Fraunhofer IGD

Technische Universität München

Methodology for evaluation of precision and accuracy of different geometric 3D data acquisition methods

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Final Presentation

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Presentation Outline

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    1. Motivation
    2. Research Objective
2. Study-case
3. Methodology
4. Results and discusssions
5. Conclusion
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1. Introduction

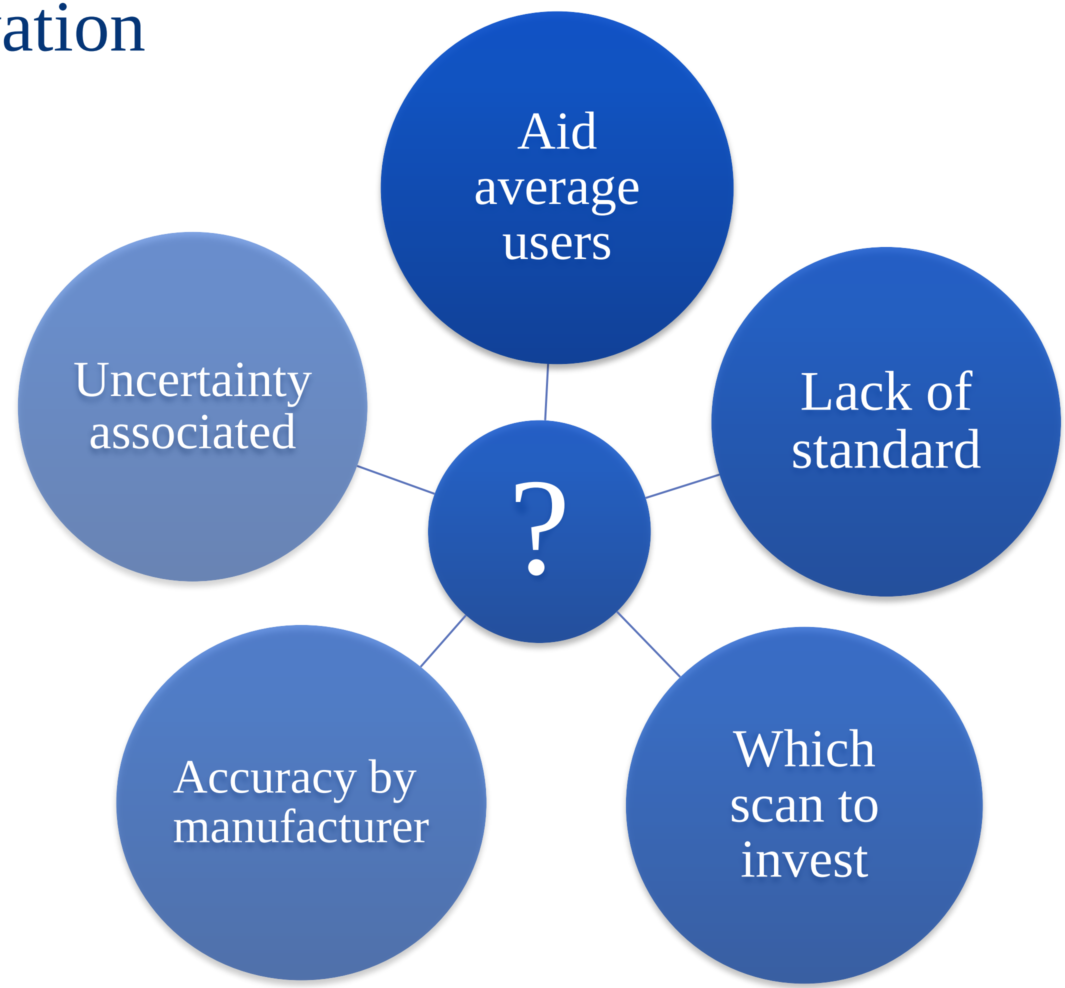
- 3D optical systems have found popularity among innumerous field of application, as in Geomatics and Cultural Heritage domain [1].

- With triangulation method being widely applied [2].

- The amount of available sensor is constantly growing [3].

- Users venturing themselves with no or prior knowledge of the scan system [1].

1.1 Motivation



1.2 Research Objectives

- Develop a general solution to assess accuracy for different optical 3D scan systems with the visualization of measurement uncertainty supporting the results.

2. Related work

Accuracy Assessment

- Triangulated systems
- VDIVDE 2634 Part 3

Measurement Uncertainty

- Test procedure
- Measurement uncertainty

Visualization

- Support the results

2.1 Accuracy assessment

- With the growth of optical 3D scanning systems application in metrology, it became more and more evident the need of a common standard for assessing system`s accuracy [1].

- VDIVDE arises in this scenario establishing test in order to assess the precision and accuracy of an evaluated system [5].

- The guideline is divided in 3 parts:
  - Part 1 – Imaging systems with point-by-point probing;
  - Part 2 – Optical systems based on area scanning; and
  - **Part 3 – Multiple view systems based on area scanning.**

2.1.1 VDI/VDE Part 3

- To acquire the accuracy of the system the guideline defines some quality parameters.

- In this presentation, we focus on:
  - Probing Error
    - Probing error form
    - Probing error shape
  - Sphere Distance

2.1.1.1 VDI/VDE Part 3 – Probing Error

- The Probing Error is divided in Probing Error Form (PF) and Probing Error Size (PS).
  - Probing Error Form (PF): comprehend the radial deviation of the measured points to its theoretical surfasse, the best-fit sphere [4][6].
  - Probing Error Shape (Ps): Difference between the diameters of measured sphere and the calibrated sphere [7].

2.1.1.1 VDI/VDE Part 3 – Probing Error

- Suggested setup

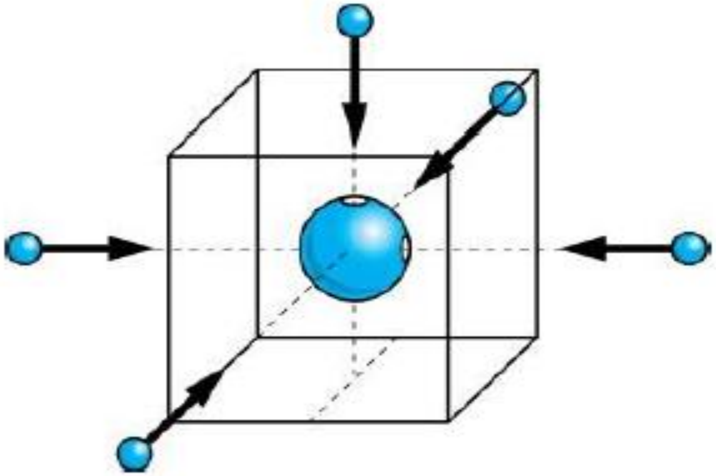


Figure 01: Different positions of the sensor related to the sphere position (Bojan Acko *et al*, 2012)

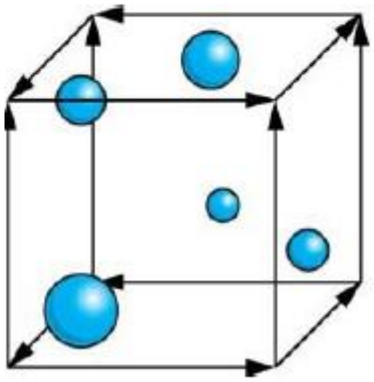


Figure 02: Position of the sphere within the sensor measuring volume (Bojan Acko *et al*, 2012)

2.1.1.2 VDI/VDE Part 3 – Sphere Spacing Error

- Sphere Spacing Error (SD)
  - The quality parameter Sphere Spacing Error (SD) defines the length in between the centers of two spheres and compares it to the calibrated length, in order to define the system's deviation [4][7][8].
- Suggested set-up

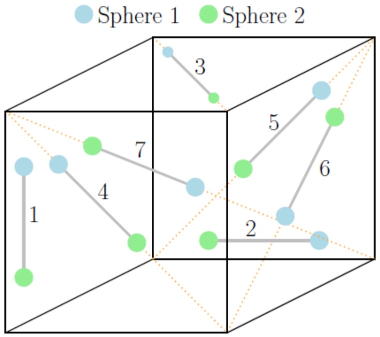


Figure 03: Proposed arrangement for the error of the length (Eyþór R. Eiríkssona *et al*, 2016)

2.2 Measurement uncertainty

- The *accuracy* express the difference between the measured data and the *true value* [10].

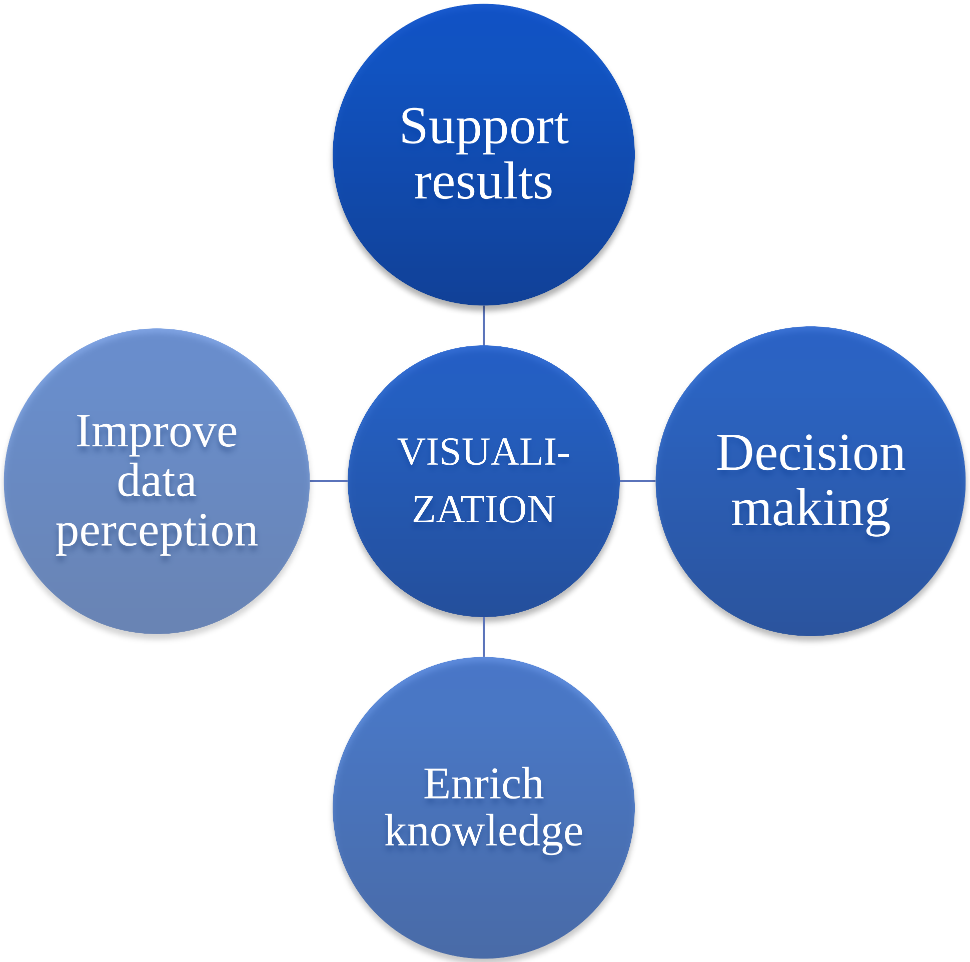
- True value cannot be achieved in practice and thus, the measurement uncertainty should be always specified [6][9];

- Any measurement will then be defined as [6]:

$$Xo \pm U$$

- In this master thesis, measurement uncertainty is calculated for the VDI/VDE 2634 and GUM guide.

2.3 Visualization



3. Study-case: Cultural Heritage Digitization (CHD)

Figure 04: Photogrammetric system (Fraunhofer IGD - CHD, 2017)

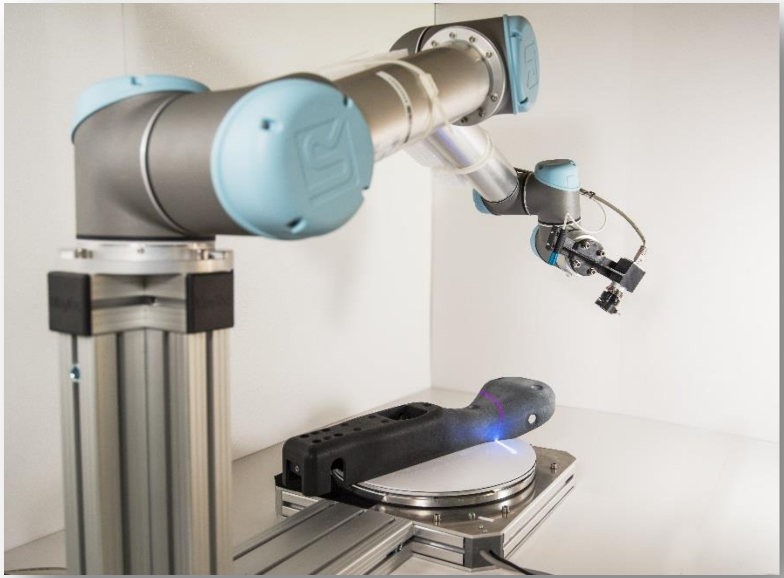


Figure 05: Laser Line Sensor (Fraunhofer IGD - CHD, 2017)

4. Methodology

Phase I
- Artefact design
- Artefact preparation

Phase II
- Adpated Tests
- Point cloud acquisiton

Phase III
- Best-fit model
- Evaulation of the quality parameters

Phase IV
- Measurement uncertainty assumption
- Online survey

4.1 Input Preparation

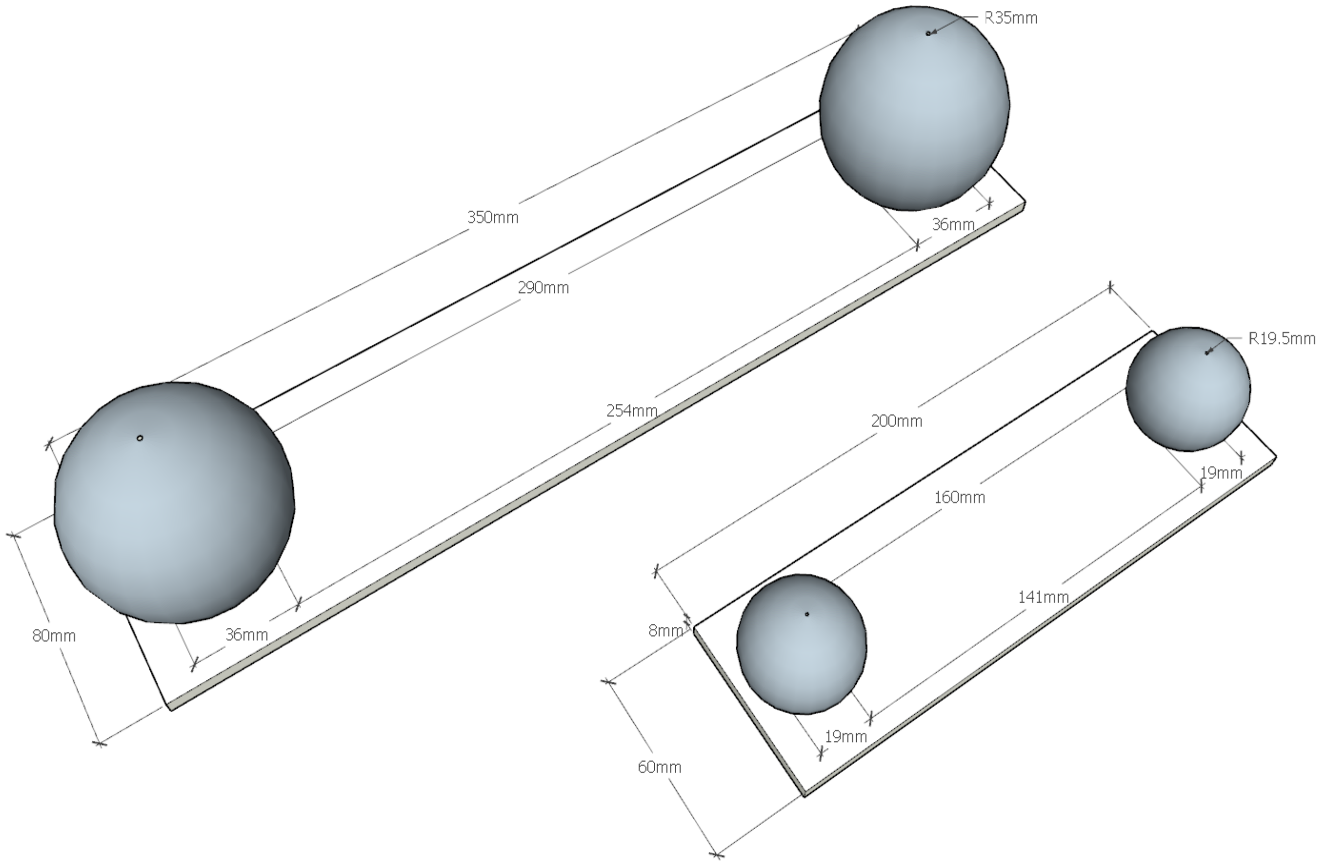


Figure 06: Sketch of the spheres plates created in SketchUp.

4.1 Input Preparation

Figure 07: Sphere plate before and after its preparation

4.2 Adapted test – Probing Error

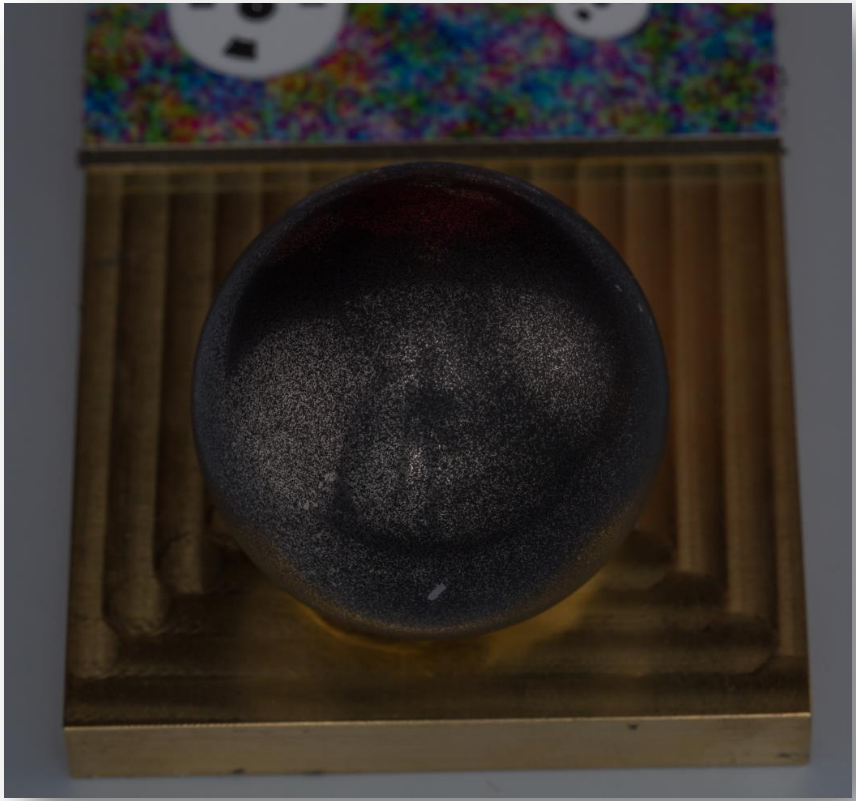


Figure 08: Probing error acquisition

4.2 Adapted test – Sphere Spacing Error

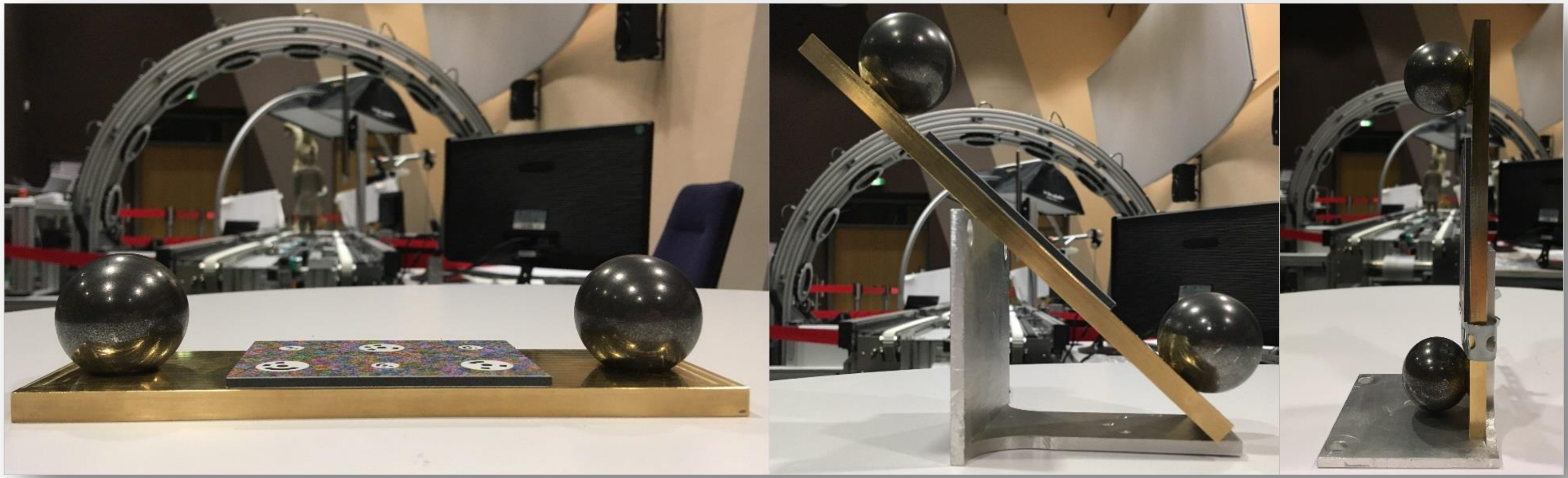


Figure 09: Sphere Spacing Error acquisition

4.3 Best-fit algorithm

4.4 Evaluation

- Probing Error Form

$$PF_{pos} = \sigma(\Delta r)$$

- Probing Error Size

$$PS_{pos} = Dm_{PF} - D_{calib}$$

- Sphere Spacing Error

$$SD_{pos} = Lm_{SD} - L_{calib}$$

$*$ pos refer to each measured position.

4.4 Assessment

- The previous parameters are said to be assessed, when:

$$|MPE_{xx}| - U \geq \begin{cases} PF_{pos} \\ PS_{pos} \\ SD_{pos} \end{cases}$$

4.5 Measurement uncertainty

- Refer to the uncertainty in the measurement and pre-processing stage, after acquisition of the point cloud.
- Only account for uncorrelated data.
- This research does not make distinction between the types of uncertainty
- Consideration: Test procedure uncertainty + randomness of the observations + inaccuracy when defining the local coordinate system.
- The uncertainty in the end is a combination of all uncertainties associated to the corresponding coverage factor.

4.6 Online survey

- Visualizations was added to the quality parameters and measurement uncertainties.
- Goal: enhance the understanding about sensor’s abilities.
- Two plots created for each quality parameter.
- Audience questioned about the readability and effectiveness of each plot.

5. Results

5.1 Probing Error analysis

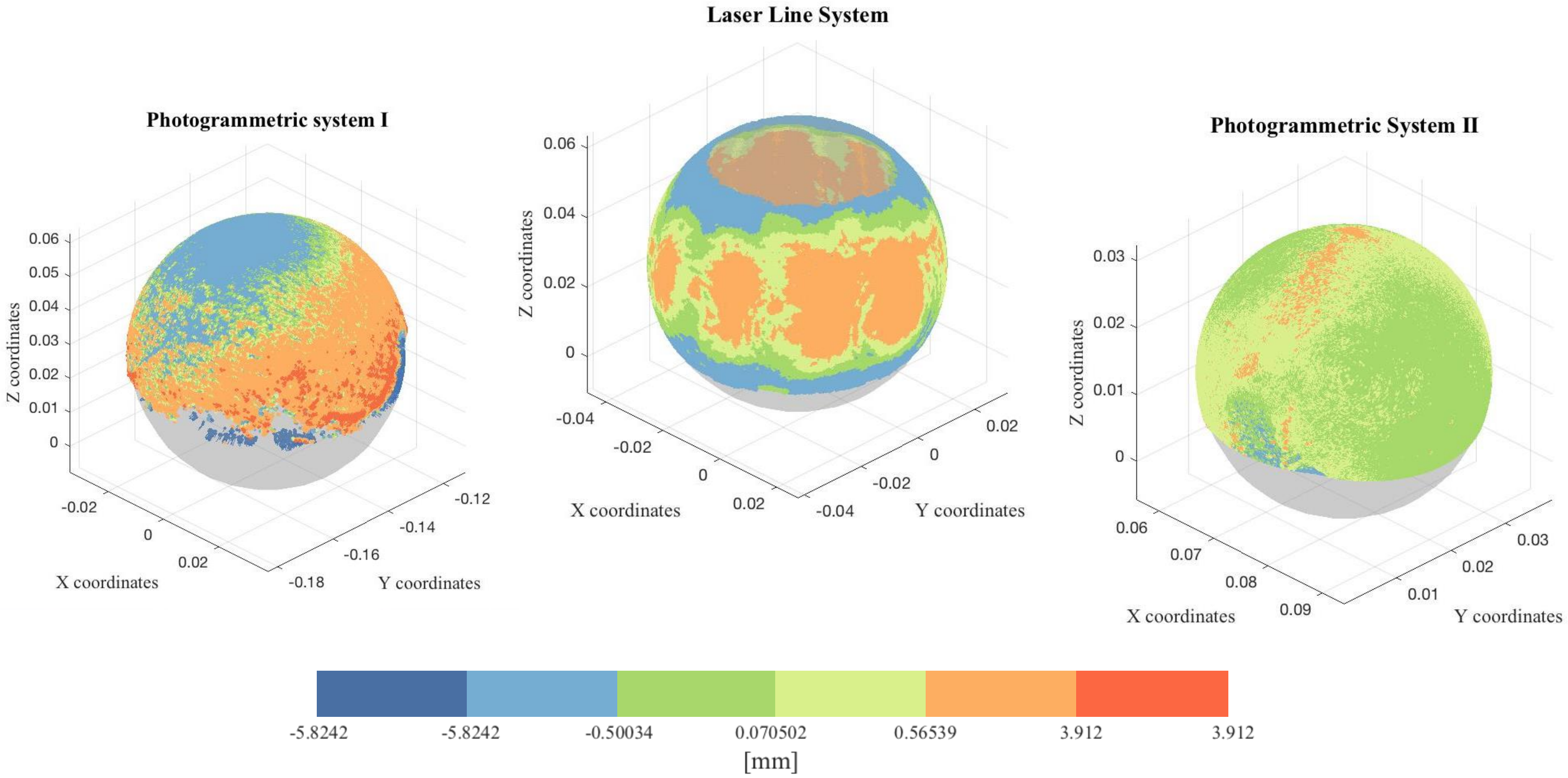
	PF μm	**PS μm**	**|MPE| - U μm**
Laser Line Scanner	168.7	2430.3	4973.1
Photogrammetric system I	400.4	477.0	473.1
Photogrammetric system II	13.5	67.2	122.6

5.2 Measurement Uncertainty

- Uncertainty Budget

Uncertainty Canon 5DSr + Canon 100mm lens - Probing Error Form					
Uncertainty Source	Standard uncertainty	Type	Distribution	Un	DOF
Probing Error Form	13.5	A	Normal	µm	2
Targets uncertainty	8.7	B	Rectangular	µm	infinity
Test procedure	13.7	B	Normal	µm	infinity
Combined standard uncertainty (u)					21.1
Expandend uncertainty (95%) - k=2					42.2

5.3 Visualization - PF



5.4 Visualization - PS

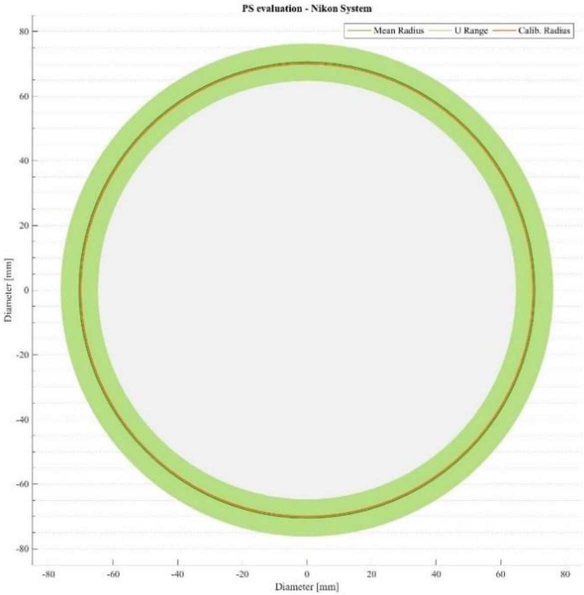


Figure 10: Photogrammetric system I

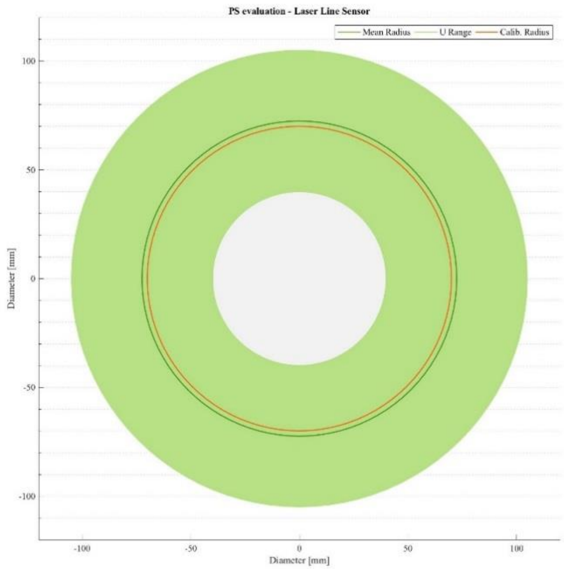


Figure 11: Laser Line Scanner

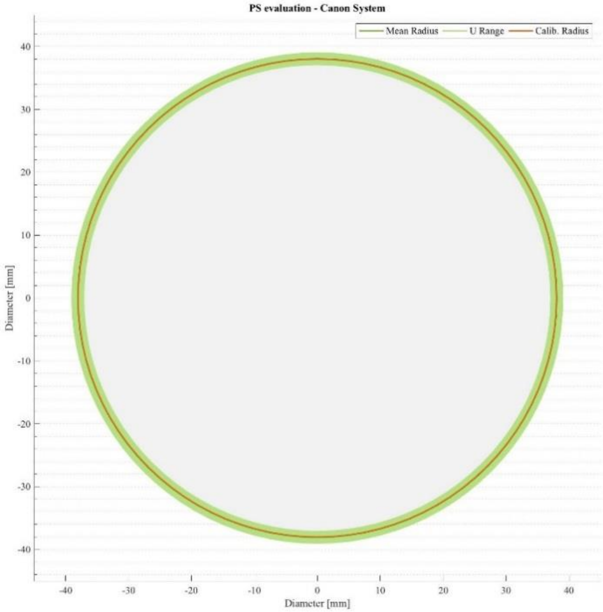


Figure 12: Photogrammetric system II

5.5 Visualization - SD

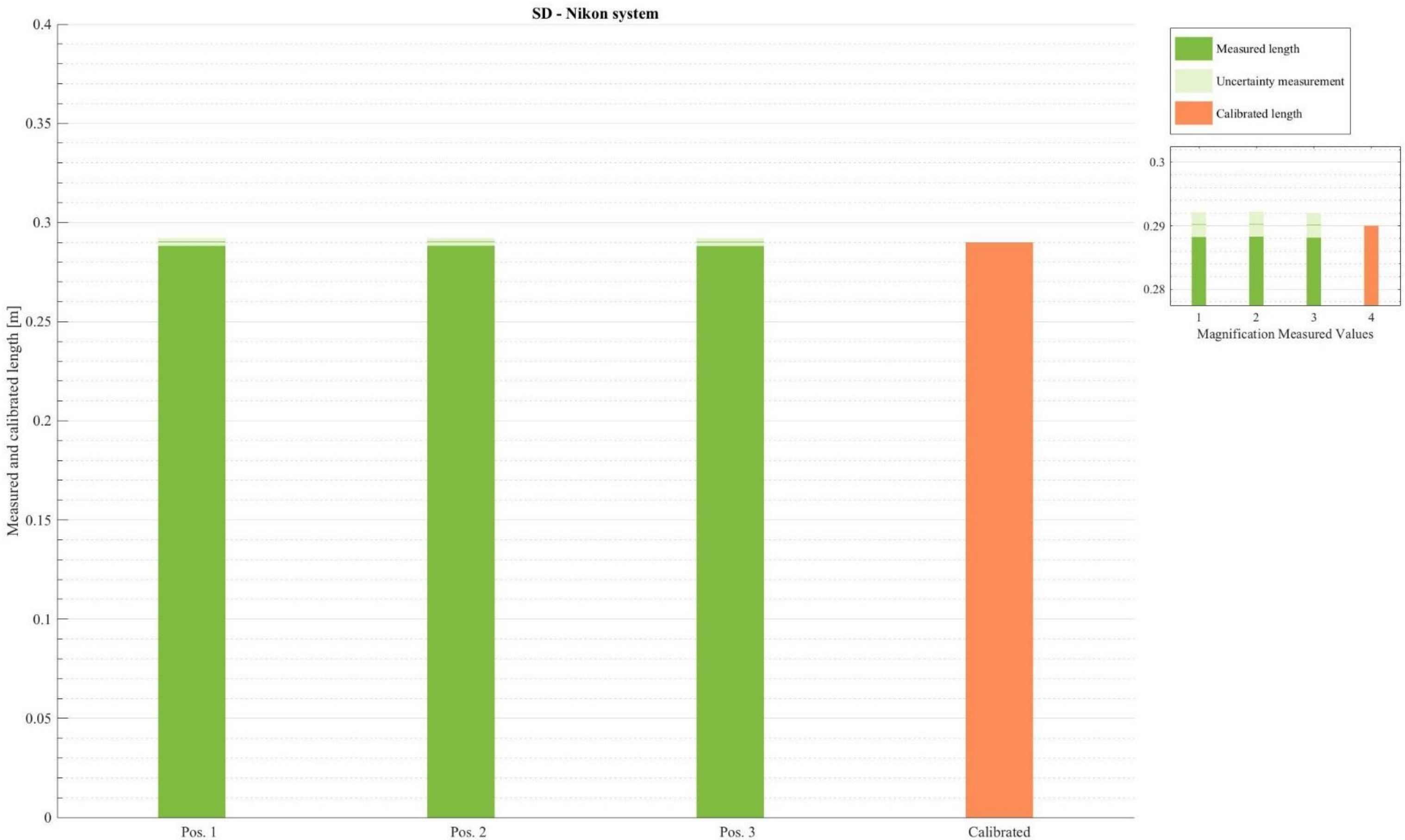


Figure 13: Photogrammetric system I – SD evaluation

6. Conclusion

- The proposed solution covers all steps from the acquisition to the visualization of the results.
- Different sensors can be assessed through the proposed solution and reliable results can be extracted with the aid of the algorithm.
- The developed solution can be applied to any scan system that complies with the VDI/VDE 2634 Part 3.
- This solution can be applied for experienced and non-experienced users.
- The online survey showed that the plots can enhance the user readability of the generated data.

7. Further work

- Introduce more repeatability on the measurement.
- Consider a new coating property.
- As the algorithm connects the accuracy and visualization part, errors (i.e machine error) should be further evaluated.
- Create a more unique visualization, integrate the plots (i.e display the plots in a dashboard).

Thank you!!!

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