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Comparison of Photgrammetric Techniques for Surface Reconstruction from Images to Reconstruction from Laser Scanning

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Abstract: The techniques of photogrammetric reconstruction were compared to the laser scanning in the article. The different conditions and constraints were introduced for reconstructed images, e.g. different materials, lighting condition, camera resolution, number of images in the sequence or using a-pripori calibration. The authors compare the results of surface reconstruction using software tools avaliable for photogrammetric reconstruction. The analysis is preformed for the selected objects with regard to laser-scanned models or mathematical models.

Keywords: photogrammmetric 3D reconstruction, laser scanning, mesh comparison

1. Introduction

Laser scanning has historically been in common use for scanning small objects in a controlled environment, where there is a possibility of scanning the whole object from different viewpoints to obtain complete surface representation. This is due to the fact that 3D scanners often have a small field of view and larger objects often have to be scanned in several iterations and then combined together in order to reproduce and complete the model [4, 11]. However, there are some particular devices such as LIDARs that are in fact laser scanners optimized for capturing large geographic areas and similar scenarios. On the other hand, photogrammetry offers methods that have mostly been used for scanning large-scale areas, such as air photography, cartography, mapping of archaeological sites and other situations with large objects, when there is no need to capture small details, but rather focus on extracting measurements, etc. Nowadays, photogrammetry is rapidly becoming more and more common, for reconstructing high detailed 3D models. Previously it was used in combination with laser scans as a compliment to provide accurate textures for the 3D surface model that were generated by laser scanning.

Attempts to reconstruct digital 3D models with the help of photogrammetry were already done in 1984 [3] and there are even some cases where the results of reconstructions have been compared to laser scanning techniques [2, 7]. However most of them are, as mentioned earlier, focused on archaeological, architectural or geo-data scenarios where the objects are usually very large in scale. In the article we focused on the smaller objects, up to 1 cubic meter, and as some earlier research suggests [2] this area might be where it gets more challenging for photogrammetric reconstruction of models.

Scanning is the three-dimensional measurement process, usually using different optical devices and measuring principles. Generally, most 3D scanners use the photography to reconstruct depth of the analyzed scene. As far as single image is insufficient the additional information has to be included. For example the knowledge of laser line position or structural light together with the image enables the measurement of 3D shape using triangulation methods, calibrated systems with solved correspondence yields the 3D reconstruction of a scene, recently photogrammetric methods enables reconstruction for any sequence of images taken from uncalibrated cameras from different viewpoints of unknown positions. As far as different reconstruction techniques are used different kinds of artifacts are supposed to appear during the measurement. That is the main reason why there is no standard reference which could be used to calibrate different kind of scanners.

Different techniques additionally impose different requirements on the scanning scene. While for laser scanning the measurement is based on the deformation of laser line on the scanning surface and texture changes are sources of noise, in photogrammetric systems texture changes are clue factors for establishing the correspondence.

Another important difference between laser scanning and photogrammetric technique is that laser scanning yields partial results from different viewpoints which accuracy is defined by the manufacturer, but overall process of reconstruction requires additional registering and merging partial scans into final model. In photogrammetric technique this registration is performed at the early stage of processing during finding the correspondence between sequence of images.

Therefore the aim of the work is to compare the overall process of reconstructing of the final model on a scene for both reconstruction techniques.

2. Photogrammetric reconstruction

The core principle for photogrammetry is triangulation. Several photographs (at least two or more) with overlapping information is used to design *rays*. According to them the distance from the camera position to the object coordinates can be calculated. In photogrammetry the difference in the XY-plane is used to triangulate the measured point. Furthermore photogrammetry applies this principle to multiple points at a time.

The transition from physical object to digital 3D model can be done using both 3D laser scanning or photogrammetric approach. However, in particular, photogrammetry data consists of 2D input in form of photographs, thus we have to convert a sequence of images into spatial representation. One can say that photogrammetry is the reversed process of photography, but, unfortunately, the photographic process looses the information about the 3rd dimension. So, to compensate for this missing information several photographs (absolute minimum of two) have to be used to obtain the reasonable results. As a final result of photogrammetry we obtain a point cloud or reconstructed mesh.

Several parameters should be given and adjusted for best results from the input images. First one is the focus of the camera, since photogrammetry uses pixel for points in triangulation, blurry images outsite the object are very tricky for pinpointing the position of features and other elements that are out of focus. Furthermore, the resolution is a very important parameter as the reconstruction proces requires matching many characteristic points extracted from raster images. Consistent lightning is also a factor that helps photogrammetry in identifying various elements in the photograph. Varying light casts different shadows from picture to picture and this can have a destructive effect, as the same feature can have varying intensity and color depending on the image analyzed at the moment.

2.1. Photo environment setup and camera parameters

The data acquisition environment was set up in a home setting with stable lightning conditions. We used uniform ambient light and one spot light source placed near the camera viewing position. A tripod was used to aid the stability and positioning of the camera. The rotary table was used to uniformly distribute the observation points. The focus of the camera was set for the same value for the whole sequence to ensure the repeatability of measurements. We also tested the quality of reconstruction under varying conditionsof focus, lighting and resolution

The tests were performed using several cameras: (1) Canon EOS 300D – 3072×2048, (2) SONY DSC-HX20V – 4896×3672 and 1920×1080 (full HD sequences), (3) Smartphone SONY Z1 – 5249×2952. The focus was set individually for each image seguence. Depending on the lightning conditions registered by the camera different shutter speeds were adjusted automatically. The pictures were saved digitally in *JPG* format or as *MP4* sequence of FullHD images.

2.2. Stages of Photometric Reconstruction

The article exploits 3D reconstruction scheme proposed in [8] expressed in the following stages: (1) searching for patches for multi-view images and reconstruction of spatially oriented sets of points (patches) covering the surface of the object or scene; (2)

conversion of patches to a polygon mesh; (3) improving the resulting mesh.

The term *patch* p was used in the discussion. It means a local estimation of tangent plane to the surface of the object. Formally, it can be expressed as a central point $c(p)$ with the assigned unit vector normal $n(p)$ directed to the camera position. A special reference image $R(p)$ attached th the patch p.

Matching of points among images is realized by calculating the value of special *function of photometric discrepancy* [8]:

$$g(p) = \frac{1}{|V(p)\backslash R(p)|} \sum_{I \in V(p)\backslash R(p)} h(p, I, R(p)) \tag{1}$$

where: $V(p)$ – set of images where the patch p is visible; $V(p)\backslash R(p)$ – the selection of images without the considered image $R(p)$; $h(p, I_1, I_2)$ – photometric discrepancy between images I_1 i I_2.

The function h is calculated in the following steps: (1) the imposition of grid $\mu \times \mu$ on p, (2) sampling pixel colors $q(p, I_i)$ by bilinear interpolation at image projections of all the points of the grid in each image I_i, (3) calculation the value of one minus the result of the normalized cross-correlation between $q(p, I_1)$ and $q(p, I_2)$.

Another examples of photometric discrepancy functions were introduced in [16].

Further stages of reconstruction are focused on converting surfel model to mesh representation. The traditional triangulation routine is not sufficient to reconstruct such data since we have additional info about the orientation of each point. We can treat it as Poisson surface and convert using a special algorithm to the mesh representation. The suitable algorithm was described in [10] and implemented in MeshLab Software Tool.

The last stage of the reconstruction is mesh refinement. We can use the iterative minimization of energy functions[8]: (1) geometric smoothness energy $E_s(\mathbf{v}_i)$ containing local Laplacian operator Δ in position $\mathbf{v}_i$

$$E_s(\mathbf{v}_i) = |\zeta_1 \Delta^2 v_i - \zeta_2 \Delta \mathbf{v}_i|^2 / \tau^2, \tag{2}$$

where: τ is average edge length and ζ_1, ζ_2 are experimentally chosen constants, and (2) consistency energy of the reconstructed patches $E_c(\mathbf{v}_i)$

$$E_c(\mathbf{v}_i) = \max\left(-\epsilon, \min\left(\epsilon, \frac{d(\mathbf{v}_i) \cdot \mathbf{n}(\mathbf{v}_i)}{\tau}\right)\right)^2, \tag{3}$$

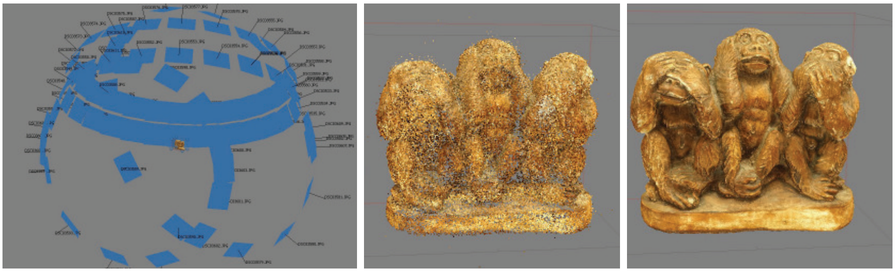
$$d(\mathbf{v_i}) = \sum_{p \in \Pi(\mathbf{v}_i)} w(\mathbf{p}) \left[\mathbf{n}(\mathbf{v}_i) \cdot (\mathbf{c}(p) - \mathbf{v}_i)\right] \tag{4}$$

where: $\mathbf{n}(\mathbf{v}_i)$ is unit normal at $\mathbf{v}_i$, ϵ – the assumed energy limit, $d(\mathbf{v}_i)$ – a signed distance between $(\mathbf{v}_i)$ and reconstructed patches along $\mathbf{n}(\mathbf{v}_i)$, $\mathbf{c}(\mathbf{v}_i)$ – a patch center, $\Pi(\mathbf{v}_i$ – set of patches closest to $\mathbf{v}_i$, $w(\mathbf{p})$ – gaussian function of the distance between $\mathbf{c}(p)$ and the line of standard deviation ρ for relevant image pixels.

In our approach we additionally compare the influence of mesh refinement on the reference model.

2.3. Software tools for reconstruction

The PhotoScan software [1] was used to reconstruct the 3D surface model in most cases.We also tried another techniques of reconstruction such as 123DCatch.



a) b) c)

Fig. 1: Photogrammetric reconstruction of surface model: a) layout of observation points, b) rough point cloud, c) mesh of surface model.

The procedure of photograph processing and 3D model construction using PhotoScan software consists of the four stages described below.

Camera alignment. The software searches for common points in the collection of photographs. To be able to match them, the position and orientation of the camera is calculated for each picture (see fig. 1a). The result of this process is a sparse point cloud where a number of points have been identified and matched over the different camera positions (see fig. 1b). The sparse data is used further in the process of reconstruction. It is based on the set of camera positions gathered in this stage.

Dense point cloud. The generation of a dense point cloud is done with the help of the estimated sparse cloud representation and the respective matching photographs. The point interpolation is processed in this stage to generate a dense point cloud with the help of the initially calculated camera positions.

Mesh construction. The third stage consists of constructing a 3D polygonal mesh representing the object surface based on the dense point cloud (see fig. 1c). We can treat the resulting mesh as a height field, which is used for terrains or aerial photographs. The second way form is a general mesh used for closed objects, statues, buildings, etc. The second form requires higher memory consumption and more complicated processing methods. This method is used in our case.

Mesh optimization and texturing. Once the mesh is constructed, the user has the ability to edit it. Non-complex corrections such as mesh decimation (simplification), removal of detached components or closing of holes can automatically be performed by the software in the mesh generation process. Furthermore, the final stage of the model construction is the application of textures.

3. 3D Reconstruction Using Laser Scanning

High precision of laser scanning techniques made us use it as reference facility with determinated measurement error [12]. We used Konica-Minolta VI-9i to obtain reference surface models for testing the accuracy of photogrammetric models.

Konica-Minolta VI-9i is a triangulating laser scanner consists of two components: a laser transmitter and a CCD receiver. The transmitter consists of a laser diode producing a stripe of light which is projected onto the object. The receiver is a CCD sensor, which detects the reflection and due to displacements in the object the angle of reflection varies depending on form and distance. The measured displacements make it posible to obtain the spatial points coordinates basing on the principle of triangulation. This measurement is repeated many of times for different stripe position to generate a dense mesh representing the surface of the object.

The Vivid VI-9i used for measurements is decicated for small to medium sized objects which can be captured with high detail thanks to three exchangable lenses: TELE with $f = 25mm$, MIDDLE with $f = 14mm$, WIDE with $f = 8mm$.

Model reconstruction from laser scans. Measurements are aquired as partial representations of the object with overlapping area. This process was completed with help of rotary stage that ensured the rough registration and the coverage of the whole object. The overlapping area is required to perform the automatic positioning (aligning) of 3D scans and register the complete object data.

This was achieved by aligning each individual piece in respect to the others [13, 14] and then merging them into a single shape to construct a 3D model [15]. In fact we used the efficient software tools such as RapidForm, Geomagic or Meshlab to perform the processes of mesh aligning and merging.

4. Comparison of the Reconstructed Objects

We treat the laser-scanned surface models as the reference surface for the comparison, the other surfaces reconstructed with help of the photogrammetric applications are given as test surfaces. We measured the distance between reference and test surfaces and then compare them with regard to mean square error, error deviation and percentage of surface coverage.

4.1. The choice of the reconstructed objects

Both laser scanning and photogrammetric techniques have its preferences with regard to the maesured object. The object have to fulfill certain conditions, concerning its shape, shining, colors, to perform the precise reconstruction.

It is worth to notice that black or deeply dark materials are hardly recognizable for laser scanner. Colorful materials can be measured with different distance for each material even if scanning area is completely flat. Shining or blinking elements are also difficult to scan due to nondeterministic artefacts appearing on the scanned surface.

On the other hand photogrammetric methods are very sensitive for changing of colors and lighting. Objects of uniform color are very hard or even impossible to reconstruct. When the surface of the object has a complex pattern the results of reconstruction are much better.

We also chose some objects and made a comparison of their reconstruction with regard to laser-scanned model or mathematical models.

Photogrammetry methods are nondeterministic and highly dependent on input data. Intuitively, good quality reconstruction characterizes in maximum preservation of unaltered visual information. Visual dependencies in particular data sets are very important, so the source images should be of the best possible quality. In most cases it is better to omit a blurry or highly shaded photographs rather than put it in a sequence of better quality images. Such images simply only introduce the noisy unwanted data into the aggregated spatial tied points.

4.2. Quadric-based accuracy analysis

Scanners are considered as measuring devices. Comparison of different measuring devices requires not only the comparative analysis of techniques used and working conditions, but also making confrontation of the achieved measurements of physical object regarded as reference. Accuracy is the degree of agreement between a measurement and the conventional true value of the object being measured [9].

The main idea of quadric-based analysis was to compare the reconstructions of objects described by the implicit function. We assume that known model of the physical object as the ground trouth that could be used as a reference. We designed models of quadrics and printed them on 3D printer in FDM technology. Then models were painted using unstructurized patterns to ensure the proper correspondence. The following examplary quadrics were analysed (see fig. 4.2.).

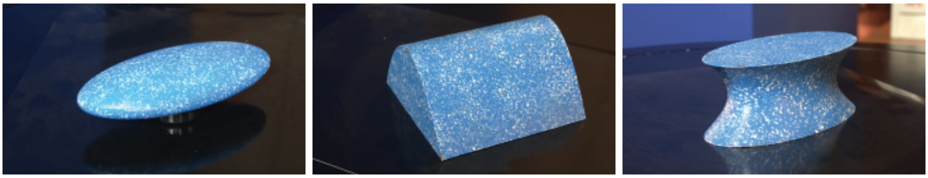


Fig. 2. The considered quadrics

The quadrics are defined with the implicit functions:

for ellipsoid: $$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} - 1 = 0,$$

for parabolic cylider: $$\frac{x^2}{a^2} + z = 0,$$

for hyperboloid of one sheet: $$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} - 1 = 0,$$

CAD model of surface was prepared for each quadric. Additional arbitrary planes were used to constrain quadrics and to enable establishing of water–tight model, that is printable on the 3D printer. In fact we measured the accuracy of both processes of scanning and printing.

4.2.1. Technique of acuuracy measurement

For ellipsoid in order to measure accuracy of printing and scanning processes two approaches were applied:

- using distance from measured points to the ellipsoid given by implicit mathematical function,
- using distance from measured points to the model of ellipsoid defined as the triangular mesh.

The distance of the point $P_0 = [x_0, y_0, z_0]$ to a surface $G(x, y, z)$ can be regarded as the shortest distance form the point to the surface measured along normal to the surface. This assumption allows to find the distance as the solution of the following set of equations:

$$G(x, y, z) = \frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} - 1 = 0, \quad (5)$$

$$\begin{bmatrix} x_0 \\ y_0 \\ z_0 \end{bmatrix} - \begin{bmatrix} x \\ y \\ z \end{bmatrix} = t\frac{\nabla G(x, y, z)}{2} \tag{6}$$

where normal to the ellipsoid is the half of the gradient $\nabla G(x, y, z)$ [6], $P = [x, y, z]$ point of the ellipsoid the nearest to P_0.

$$x0 = x\left(1 + \frac{t}{a^2}\right) \qquad y0 = y\left(1 + \frac{t}{b^2}\right) \qquad z0 = z\left(1 + \frac{t}{c^2}\right) \tag{7}$$

$$\begin{aligned} F(t) \quad = \quad & a^4x_0^2\left(b^2+t\right)^2\left(c^2+t\right)^2 + b^4y_0^2\left(a^2+t\right)^2\left(c^2+t\right)^2 \\ & +c^4z_0^2\left(a^2+t\right)^2\left(b^2+t\right)^2 - \left(a^2+t\right)^2\left(b^2+t\right)^2\left(c^2+t\right)^2 = 0 \end{aligned} \tag{8}$$

The polynomial of degree 6 of parameter t was received, which was solved by matlab code. For each real root of the equation the point on the ellipsoid was found from the equation 7. The point the nearest to $P0$ was the solution. The procedure was repeated for each reconstructed point, the average of shortest distances was a measure of accuracy.

Laser scanner accuracy analysis

Each primitive was scanned using Konica Minolta VI-9i laser scanner using a rotaty table. Scans were taken from a number of viewpoint, using different scanning options: single scan option or average of three times scanning (with different laser power). Two registration strategies were applied: in the first all scans were registered using the overlapped regions of particular scans and next compared to the model, in the second the model was used in the registration process.

Table 1. Accuracy results for single scanning [mm]

	ellipsoid	paraboloic cylinder	hyperboloid
average dist (reg. without model)	0.117	0.274	0.315
after merging	0.147	0.366	0.332
average dist (reg. using model)	0.094	0.127	0.142
after merging	0.125	0.151	0.199

Conclusions

The best accuracy, closest to the nominal accuracy of $0.050mm$, given by the manufacturer is achieved using three times scanning. In this mode scanning are performed

Table 2. Accuracy results for three times scanning [mm]

	ellipsoid	paraboloic cylinder	hyperboloid
average dist (reg. without model)	0.075	0.092	0.165
after merging	0.124	0.113	0.195
average dist. (reg. using model)	0.054	0.073	0.1
after merging	0.081	0.088	0.1

with three different laser energy and then is averaged. In the single scan mode the accuracy is about two times worse.

The accuracy depends on the inclination of the surface normals relativeto the central beam of the scanner camera. Therefore, it depends on the position of the model and pecentage of surface faces with obtuse angles between their normals and center beam of camera. The best accuracy can be acchieved for ellipsoid.

Accuracy highly depends on the registration process. When registration is perfomed using only the overlapping surfaces of scans from neighbour viewpoints the accuracy is lower then in registration proces using the model of a quadric.

The final accuracy depends on the registration. Additionaly megring process decreases the overall accuracy.

4.2.2. Photogrammetric reconstruction accuracy

Due to the fact that the photogrammetric reconstruction consists of several stages, the estimation of the accuracy of the reconstruction should be performed for each stage. A major problem during accuracy estimation is that reconstruction using uncalibrated images is carried out in an unknown scale - only known are relative proportions of the objects of the reconstructed scene. Therefore the estimation of the scale is done using modified ICP algorithm. The estimated transformation matrix is then applied to the results of all stages of reconstruction. Reconstructed scene contains of analyzed the reference object and other elements of the scene, the location of which can be fixed or can change due to the rotation of the turntable.

Conclusions

Number of images (angular distance between viewpoints) influences on the accuracy of the reconstruction. So called "Tie Points" - the 3D recosntructions of first estimation of corresponding points are the bases for the further reconstruction - generation of dense point cloud and mesh reconstruction process. There exist the extrema for the accuracy for Tie points estimation, which enables approximation of the optimal number of viewpoints.

Table 3. Accuracy results for tie points estimation [mm]

	2°	(3.5 – 5)°	(9 – 10)°	(18 – 20)°	(26 – 30)°
ellipsoid: number of points	25165	25860	14226	5554	2310
average dist.	0.115	0.097	0.074	0.065	0.122
paraboloic cylinder: nb of points	43838	43490	21888	12883	6809
average dist.	0.122	0.087	0.082	0.165	0.178
hyperboloid number of points	40611	27320	12822	4445	2761
average dist.	0.146	0.123	0.123	0.171	0.27

Table 4. Overall accuracy [mm]

	2°	(3.5 – 5)°	(9 – 10)°	(18 – 20)°	(26 – 30)°
ellipsoid: number of points	55432	57095	59266	59031	56864
average dist.	0.069	0.072	0.073	0.076	0.105
paraboloic cylinder: nb of points	71278	72438	86178	81682	86873
average dist.	0.060	0.059	0.059	0.088	0.087
hyperboloid	45455	44960	42250	41036	65519
average dist.	0.100	0.109	0.116	0.153	0.273

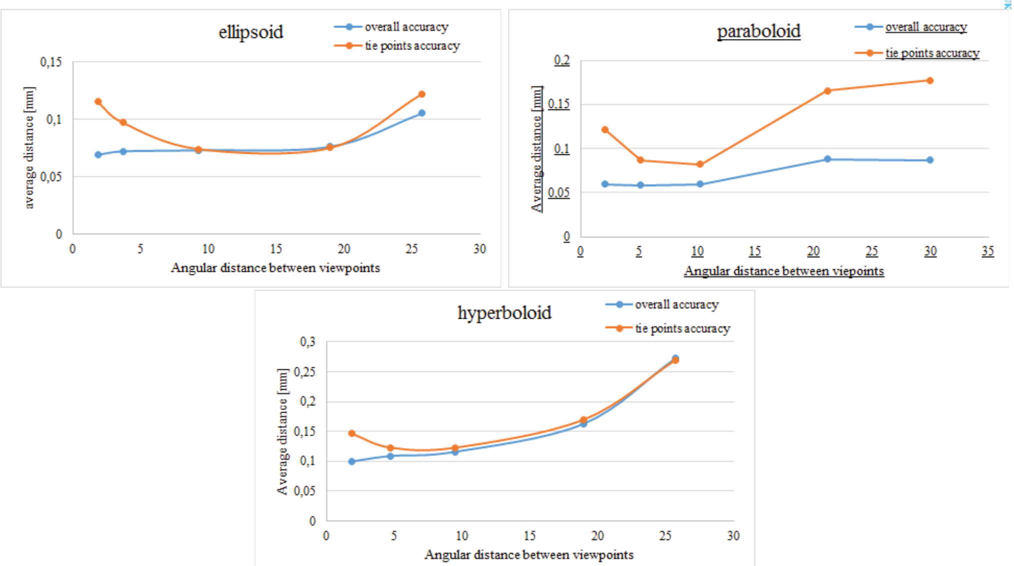


Fig. 3. Accuracy of reconstruction of quadrics

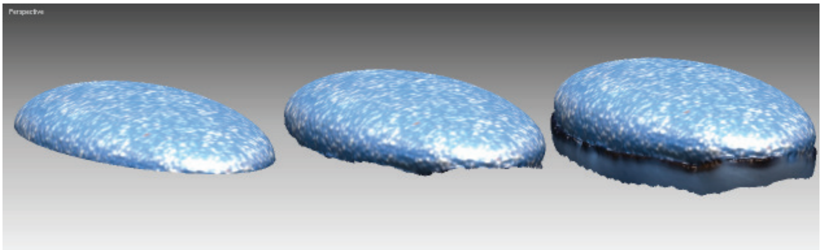


Fig. 4. Reconstructions for different artifacts levels

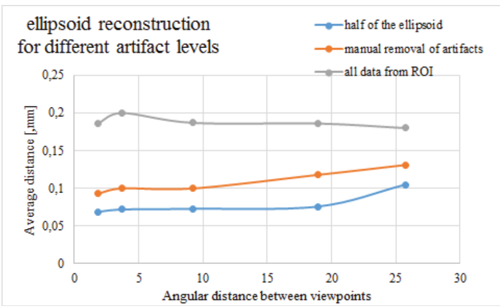


Fig. 5. Accuracy for different artifacts levels

Accuracy of overall recosntruction is slightly better then tie points accuracy. It is a result of filtering and smoothing appled during mesh generation of dence point cloud and meshh recontruction.

As in the analysis of laser scans accuracy depends on the inclination of local surface normals to imaging device.

Disadvantage of photogrammetric reconstruction is the necessity of manual removal of artifacts, the accuracy highly depends on the degree of removed artifacts.

4.3. Optimization of reconstruction method

A number of criteria were considered for image properties of photogrammetric reconstruction: image resolution, number and distribution of images in a squence, quality of lenses, camera calibration, lighting conditions, reflectance of materials, etc. We compared the selected surface models to the reference objects obtained using laser scanning.

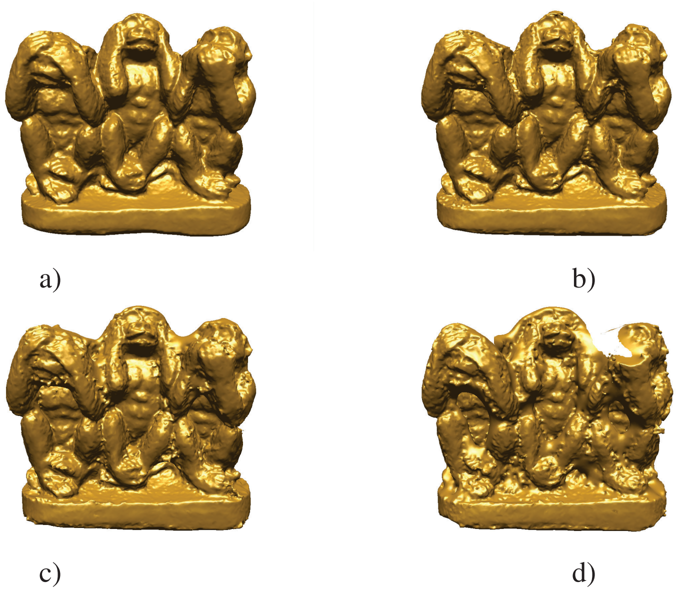
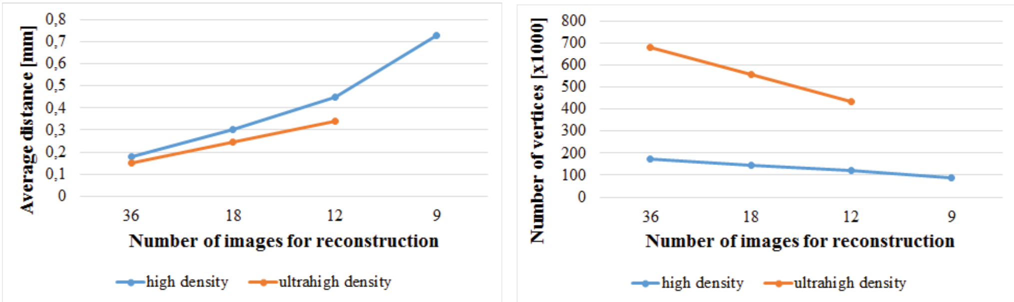


Fig. 6: Influence of image quantity on reconstruction quality: a) reconstruction from 36 images (angle distance 10°), b) reconstruction from 18 images (angle distance 20°), c) reconstruction from 32 images (angle distance 30°), d) reconstruction from 9 images (angle distance 40°).

We tested the influence of the number of images in the sequence on the quality of photogrammetric reconstruction (fig. 6). Tests were carried out for two given interpolation densities of the output dense point clouds: high and ultra high. The average distance was counted for each reconstruction with respect to the reference model from laser scanning (fig. 7a).

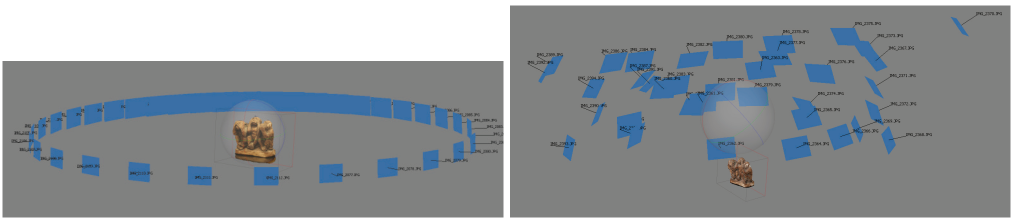
We also checked the influence of the number of images in the reconstruction sequence on the number of vertices in the model for high and ultrahigh density (fig. 7b). It is visible that the quality of reconstruction is better when the number of images grows, but the quality does not grow in linear way. When we multiply the sequence quality the average matching error grows slightly. Moreover, if the number of images for reconstruction exceeds a certian value the measurement data becomes so redundant that the quality of matching can even decrease. And that was shown in previous experiments on prymitives.



a) b)

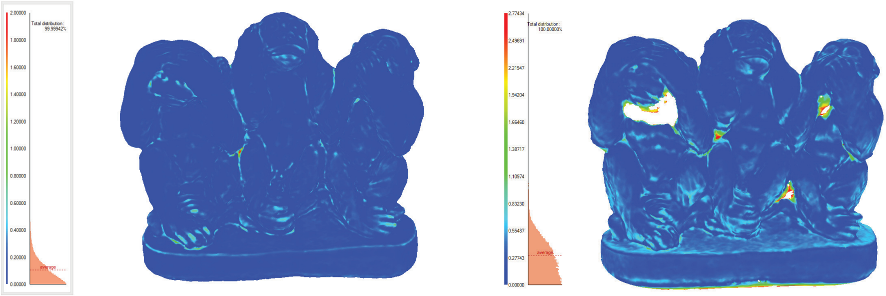
Fig. 7: a) Influence of the number of images in the sequence on the quality of photogrammetric reconstruction, b) influence of the number of images in the sequence on the number of reconstructed vertices.

We checked the influence of regularities in image acquisition on reconstruction quality. We considered two strategies of image acquisition (see fig. 8): (a) from fixes points using rotary stage and (b) taken free-hand. In both cases we used Canon 300D camera. The images were of 3072×2048 resolution. In fig. 9 the comparison to the reference laser scan was shown. The average deviation equals 0.11 for regular reconstruction (a) and 0.29 for free-hand reconstruction (b). Even if there was the same number of matched images (36 items) the model coverage is better for regular acquisition.



a) b)

Fig. 8. Strategies of image acquisition for reconstruction: a) fixed positions with rotary stage, b) free-hand acquisition.



a) b)

Fig. 9: Influence of image layout on reconstruction quality: a) fixed positions with rotary stage, b) free-hand acquisition.

Also, we show the influence of raster size and camera type for sequences from different cameras (fig. 10). We compared the reconstructions from images taken by four cameras. The quality of reconstruction mainly depends on camera optics. In figure 11 show two contradictory cases: first Canon 300D where average deviation is less than $0.11mm$ (), the comparable result was obtained for camera Sony HX20V – $0.1mm$ and the worst case for smartphone camera where the average deviation reaches $1.86mm$.

a) b) c)

Fig. 10. Source images for reconstruction: a) Sony HX20V, b) Canon 300D, c) smartphone SonyZ1.

5. Summary

Photogrammetric reconstruction quality varies considerably depending on the properties of the material used and the environment. In some cases we obtained the surface model almost identical to the reference model. The best results were achieved for images taken in stable light conditions with object covered distinguishable pattern and photographed on rotary stage evenly distributed observation points at an angle of at least $20°$.

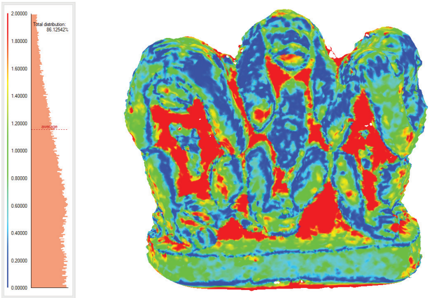


Fig. 11. Influence of the camera type on reconstruction quality – smartphone SonyZ1.

The important thing is scale correction, as the preliminary surface models do not have the scale factor fixed. The best way to resolve that drawback is putting the reference object with known dimensions into the scene. The second way is matching the scale of the object to the reference one. This can be done by the modified registration procedure using ICP optimizing scale parameter as well as translation and rotation. It means one additional parameter in optimization, as we treat scale s as isotropic scalar value.

It is fair to say that amateur photogrammetry can yield very good results when used for digital reconstruction of 3D objects. Although, as mentioned before the high quality results are not very consistent and requires some favorable conditions of both the acquisition process as well as the shape and features of the object surface. If these prerequisites are not matched the results in most cases are very underwhelming compared to those of a laser scanner. However, strictly numerically the results are not very far off and it is still debatable if the methods produce comparable results.

Acknowledgements

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Porównanie fotogrametrycznych technik rekonstrukcji powierzchni z obrazów do rekonstrukcji z wykorzystaniem skanera laserowego

Streszczenie

Skanowanie 3D jest procesem pomiarowym realizowanym przy użyciu urządzeń optycznych z wykorzystaniem różnorodnych metod pomiarowych. Do odwzorowania głębi analizowanej sceny skanery 3D wykorzystują najczęściej techniki fotograficzne. Jednakże pojedyncza fotografia jest w tym przypadku niewystarczająca, konieczne jest wykorzystanie dodatkowych informacji, np. wiedza o położeniu laserowego prążka w obrazie albo rozkład światła strukturalnego w połączeniu z analizą kształtu metodą triangulacyjną za pomocą skalibrowanego układu pomiarowego.

Ostatnio też do rekonstrukcji 3D wykorzystuje się nieskalibrowane obrazy pochodzące z różnych punktów obserwacji. Niestety przy zastosowaniu tych technik pojawia się szereg niedokładności pomiarowych przekładających się negatywnie na jakość wynikowego odwzorowania.

Dodatkowo różne techniki skanowania wprowadzają odmienne ograniczenia dotyczące uwarunkowań akwizycji. Przykładowo, skanowanie laserowe w skanerach triangulacyjnych wymaga dokładnego odwozrowania odbicia zniekształconego prążka promienia laserowego, natomiast w przypadku technik fotogrametrycznych istotna jest analiza różnorodności obserwowanej tekstury obiektu.

W artykule porównano fotogrametryczne techniki rekonstrukcji z technikami scanowania laserowego. Przenalizowano uwarunkowania i ograniczenia związane z akwizycją danych pomiarowych, takich jak: różnorodność wykorzystanych materiałów, warunki oświetleniowe, rozdzielczość kamery, liczba obrazów w sekwencji, wpływ kalibracji wstępnej. Autorzy dokonuja porównania zrekonstruowanych powierzchni wyselekcjonowanych obiektów w odniesieniu do zrekonstruowanych obiektów wzorcowych pozyskanych metodą skaningu laserowego wysokiej rozdzielczości, bądź do wzorcowych modeli matematycznych.