.ro

Abstract. Photogrammetry is the technique used to convert a real geometry of a part into a 3D computer file starting from images. The paper aims to compare some free and commercial application packages used in Photogrammetry, based on the same images taken from an axial turbine blade. The blade geometry can be included in a bounding box with the following dimensions: 233 x 125 x 82 mm. The geometrical entities generated with these applications will be compared through Cloud Compare software.

1. Introduction
The reverse engineering technology based on Photogrammetry is utilized in the following particular fields: archaeology, cultural heritage, forensics, biology, full head and body scanning, topography and mapping, art and design, geology, ecology [1]. The mechanical field is not widely presented in literature in correlation with Photogrammetry. However we can illustrate some papers: reference [2], which compares the surface of a converter cone scanned by terrestrial laser-scanner and generated through the Photogrammetry technique; reference [3], where the reverse engineering technique is performed on an operational prototype of a Francis runner geometry using Agisoft Photoscan software; references [4] and [5], where the same reverse engineering technique is performed on a Kaplan blade runner Geometry through the Photogrammetry technique; references [6] and [7], where the Photogrammetry technique was applied to reconstruct the geometry of a scaled axial blade and Pelton bucket respectively. The images of the axial blade were captured with a high quality camera; a number of 78 photos were captured with a NIKON D610 camera; the mean ISO-value for each photo is 1600 by a shutter of 1/125, the resolution was 6016 x 4016 and the focal length 50 mm; one image of the blade is presented in figure 1. Around the blade calibrated scale bars and some other objects were placed to help application packages to recognize and reconstruct the blade geometry. The Agisoft Photoscan software [8] was selected to reconstruct the reference blade, which will be compared with the blade geometry reconstructed through the following application packages: 3DF Zephyr Free v4.302 [9], Regard3D v 0.9.5 [10], Visual SFM v 0.5.22 [11]. Currently, the Agisoft Photoscan was replaced by the Agisoft Metashape 1.5.0 software, but these tests were done with the Agisoft Photoscan software version 1.2.5. The Agisoft Metashape is a commercial software which can be bought for 179 $ for the standard edition and 3499 $ for the professional edition. But, from our point of view, the standard edition is enough for mechanical purposes. The other application packages are free and/or open source. To increase the precision of the reference blade a number of 78 images were used in the Agisoft Photoscan software; to reduce the computational time for the compared blades
only 40 images were selected. For all blades the points around the blade were removed to eliminate the negative influence on the comparison.

2. The reconstruction of the reference blade in Agisoft Photoscan software

The 3D reconstruction of the reference blade requires the following stages in Agisoft Photoscan software [8]: Acquire photos, Import Photos, The inspection of the images, Align Photos and build sparse cloud, Build Dense Cloud, Build Mesh, Build Texture, Scale the geometry, Export the geometry. Regarding the scale step a mention must be made: every reconstruction is generated with an arbitrary scale, translation and rotation, because photogrammetry is a scale-less method; the user must use external means to 'scale' the clouds (e.g. use the length of a known object visible in the clouds like a scale bar, etc.). Some photogrammetry application packages may provide tools or specific methods to properly scale their output clouds.

As a consequence, to compare the reference blade with the compared blades, the last one will be scaled - based on the L=228 mm dimension from figure 1 - and aligned with the first one in the CloudCompare software v 2.10.1 [12]; this dimension is used only for the scaling process; additionally, the dimensional differences between the reference and compared blades were computed in the CloudCompare software. These differences are calculated as multiple distances between the first and second mesh points of the two blades. The following parameters were operated to reconstruct the reference blade: 78 aligned cameras, figure 2, alignment parameters: (accuracy High, Key point limit: 120,000), sparse point cloud of 169,445 points, dense point cloud of 1,941,616 points.

The reconstructed geometry of the reference blade was exported as a .obj file and is identified in this paper as Blade 1.

3. The reconstruction of the compared blade in 3DF Zephyr Free software

The 3DF Zephyr free edition is free for personal use, is available for learning because it’s not time limited in any way, can operate as a viewer to share the .zep files with the customers. The most significant limitation in the free edition is that up to 50 photos can be used. The following specifications were operated to reconstruct the reference blade: 27 aligned cameras, figure 3, out of 40 images, sparse point cloud of 11,850 points, dense point cloud of 539,736 points, the mesh with 50,988 triangles and 25,502 points, textured mesh with 50,988 triangles and 28,041 points. The reconstructed geometry of the compared blade was exported as a .obj file and is identified in this paper as Blade 2.

4. The reconstruction of the compared blade in Regard3D software

Regard3D is a free and open source structure from motion software. It converts photos of an object, taken from various angles, into a 3D model of this object. The 3D reconstruction of the reference blade demands the following stages in Regard 3D: Create new project, Add Picture Set (40 images),
Compute matches (23 aligned cameras out of 40 images), Triangulate (11,066 points), Densification (679,158 points), Surface generation. The reconstructed geometry of the compared blade was exported as a .ply file and is identified in this paper as **Blade 3**.

5. **The reconstruction of the compared blade in Visual SFM software**
Visual SFM is a GUI application software for 3D reconstruction using the structure from motion (SFM), which is free for personal, non-profit or academic use. The 3D reconstruction of the reference blade demands the following stages in Visual SFM: Add the images into your SfM Workspace (40 images), Run feature detection & full pairwise image matching, Run sparse reconstruction, Dense reconstruction, Save the SfM workspace including 3D reconstruction. The reconstructed geometry of the compared blade was exported as a .ply file with 677,319 vertices and is identified in this paper as **Blade 4**.

6. **The comparison between Blade 1 and Blade 2**
The comparison between **Blade 1** and **Blade 2** was made in the CloudCompare software by following the next steps:

- import the two .obj files of the **Blade 2** into CloudCompare; furthermore, **Blade 2** must be scaled and aligned with **Blade 1**;
- use the **Tools  Point picking** tool from the menu and select two vertices on **Blade 2** similar with point 1 and 2 from figure 1; a line between vertices will appear and CloudCompare will display the length of the line L;
- compute the scaling factor \( S_f = \frac{L}{L_1} = \frac{228}{L_1} \); select **Blade 2** and apply this scaling factor with the **Edit  Multiply / Scale** tool (use the \( S_f \) factor for all dimensions);
- select **Blade 1** and then **Blade 2**, in that order;
- select **Tools  Registration  Match bounding-box centers** from the menu; this tool will translate all selected entities so that their bounding-box centers are in the same place; the first selected entity will be used as reference; the other will be translated so that his bounding-box center comes at the same place as the center of the first entity; after these stages the two blades positions are presented in figure 4;
- again select **Blade 1** and then **Blade 2**, in that order;
- select **Tools  Registration  Match scales** from the menu; this tool will (try to) make the scales of all selected entities match; in the superior part of the command window the user can choose which entity will be the 'reference' (i.e. all others will be scaled so as to match this one); this operation will scale **Blade 2** more precisely comparing with the previous **Edit  Multiply / Scale** command;

![Figure 3](image3.jpg) **Figure 3.** The 27 aligned cameras out of 40 images in the 3DF Zephyr software.

![Figure 4](image4.jpg) **Figure 4.** **Blade 1** and **Blade 2** after Match bounding-box centers and Match scales stages.
again select Blade 1 and then Blade 2, in that order;
select Tools ⇒ Registration ⇒ Align (point pairs picking) from the menu; this tool lets the user align two entities by picking at least three equivalent point pairs in both entities; this method is very useful to align clouds quite precisely; then the user must specify (with the classical 'role' assignment dialog) which cloud will be the Reference (fixed) and which one will be the aligned cloud (the one actually moving at the end); in our case the Reference was Blade 1 and 4 points were selected in the same order for Blade 1 and Blade 2, figure 5 and figure 6;
again select Blade 1 and then Blade 2, in that order;
the last operation is Tools ⇒ Registration ⇒ Fine registration (ICP); ICP comes from Iterative Closest Point algorithm; this tool can automatically finely register two entities based on two parameters that can be defined (RMS difference= 1.0e-5 and Final overlap=100%;

Figure 5. The 4 points selected on Blade 1. Figure 6. The 4 points selected on Blade 2.

- now the distances between the two entities (Blade 1 and Blade 2) can be computed;
- select both of them and choose the appropriate distance calculation tool:
  - for cloud/cloud comparison, use the Tools ⇒ Distances ⇒ Cloud/Cloud dist. (cloud-to-cloud distance) tool; the default way to compute distances between two point clouds is the “nearest neighbor distance”: for each point of the compared cloud, CloudCompare searches the nearest point in the reference cloud and computes their (Euclidean) distance;
  - for cloud/model comparison, use the Tools ⇒ Distances ⇒ Cloud/Mesh dist. (cloud-to-mesh distance) tool; in this mode, for each point of the compared cloud CloudCompare will simply search the nearest triangle in the reference mesh;
- once the calculation is done, the color scale can be adjusted in the Properties of the compared entity so as to display the results in a better way, figure 7; the domain of the deviations is defined between -0.560 ÷ +0.667 mm.

7. The comparison between Blade 1 and Blade 3
The comparison between Blade 1 and Blade 3 was made using the CloudCompare software following the same steps like in the & 6. The color scale is presented in figure 8; the domain of the deviations is defined between -1.465 ÷ +1.855 mm.

8. The comparison between Blade 1 and Blade 4
The comparison between Blade 1 and Blade 4 was made using the CloudCompare software following the same steps like in the & 6. The color scale is presented in figure 9; the domain of the deviations is defined between -0.768 ÷ +1.002 mm.
Figure 7. Color scale for the distances between Blade 1 and Blade 2.

Figure 8. Color scale for the distances between Blade 1 and Blade 3.

Figure 9. Color scale for the distances between Blade 1 and Blade 4.
9. Conclusions

Blade 1 and Blade 2 were completely reconstructed, while Blade 3 and Blade 4 were reconstructed with holes in the middle area of the blade suction side. Regarding the numerical comparison between Blade 1 and others blades, expressed through the domain of the deviations, the best values are obtained for Blade 2 (3DF Zephyr Free) with \(-0.560 \div +0.667\) mm, followed by Blade 4 (Visual SFM) with \(-0.768 \div +1.002\) mm and by Blade 3 (Regard3D) with \(-1.465 \div +1.855\) mm. By comparing with the blade maximum dimension of \(L=228\) mm, the domain of the deviations seems to be too large. As a consequence, the following mention must be made: for all free and/or open source application packages (3DF Zephyr Free, Regard3D, Visual SFM), the point clouds of the blade were generated based on the default values of the parameters used in reconstruction. Of course using high values of these parameters can improve the point clouds quality and reduce the domain of deviations. In addition, the number of images used by the Agisoft Photoscan software was 78, while in the others application packages only 40 images were utilized to reduce the computational time. On the market there are others Photogrammetry application packages free or paid (PhotoModeler, RealityCapture, Pix4Dmapper, Autodesk 123D Catch, Colmap, Context Capture, SOCET SET, …) but the length of the paper is limited and we cannot include all in our study. This is the reason why the authors included only four application packages in the paper. Utilizing CloudCompare software, a procedure to scale, align and a dimensional comparison of two point clouds was proposed and applied on a mechanical component like an axial blade. The logical steps were consecutively presented in the &6. This procedure represents the significant contribution of the paper and it can be applied to compare the geometry of two similar objects with the same or different scale.

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