Quality assurance and calibration tasks in the scope of multi-sensor systems

FIG Working Week 2015
From the Wisdom of the Ages to the Challenges of the Modern World
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Motivation
Quality Assurance

Why?

- Increasing the acceptance of geo data
- Proving the performance of measurement systems
- Quantitative analysis of measurement results, e.g.,
  - object resolution
  - accuracy of measured objects
- Avoidance of expensive follow-up measurements (efficiency)
- Improvement of the actual course of action (improvement of quality values)

Difficult?

- Sensors only partially affect the quality of measurement result
- Other influence factors on the measurement results become more and more important
  - i.e. the object characteristics and calibration tasks

⇨ Quality assurance of multi-sensor systems is important and difficult

Motivation
Multi-sensor systems (MSS)

- *What is common for all multi-sensor systems (MSS)?*
  - Superior goal: Efficient data capturing of the environment
  - Image capturing sensors: w.l.o.g. laser scanner
  - Referencing sensors: 3D positioning sensors
  - Use benefits of each enlisted sensor

- *What is essential for the MSS?*
  1) Availability of a proper **time reference** for the acquired sensor data
  2) Mutual **spatial relation** of each enlisted sensor

  → Calibration task

Agenda

- Introduction
- Components of the quality assurance process for MSS
- Calibration task for a laser scanner based MSS
- Validation of QA parameters
- Conclusion & Future Work

Introduction

- According to EN ISO 9000:2005 Quality Assurance (QA) is a way of preventing mistakes or defects in manufactured products and avoiding problems when delivering solutions or services to customers. Quality assurance can be seen as "*A part of quality management focused on providing confidence that quality requirements will be fulfilled*"
- Quality assurance for MSS is…
  - An active (continuous und complete) process…
    - …which needs to be continuously updated (dynamic)…
    - …and which needs to focus on the individual MSS
- In this talk no consideration of
  - Instrumental improvements
  - The general process of quality management

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QA-measures for geodetic (measurement) processes

- **Accuracy (measurement uncertainty)**
- Reliability
- Resolution
- Sensitivity
- Completeness
- Availability (of information)
- Actuality
- Imprecision
- …

„classical" measures

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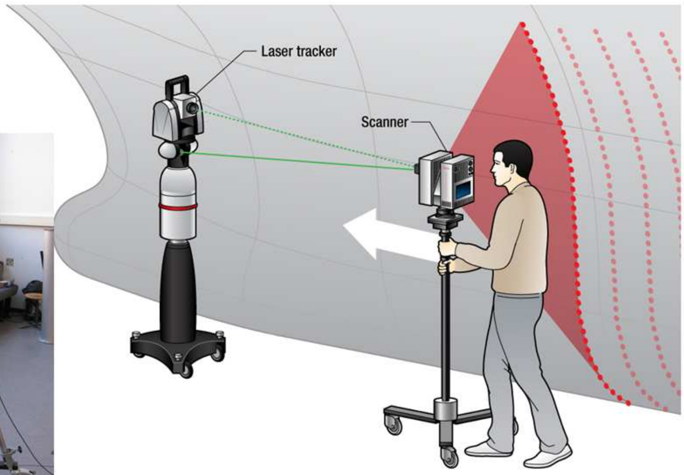
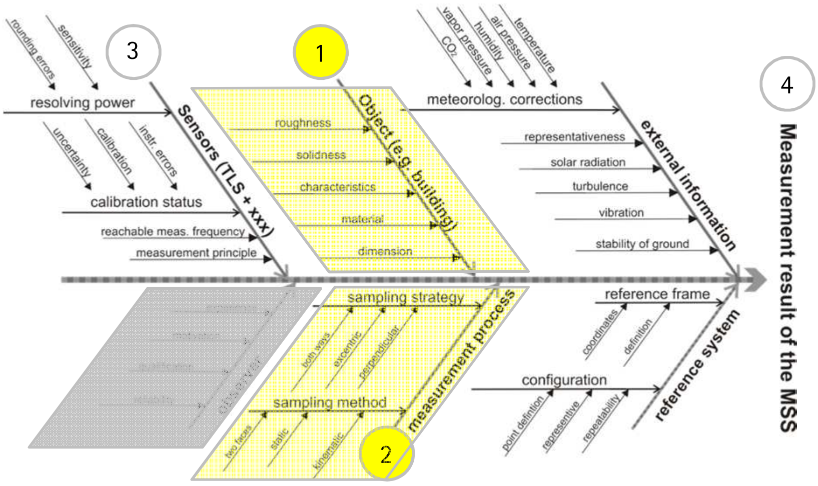
Exemplary kinematic terrestrial laser scanner (k-TLS) based MSS



[Ehm und Hesse, 2012]

Fish bone diagram for measurement results of a MSS (1) Object & (2) measurement process



[Hennes, 2007; Neumann, 2012]

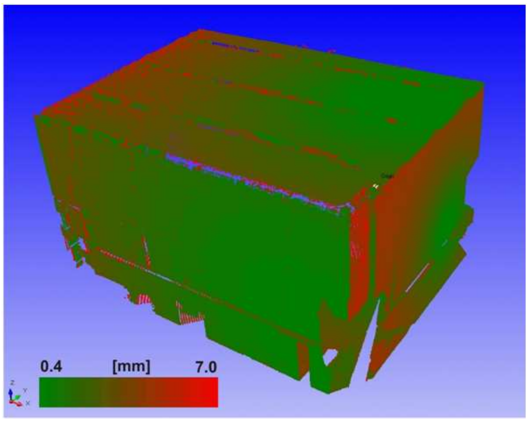
⇨ Individual treatment of the whole process necessary (e.g. DIN 18709, GUM)

Example for static TLS
Sensor- und object based characteristics

1

- Here modelled influence factors:
  - Range
  - Incidence angle
  - Intensity
- Showed measure:

$$\hat{\sigma}_i = \sqrt{\frac{sp\left(\Sigma_{P_iP_i}\right)}{3}}$$



[Vennegeerts et al., 2010]

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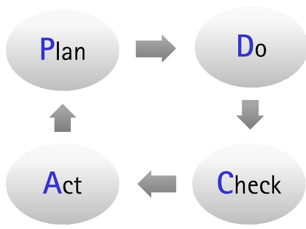
Components of QA for k-TLS based MSS

1

- Core issues of the quality assurance
  - Object related issues and geo-referencing process very important
  - Main influence factors on the measurement uncertainty
    - Range
    - Reflectivity of the object
    - Incidence angle
    - Material properties
    - etc.?



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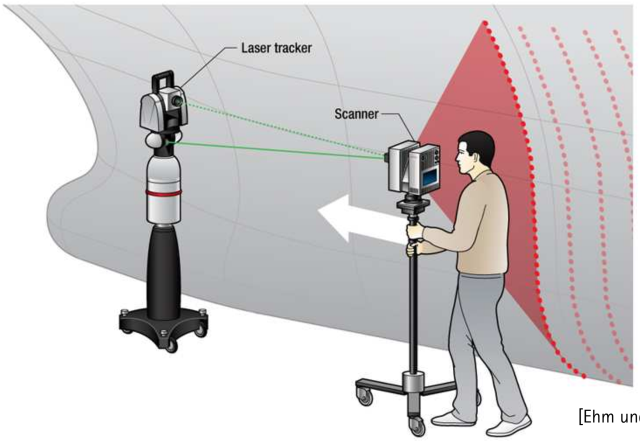
Adaption of measurement strategy in k-TLS based MSS

2

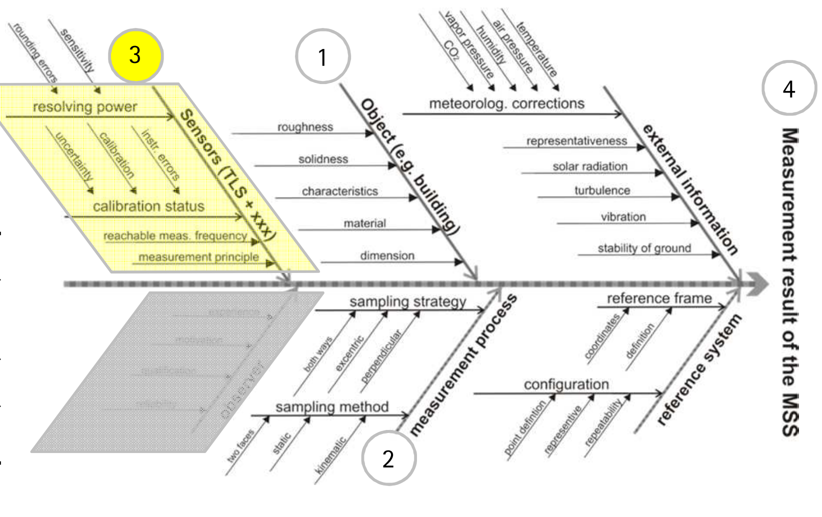
- Adopted measurement strategy (perpendicular sighting) to minimize object based characteristics



[Ehm und Hesse, 2012]

Fish bone diagram for measurement results of a MSS (3) Sensors

[Hennes, 2007; Neumann, 2012]



Calibration task for a (TLS based) MSS

3

1) Synchronisation (temporal referencing)
    - Common time scale for different data sources
    - Latency time due to imperfect synchronisation

2) **6 DoF calibration** aka spatial referencing (registration)
    - Individual sensor coordinate system → MSS coordinate system

3) Geo-referencing
    - MSS coordinate system → laboratory/global coordinate system (with in general known geodetic datum)

- An individual sensor calibration is assumed to be available

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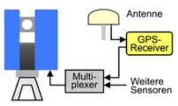
Establishment of temporal reference
Synchronisation of sensor data

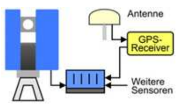
3

a) Integration of external sensor signals in data stream of laser scanner



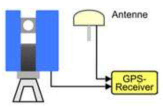
- More than one sensor → Multiplexer
- Limited to recording digital signals

b) Real-time unit/processor



- Most flexible solution (sensors, signals)
- "Draw back": extra software development required

c) <u>Trigger based: GNSS receiver | laser tracker</u>



- In general no extra hardware
- GPS Events (availability of UTC time stamp)
- <u>Release laser tracker measurement</u>

according to [Hesse, 2008]

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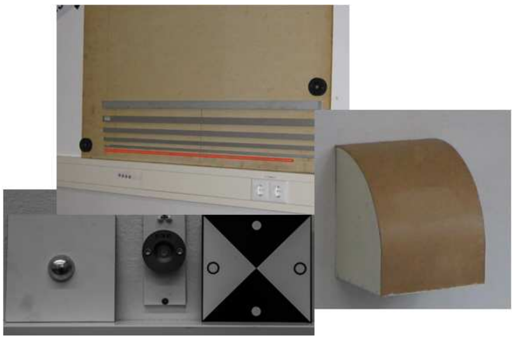
GIH

Establishment of a spatial reference
6 DoF determination and realization

3

- **6 DoF**, here in kinematic application
  - 3D Position and 3 spatial rotations
  - Geo-referencing using 3D positioning sensors, e.g.
    - Laser tracker – 6 DoF tracking device
- Calibration environment
  - 3D Lab @GIH with reference geometries
  - Reference sensor
    - Laser tracker
  - Common targets for
    - Laser scanner
    - Laser tracker



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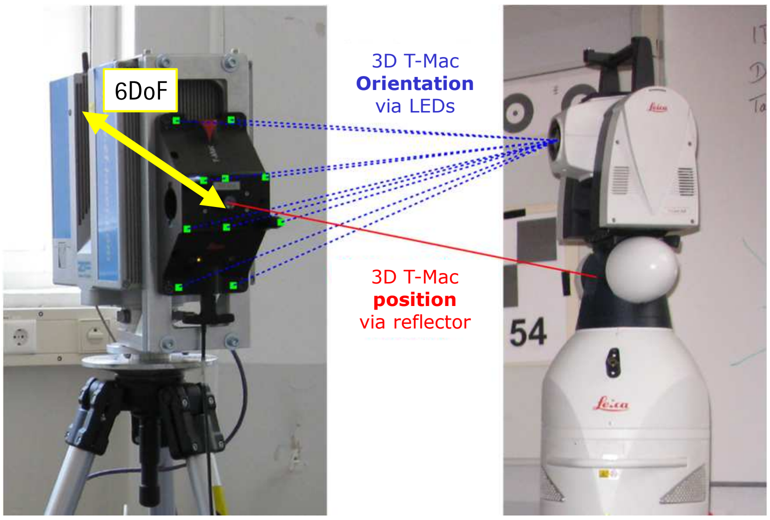
GIH

Establishment of a spatial reference
6 DoF determination and realization

3



[Dorndorf, 2015]

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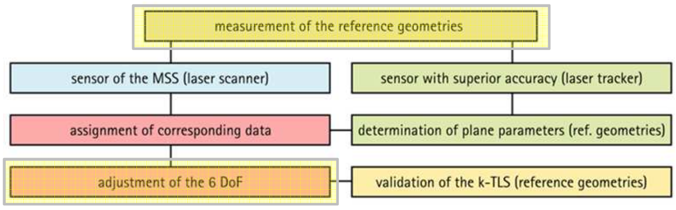
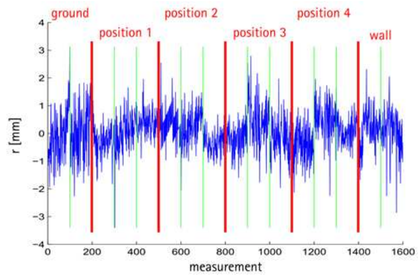
6 DoF
Calibration procedure

3

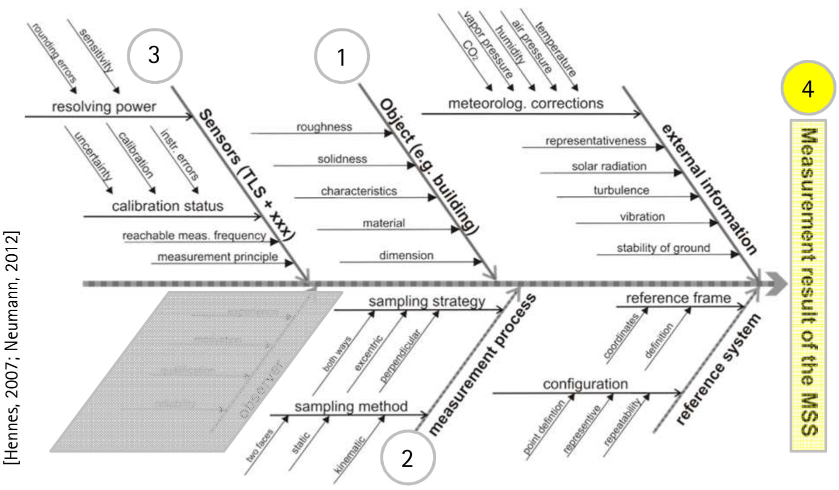




[Dorndorf, 2015]

Fish bone diagram for measurement results of a MSS
(4) Measurement results

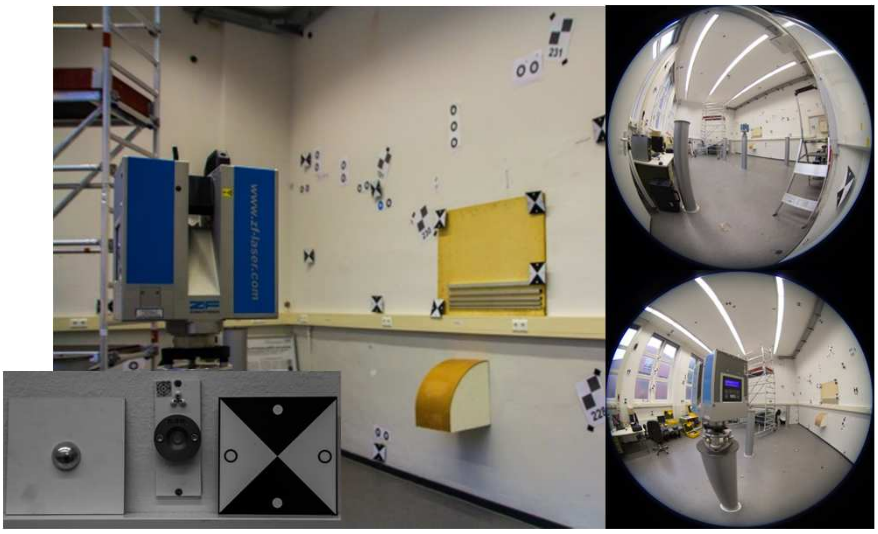
[Hennes, 2007; Neumann, 2012]



Individual treatment of the whole process necessary (e.g. DIN 18709, GUM)

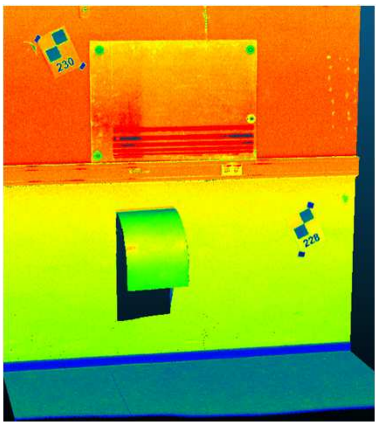
Validation of QA parameters
3D Lab calibration facilities @GIH

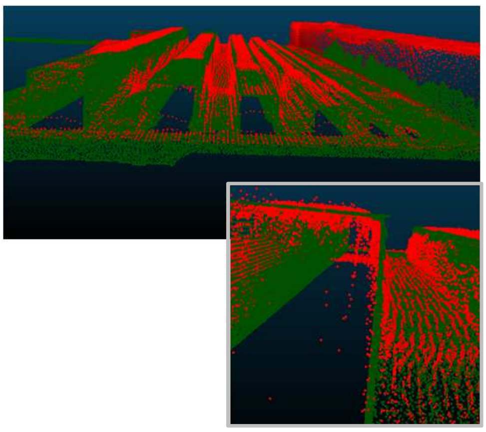
4



Validation of QA parameters in the object space
Laser tracker&T-Scan vs. k-TLS based MSS

4



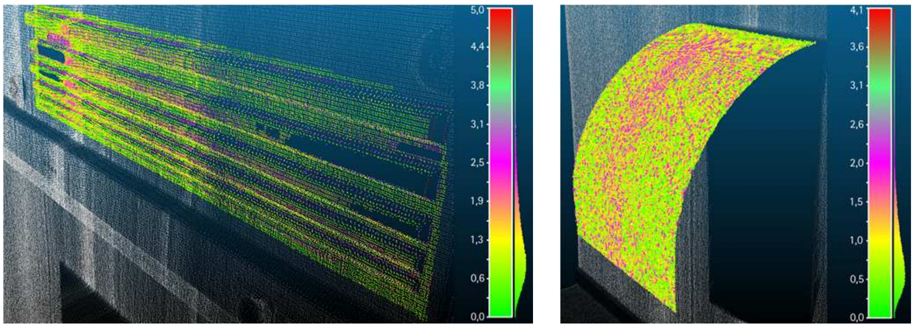


- Reference surfaces and –geometry to estimate QA parameters
- Also used for mobile mapping (e.g. bridges as reference geometry)

[Dorndorf, 2014]

Validation of QA parameters
Differences: Laser tracker&T-Scan vs. k-TLS based MSS

4

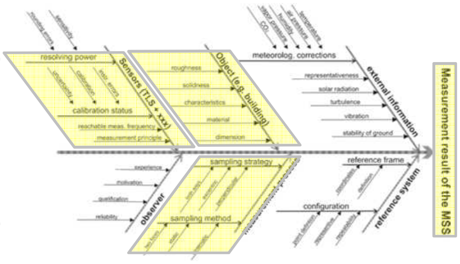


Measurement	Mean value [mm]	Sigma [mm]
Slow (rectangular pipe)	1.3	0.8
Slow (curved surface)	0.9	0.5

[Dorndorf, 2015]

Conclusion & Future work

[Hennes, 2007; Neumann, 2012]



- Integrated analysis of the sensors and i.e. the object related and environmental based factors is essential
- A few mathematical tools are available
  - But not yet considered in the QA process of MSS
- Future work: On-the-fly calibration during the general data acquisition

Thank you for your attention.

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