Report 04
OPTICAL SHAPE MEASUREMENT USING FRINGE PROJECTION METHOD

Team 1C

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Date of exercise [18-05-2023]
Date of report submission [01-06-2023]

Total score _____ **/ 5.0p.**

• Goal of the exercise

The purpose of this exercise is to familiarize students with optical methods of measuring the shape of three-dimensional objects. In the exercise the fringe projection and processing (by Mesh3D application) is used for measuring selected objects 3D shape.

• Lab run

1. Shape determination

1) Start the projector (carefully), start the Dell All-in-One computer assigned to the laboratory.
2) Start the Tempest3D program from the taskbar (icon: sun with a cloud, necessarily from the taskbar - do not search for this program on the desktop or in the START menu!)
3) If all items in the Tempest3D program are displayed in green - everything works. The projector should be turned on BEFORE starting the Tempest3D program.
4) Expand the Single Camera 3D Scanner - Actions - click on Measure. Turn off the light in the room.
5) Click Run Action and the measurement will be taken. Turn on the light in the room.
6) After the measurement is done, click Action: Open Working Directory - Run Action. This will open the folder with the measurements (the measurements are located in the subfolder Measurements - folder with the date of measurement). USB VGA Computer Mesh3D Calibration matrix 3DMADMAC system Projection system Detection system Measured object Optomechatronics - laboratory
7) Open the Mesh3D program from the taskbar. File - Import cloud of points - indicate the registered cloud.
8) If the measurement was not successful, correct the position of the object. If the measurement is registered correctly, rotate the test object by 20-30 degrees and repeat the measurement by registering the 2nd cloud. Note that two scans should have a common part of the object. Common part in two clouds of points is crucial for further merging of those clouds. The larger the common part of both clouds the higher the probability of correct merging operation.
9) Open Mesh3D application. Import both clouds of points.
10) From the menu choose [Cloud→Cloud properties]
11) Deactivate 1 of the clouds.

2. Measurements data processing

1) Set the distance between points in the cloud – resolution of acquired data: - chose from the menu [Cloud→Distance], - after distance dialog appear select to neighboring points (right mouse click), The resulting distance between the points will be used to pre-determine the parameters for cloud cleaning algorithms - it should be determined for points located in an area with parameters representative of the entire cloud.
2) The measurement data must be cleared from the measurement noise. For each of the clouds take the following steps (the order can be changed): delete groups, noise removal and discontinuity removal. These ranges of parameters for the proposed algorithms, the parameters must be chosen empirically. On their choice affects the profile shape of the object. The wrong choice of parameters may cause the removal of significant parts of the measured object- usually small details on the surface, which are treated as noise by the algorithm. If the selection of appropriate parameters for the automatic selection of noise points is

difficult, you must manually specify the points which are classified as noise - press [Alt] and then select the items using the right mouse button. Optomechatronics - laboratory All algorithms of Section 2 indicate the points that do not meet the criteria. The removal of these points is determined by the operator (you) by pressing the [Alt+Delete]. You can remove the selection with [alt+d]. You can also invert the selection of points [alt+i].

2.1 Remove the group of points separated from the main surface of the object:
- Select the [Cloud→Select groups] or click the toolbar icon.
- in the box enter the first parameter as 2-3 times larger than the distance between the points (see section 1), accept a second parameter 500,
- press [OK] to start the calculation,
- rate algorithm execution, remove spots or deselect items, and modify the parameters

2.2 Remove noise:
- Select the [Cloud→Select noise] or click the toolbar icon.
- In the box enter the first parameter as 3-4 times larger than the distance between points, the second parameter as 1.5-2 times the distance between points,
- press [OK] to start the calculation,
- rate algorithm execution, remove spots or deselect items, and modify the parameters.\

2.3 Remove cloud discontinuities – object edges improvement:
- select the [cloud → Mark discontinuities] or click the toolbar icon.
- in the box enter the first parameter as 3-4 times larger than the distance between points, the second parameter as 1.5-2 times the distance between points,
- press [OK] to start the calculation,
- rate algorithm execution, remove spots or deselect items, and modify the parameters.

3) Merging the measurement data coming from different directions:
- select the [cloud → Align the clouds] or click the toolbar icon
- select the tab Three points - on the left side, select the clouds, which are to remain stable (they will not change position in space),
- in the box on the right, select the clouds, whose position and orientation will be modified (will change position in space),
- Using the right mouse button, select three pairs of corresponding points in the two measured clouds (after selecting each point, click the corresponding button)
- preferably chose points that do not lie on one line. After all points are selected, start the procedure. If the obtained result is unsatisfactory, press [Back transformation], and then select three pairs of points again.

3.2. Accurate Merging:

- Choose an Accurate tab - Specify the parameters of the adjustment:
- [Number of points] – 1000
- [Radius] - 10 times greater than the distance between the points of the cloud, - [Minimum neighboring points] – 10
- Press [Start]. Iterative matching algorithm automatically terminates. After the algorithm stops, adjust the parameters and run the algorithm again (repeat 3-4 times). The parameters should be selected so as to obtain the best possible fit of clouds (smallest RMS error). Higher number of points to fit improves the stability of the algorithm, but increases computation time significantly.

4) The final cleaning of the measurement data:
- perform operations similar to those from step 2 for combined clouds, All the clouds of the project in the properties of clouds have to be activate. The parameters given to algorithms should correspond to the parameters chosen for the individual clouds, they can be slightly reduced (5-10%). *We performed it at least 4-5 times.*

5) Cloud optimization:
- press the Cloud→Smooth cloud] or click the toolbar icon - select the smoothing:
- plane – the neighboring points treated equally,

- Laplace - points in the neighborhood are weighted differently (based on their neighborhood)
- smoothing parameter should be 3-4 times greater than the distance between the points in a single cloud, - press [OK] to start the calculation.
- Smoothing algorithm allows for removal of small local noise, which remained within the clouds, further improves the fit of clouds in the area of coverage. Smoothing the clouds is the algorithm that interfere with the originally obtained the position of points - modifies them based on the environment. Too large a parameter will result in loss of information contained in a cloud of measurement - minor details become visible. As a result, the operation of this algorithm selected a small number of points that are considered as noise. They need to be removed

6) Cloud simplification:
   - Press the [Cloud→Simplify cloud] or click the toolbar icon - Select the simplification mode:
   - Uniform - the method will leave equidistant points (distance defined parameter),
   - Adaptive – more points will be left when curvatures in a cloud of points are presents,
   - Smoothing parameter in the case of simplification:
   - Uniform: 0.5-2mm,
   - Adaptive: 0.03-0.2 mm,
   - Press [OK] to start the calculation,
   - Algorithm indicates the unnecessary points - delete indicated points. With proper preparation of cloud of points adaptive algorithm gives better results. Fragments of an object with complex geometry are represented by more points than the fragments of a simple geometry. The use of adaptive smoothing without simplifying clouds usually does not work properly due to the presence of small noise and mismatches in the cloud.
7) Triangle mesh creation:
   - press the [Mesh→Create mesh] or click the toolbar icon
   - specify parameters to create a mesh. Mesh creating parameter should be set based on the distance between points in the cloud. In the case of uniform simplification of COP the mesh creation parameter can be read directly from a simplification parameter.
8) Triangle mesh gradients minimization:
   - Select the [Mesh→Minimize gradients], or click on the toolbar icon (*),
   - Click on the toolbar icon
   - unselect the triangles (**)
9) Texture imposition:
   - press the [Mesh→Create texture] or click the toolbar icon
   - in the texture creation window set:
   - [texture type] - orthogonal,
   - [width] - 512 pixels,
   - [height] - 512 pixels,
   - approve the creation of texture with the [OK] - press the [Mesh→Edit texture]
   - in the window showing the texture right-click (*),
   - in the context menu click dilation (**)
   - click on the [Mesh→Mesh properties] or click the toolbar icon
   - set [Fill triangles] - textured,
   - turn of visibility of edges of triangles.

We repeated the process 4-5 times to get as finished surface as we could.

- **Results**

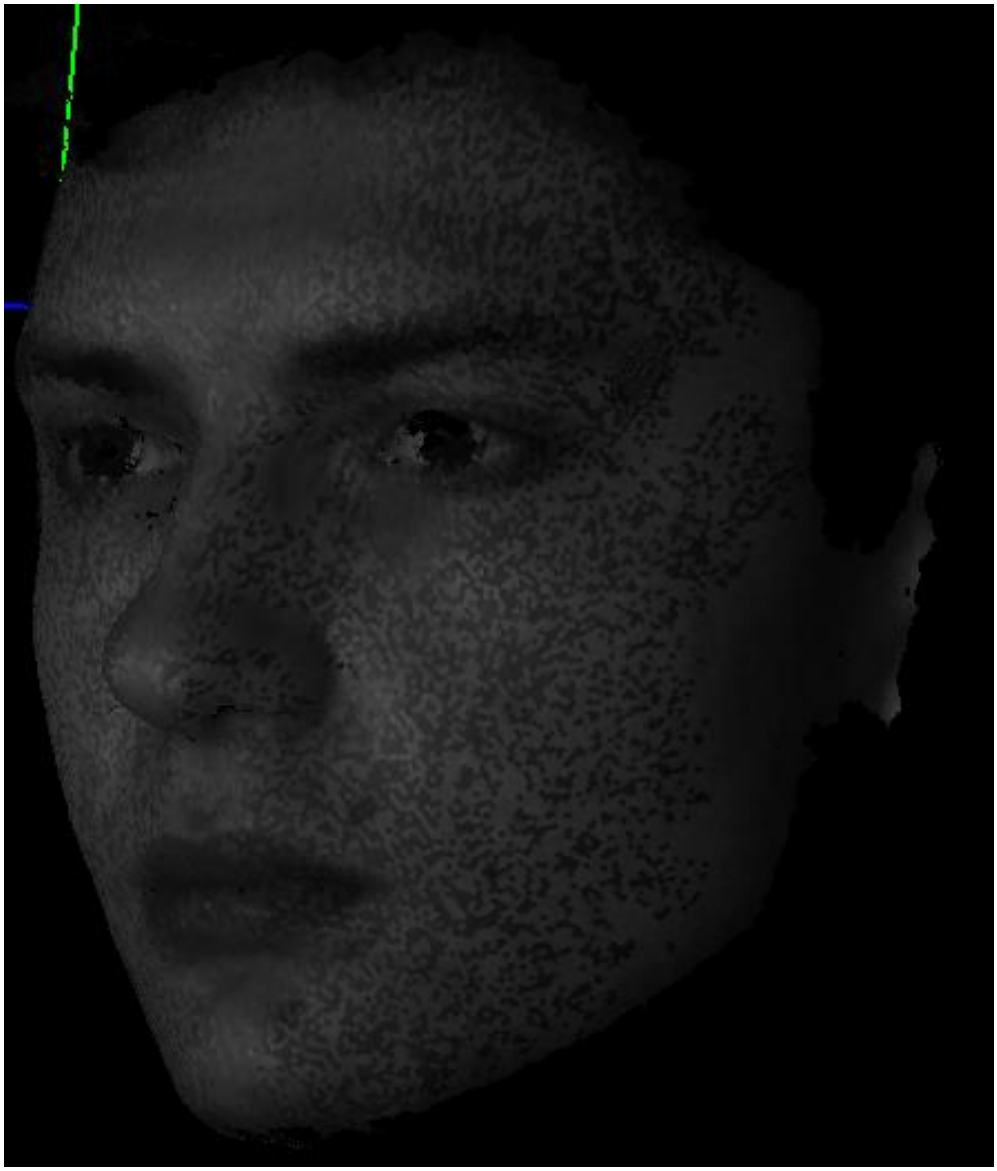

Figure 1. Left view of the Object

Figure 2. Front View of the object

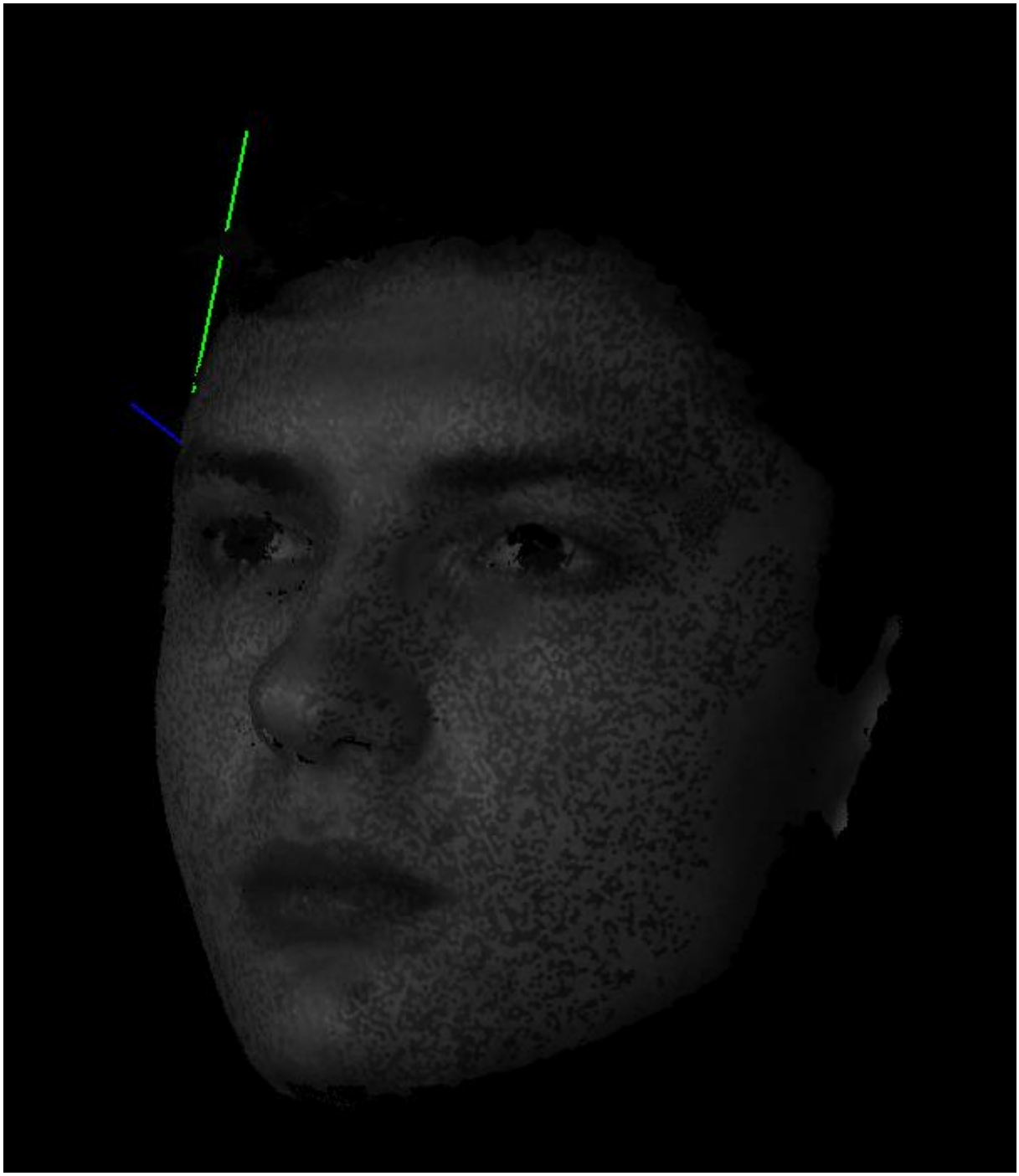

Figure 3. Right view of the Object

- ## Answers to Questions

1. **Explain briefly the fringe projection method. (1 pt)**
   By utilizing a projector to project fringes onto the object's surface, this technique creates a 3D topography of the 3D object. The object's shape causes deformation, which is caused by information being acquired by the camera and sent to the computer for processing. the outcome of obtaining a height map. This method required a non-scattering or transparent object with an anti-reflex layer covering it in order to have adequate vision of projected fringes. By applying a suitable phase unwrapping algorithm and one of the fringe analysis techniques to analyze the image, it calculates the phase modulation to provide a continuous phase distribution. The techniques just use the image to establish a form.

2. **Is collecting one measurement when analyzing an object using the fringe projection method a sufficient activity? Justify your answer. Suggest how measurements should be collected to obtain a full scan of the object. (1 pt)**

Due to some of the angles being challenging to view on the camera, taking just one measurement prevents getting a complete scan of the entire object. The room must be completely dark in order for the fringes to be plainly visible. Only what was captured on camera was the data that was gathered. Therefore, many photos taken from various perspectives of the item will accomplish the task. This technique is known as temporal phase shifting (TPS). Multiple photos must be obtained in order to achieve improved accuracy and results. Two measurements are recorded in the lab, allowing them to be combined to get better results.

3. **Describe the processing path of a single measurement cloud. (1 pt)**

The process describes how we remove extraneous points from the space after we had the point cloud that was registered. The undesired point is the point of noise that surrounds the accurate data. The ALT key can be used to select a point, and ALT+DELETE can be used to delete the point that has been selected. Both a manual and automatic selection of the point is possible. By simply clicking the right mouse button, we may manually select a rectangle, but if we want to select a polygon, we must press ALT+RMB (right mouse button). We can pick the noise by pressing ALT+RMB, then erase it by pressing ALT+I to invert. We physically remove all noise from the area before moving on to automation. But first, we must establish the distance between the point cloud, so that will be how you get the info. The initial parameter for point cloud filter algorithms will be computed using the value. When we zoom in on two chosen neighbouring points in the lab, we get a distance of 0.38mm. By using the select group operation to eliminate group points that are separated from the surface, we can automatically clear up the noise. We decide to eliminate every group that has a distance of 1 mm. The one that is at the correct distance, say 0.38mm, won't be taken out. Then, we automatically eliminate noise using the select noise technique, choosing a spacing between points of 1mm, and deleting it. Finally, we employ improved object edges by eliminating cloud discontinuities, which uses symbols to indicate breaks. We provide 2 criteria. The first will be three to four times bigger than the separation between the points. The distance between the second parameter and the deleted it is 1.5–2 times larger. Because we needed to have the appropriate distance for the additional triangular mesh, those techniques will reduce point.

4. **Describe what should be done after individual processing of recorded measurement clouds. (1 pt)**

We should try to integrate all of the cloud point measurements with the same position after cleaning each one. We will choose three common points from two measurement clouds that will remain steady automatically using the three-point method. The Align the Cloud technique is then used to automatically adjust the cloud point measurement to match the point between them. To achieve the optimal outcome, we shall repeat the technique multiple times. It is difficult to make it fit properly if we manually alter it, but we can try by translation or rotation. The noise-removal process is then repeated.

The final stage in the cleanup process is to use the cloud to eliminate any remaining local noise.
Smoothing can be done in two ways. Laplace and the method of fitting a plane. We employ them and get rid of the chosen portion. Then, as we don't want the process to take too long to produce the mesh, we use cloud simplification to lower the point by removing any unneeded ones. Both uniform and adaptive methods exist. The equidistant point will be left by the uniform technique, but the high-curvature points will be left by the adaptive method. We remove the selected point's inversion.

Finally, we employ the generate mesh technique, whose parameter specifies the triangle's maximum edge, to enable for the creation of a triangular mesh. The parameter with the fewest holes on the item will be used.

The quality (smoothness) of the mesh is then improved via reducing gradients; this procedure requires time. In order to fill the gap in the triangle mesh, we repeatedly minimize gradients. Then we dilated to get the smallest hole and filled the hole with texture. The triangle is changed from shade to texture, and then we are finished.

5. **In Mesh3D, how do you remove selected points, and how do you remove a selection? (1 pt)**

In Mesh3D, the shortcuts Alt+Delete and Alt+D can be used to remove a selection or the selected points. To alternate we use Alt+i.

- ## Reference

1. https://chat.openai.com
2. https://moodle.usos.pw.edu.pl/pluginfile.php/250643/mod_resource/content/3/ex-4-EN_v2.pdf