3D Digitization Lab Reports

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Lab 1 – Time of Flight

I. Introduction

THE use of three dimensional models of interest objects has been widely spreading throughout the engineering and science community. Three-dimensional models allow component quality checks in industrial environments; they are also useful for reverse engineering or for component design and assembly. In civil engineering, the structural damages of a building due to natural disasters or excessive loadings can be assessed by creating a 3D model. Other applications may include prosthetics or cultural artefacts documentation. Though there are several techniques that would allow one to create a model from sample, in the previously mentioned applications it is crucial to preserve the object's integrity, that is, to employ a non-destructive measurement approach. One of the main tasks is therefore, to be able to retrieve the object's shape by merely visualizing it: three dimensional non-contact scanners achieve this. This report presents the work done in the laboratory practice where a time-of-flight scanner was used to reconstruct indoor environments.

A. Large Scale 3D Scanning

Scanning of big, large scale objects is a special interest in applications such as architecture and archaeology. Here often a huge area has to be covered by the scanning process, which makes a fast and easy-to-use technique necessary. The scanner has to be transportable and robust enough to be used outdoors. On the other hand, the measurement technique has to be safety and non-invasive to avoid damage on not evacuated humans and the objects itself. The time of flight technology that senses an object by the use of a safety laser is often a good choice for such conditions.

B. Time of Flight Scanning

The time of flight scanning technology is based of the measurement of the time delay between emitting and receiving a laser beam. It can be used for large scale measurements of all kind of objects with a rough surface that can reflect the laser back to the scanner. Advanced scanners are able to measure not only using a single, but multiple pulsed beams. This allows to measure several points simultaneously and speeds up the acquisition time.

The main advantages of the time of flight technology are the high portability of the devices and the general simplicity of its use. It is flexible enough to operate with varying resolution that allows to take fast measurements if required. Drawbacks of this method are mainly its sensitivity to environmental light, interferences with parallel operating scanners.

C. TRIMBLE GS 101 3D Scanner

In the lab a TRIMBLE GS 101 3D Scanner was used. It main characteristics are its standard range of 2 - 200 m at a recommended operating range of 100 m. The scanner has a maximum scanning speed of 5000 points per second and a 360° horizontal and 60° vertical field of view. Additionally it is equipped with a color camera, operating at a resolution of 768×576 pixels in real time mode and has the ability of taking snapshots with a resolution up to 9 mega pixels.

II. Experiments

At the beginning we followed the tutorial and became familiarized with the software PointScape, by using the video view to control the camera (tilting and zooming). After taking a video snapshot we made our scan with the proposed parameters. After saving the retrieved point cloud we proceeded to the next task.

The objective of the next task was to obtain measurements of the laboratory room from two positions. This made it necessary to additionally acquire three reference points, in order to register the two point clouds from the two positions. PointScape provides a special feature to acquire the reference points and is even able to fit the detailed point cloud of the reference points to a given ideal shape. In our case the ideal model of the reference shape were spheres located on the walls of the laboratory. The program was able to identify the shapes of our reference points appropriately as spheres and fit the measurements accurately. Once the reference points were set successfully, we continued with acquiring the room as we did in the very first task.

The second step of the exercise was to ask the lab assistant to move the scanner to another position and repeat the previous procedure. The second acquisition should then be registered and merged with the first one, by the use of the reference points. Unfortunately we experienced technical problems the scanner. After the replacement it was not following the rotations commands as expected. As if the rotation actuator would have not been calibrated correctly it rotated to random positions. Even with the help of the assistance it was impossible for us to figure out or localize the problem. Several attempts were made to solve the inconvenience, such as reboot of the scanner and the complete equipment (PC and software), and using the recalibration functions of the PointScape software.

Even if the problem could not be solved on the place, we continued nevertheless with the lab practice. The lab assistant provided us with previously generated data and so we were able to proceed. We used the RealWorks Survey software to merge the two point clouds we had. The process was straight forward and quickly accomplished successfully with the generation of the mesh of the measurements.

III. Conclusion

Despite the problems we had with the hardware, the complete acquisition procedure was fairly simple. After having a short look into the tutorial and onto the GUI, the software was user-friendly and allowed us regardless our inexperience with the scanner. Furthermore the post-processing stage was not difficult to achieve either.

The measurements were done fast, if the resolution was not chosen to be too high. On the other hand the scanning of the reference points showed the true scanning capacity. The point clouds on the reference points were really dense. However, it has to be considered that we took only measurements of relatively near objects (approx. 10m), compared with the recommended operation range of the device (100m). The further away the scanned objects are the less the maximum resolution of object will be.

Lab 2 – Fringe Projection

I. Introduction

During this lab a KR16 robot arm with a KRC2 robot controller was employed to manipulate a Steinblicher Comet 5 sensor which uses fringe projection to scan an object of interest and obtain 3D points. The software employed was Comet Plus, which was easy and straightforward to use to obtain and merge the 3D points acquired with different views with Comet 5.

The lab session was divided in several experiments:

1) Free surface matching
2) Surface matching using tie points
3) 3D scanning using reference points

All of these experiments require the acquisition of 3D points in several views (at least 2), which is done through fringe projection. The Comet 5 'head' consists basically of a camera and projector. The camera captures the object and the fringe pattern projected by the projector. During acquisition, it is important to configure some parameters to guarantee a proper capture. The two parameters that we were able to try and configure were the following:

- Exposure time: it is simply the exposure time of the camera mounted in the Comet 5 head. The exposure time should be as large as possible but at the same time not too high to avoid saturation.
- Fringe quality: this parameter is used by the software to discard points that are not considered accurate enough to be used. The criterion is the angle between the normal of the surface where a given point lies on and the camera. If it is higher than a given value then the corresponding points are discarded. This value is called fringe quality.
- Gradient X: NO ONE REMEMBERS!

An example of a single-view 3D point acquisition is shown in figure 1. Once several set of points from different view have been acquired, it is necessary to register them in order to generate a final 3D point cloud. In this lab three methods were tested and are discussed below.

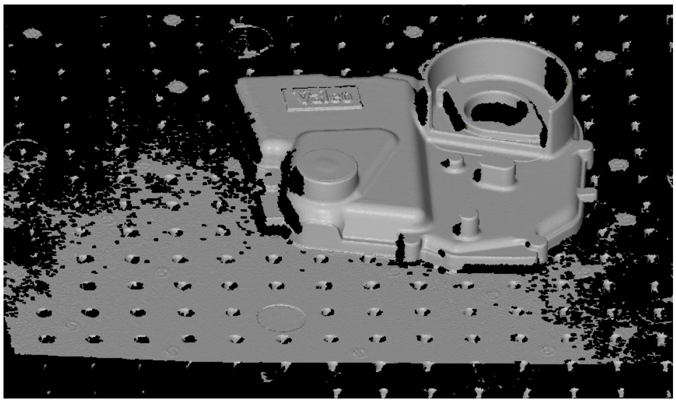

Figure 1: Example of 3D points from a single view

II. Free Surface Matching

This method registers the different point acquisitions by employing either an automatic or manually assisted method. The automatic method only works properly if the angle between different acquisitions is small enough, generally less than 45 degrees. In the cases where automatic registration does not work adequately, it is possible to manually select matching points between two different views to help the algorithm. An example of manual aided matching is shown in figure 2.

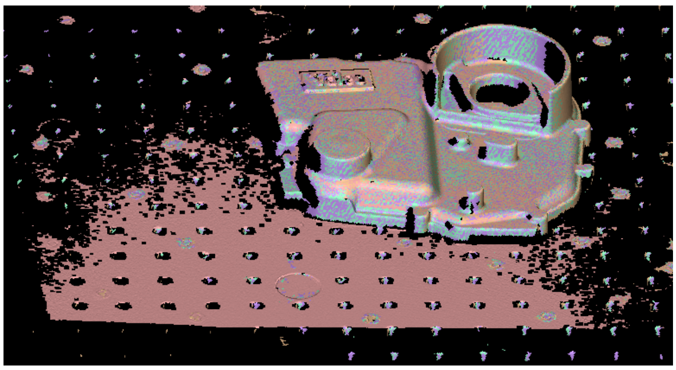

Figure 2: Manual matching of three different views

III. Surface matching using tie points

A possibility to ease the registration process is to use tie points. Tie points are special stickers that are sticked on the object surface in a random fashion. The tie points are used to provide a good initialization for the automatic registration algorithm. Even though this method is highly effective, placing tie points in objects with large surfaces can be time consuming.

IV. 3D scanning using reference points

Scanning using reference points is an alternative to tie points. The advantage over the later is that there is no need to stick tie points to the object but it needs reference points to be placed on the scene, such as reference points on the surface where the object to be scanned is placed. An important amount of off-line work is needed to calculate the precise location of each reference point. An example of reference point matching can be seen in figure 3.

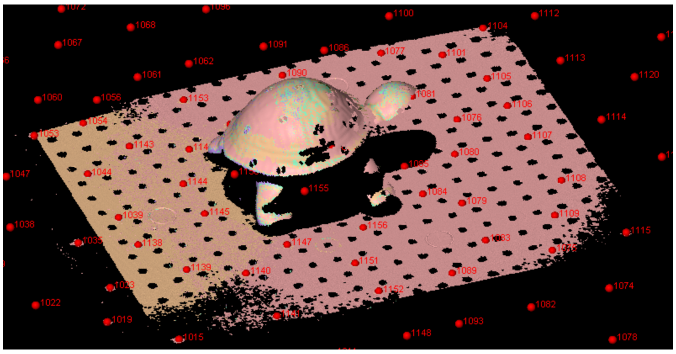

Figure 3: 3D point matching with reference points

V. PARAMS

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VI. Conclusion

Fringe pattern projection is a powerful technique for contact-less 3D scanning, allowing precise measurements with a flexible setup. The configuration of the fringe quality parameter depends on the specific application and is also related to the geometry of the object and the accuracy needed for the 3D points to be captured. If the fringe quality value is lowered then it will be necessary to acquire points from more viewpoints in order to get a good estimate of all the points needed.

Regarding the registration techniques, automatic registration can only be applied if the angle between two viewpoints are within a certain range. Otherwise it is necessary to provide manual correspondences in order to initialize the automatic registration process. This could be time consuming for complex objects and several viewpoint acquisitions. As discussed before, a possible solution is to stick tie points over all the surface of the object to scan. In this case the software is able to perform automatic registration but it could take an important amount of time to place the tie points in objects with large surfaces. Finally, if reference points are available, registration is easier and precise measurements can be obtained.

Lab 3 – Romer G-Scan Rx2

I. Introduction

DURING this lab, the Romer G-Scan Rx2 non-contact scanner was employed. The G-Scan Rx2 is a laser scanner of relatively small size, which is manually moved to capture an object or surface of interest.

II. 3D point acquisition

The first step with this scanner was to scan a given object. This required precise movements from the student operating the G-Scan Rx2, given that it is needed to keep a specific distance between the scanned surface and the scanner. Once several points were acquired, a mesh was calculated based on them, by using the functionality included in the software provided. An example of the acquired points is shown in figure 4.

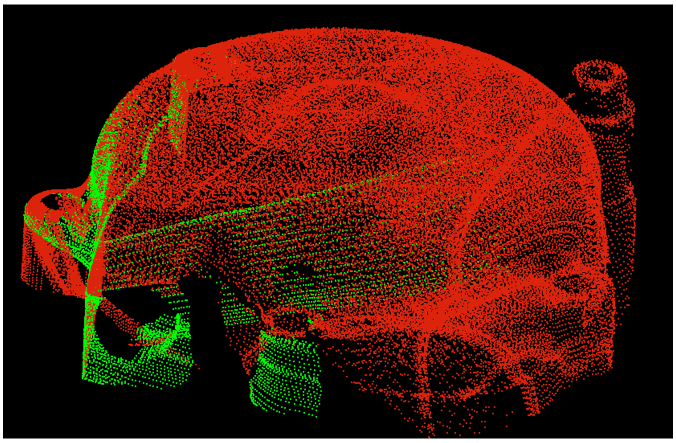
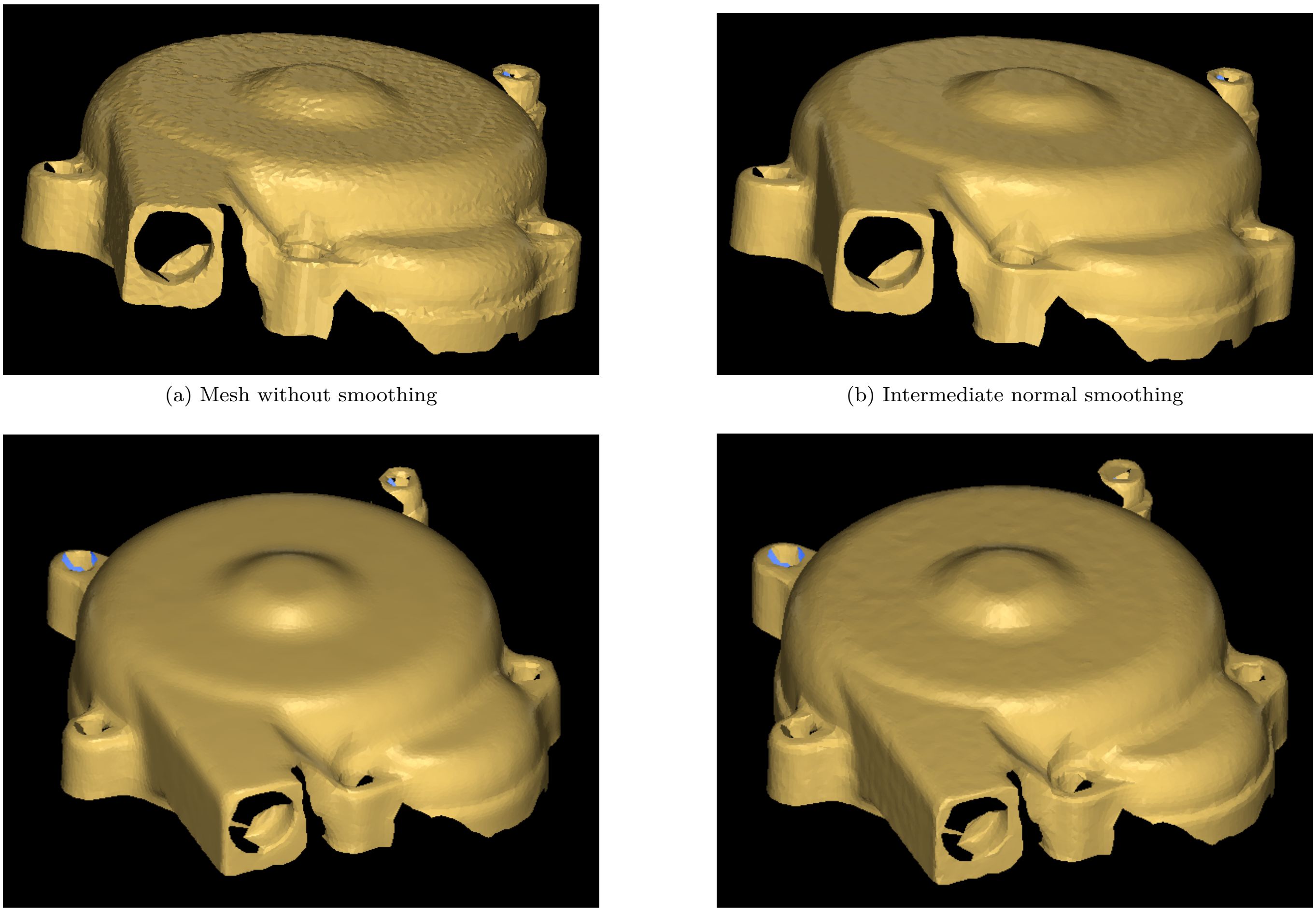


Figure 4: Point cloud of acquired points with Romer G-Scan Rx2

III. Mesh creation

The software provided can generate a mesh from a given point cloud. When doing so, there are a few parameters regarding surface smoothing that can be varied. The two main options are normal smoothing and smoothing with deviation control. The main difference between both of them is that normal smoothing applies smoothing isotropically, which can lead to undesired results in surfaces with sharp edges. To overcome this problem, smoothing with deviation control allows the user to control how the smoothing behaves with sharp edges and non-sharp surfaces. Figure 5 shows the raw mesh without any smoothing and three different smoothed meshes obtained with different parameters. It can be seen that smoothing with deviation control gives the best result since it is able to smooth strongly flat sections while preserving hard edges.



(a) Mesh without smoothing

(b) Intermediate normal smoothing

(c) Strong normal smoothing

(d) Smoothing with deviation control

Figure 5: Mesh creation and smoothing with Romer G-Scan Rx2 software

IV. Post-processing

For post-processing, the software Rapidform was used. The main goal of experimenting with post-processing during this lab session was to familiarize with part inspection, which plays an important role in industry.

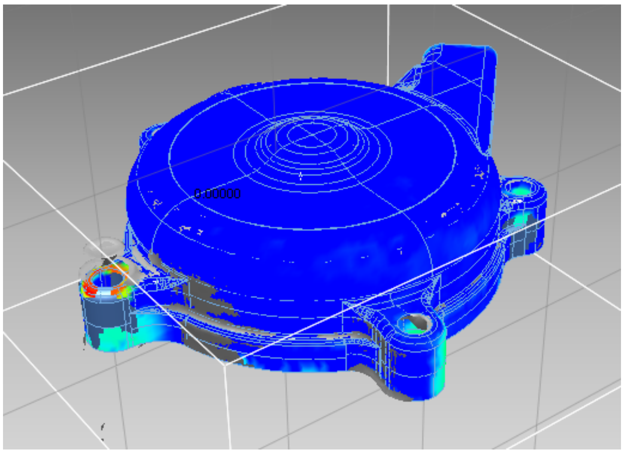
The main idea is to compare the acquired mesh with a CAD model to check for discrepancies between both, which could be interpreted as defects if they exceed certain level. The first step is to register the mesh and the CAD model with Rapidform. This is easily done with the Best Fit Alignment algorithm provided by Rapidform, which requires only a few clicks to manually initialize it.

Once registration is done, it is possible to calculate the deviation between the CAD model and the acquired mesh. Figure 6 shows the results obtained, displayed in four different modalities. It is important to point out that the modality to choose depends on the application and needs. In some cases the absolute error might be enough, but in other situations it could be important to know which is the sign of that error (with respect to the surface normal), since, for instance, positive errors might be considered as defects and positive ones not, as long as they are small enough. Moreover, error annotation is an important tool to provide precise values together with the location of a given defect.

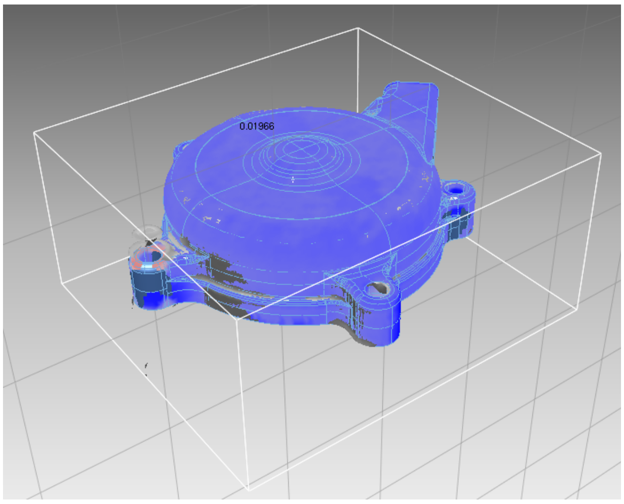
V. Conclusion

During this lab session we were able to familiarize ourselves with the Romer G-Scan Rx2 device and the provided software. Acquisition of 3D points was not as easy as we expected but after a few attempts we were able to acquire enough 3D points to create the corresponding mesh. Regarding mesh creation, mesh smoothing is an important step and the right parameters have to be chosen in order to create a 3D model that represents the object accurately enough.

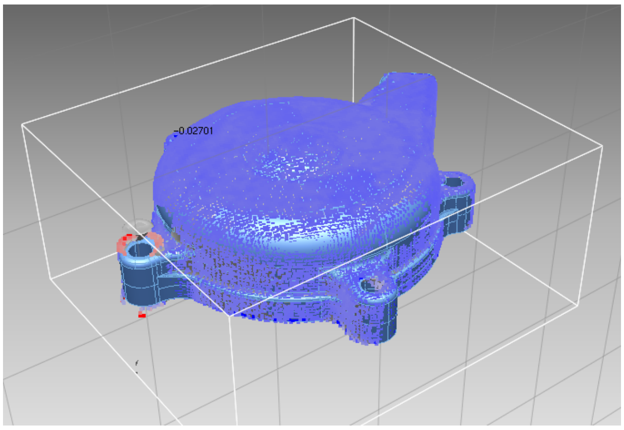
Finally, defect inspection was performed by using the Rapidform software to compare the acquired mesh with a reference CAD model. Even though we were not able to generate the 3D HTML file with the annotated vertices (due to a software error every time we tried this option), the results obtained showed us the power of 3D object scanning for defect inspection.



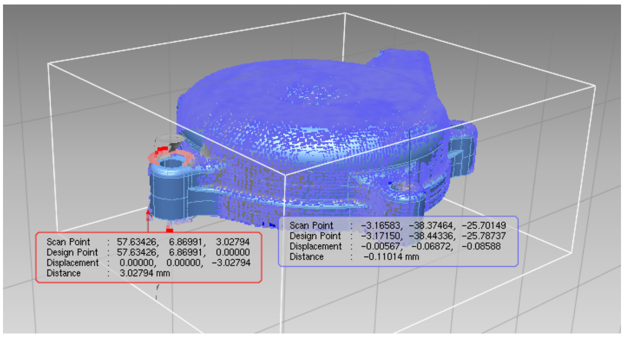
(a) Absolute errors between CAD model and acquired mesh



(b) Signed errors between CAD model and acquired mesh



(c) Point errors between CAD model and acquired mesh



(d) Annotated errors between CAD model and acquired mesh

Figure 6: Mesh creation and smoothing with Romer G-Scan Rx2 software