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

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Jens-André Paffenholz, Hamza Alkhatib and Ingo Neumann
Geodetic Institute, Leibniz Universität Hannover, Germany

Motivation

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
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 and 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

Accuracy (measurement uncertainty)
Reliability
Resolution
Sensitivity
Completeness
Availability (of information)
Actuality
Imprecision
...

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

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

Individual treatment of the whole process necessary (e.g. DIN 18709, GUM)
Example for static TLS
Sensor- und object based characteristics

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

- Showed measure:
\[ \tilde{\sigma}_i = \sqrt{\frac{\bar{P} \cdot \Sigma_{P\sigma}}{3}} \]

[Venneweerts et al., 2010]

Components of QA for k-TLS based MSS

- 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.

Plan \[\rightarrow\] Do

Act \[\leftrightarrow\] Check
Adaptation of measurement strategy in k-TLS based MSS

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

![Fish bone diagram for measurement results of a MSS](image)

[Elm und Hesse, 2012]

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

[Henri, 2007; Neumann, 2012]
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 $\rightarrow$ MSS coordinate system

3) Geo-referencing
   - MSS coordinate system $\rightarrow$ 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**

a) Integration of external sensor signals in data stream of laser scanner
   - More than one sensor $\rightarrow$ Multiplexer
   - Limited to recording digital signals

b) Real-time unit/processor
   - Most flexible solution (sensors, signals)
   - "Draw back": extra software development required

c) **Trigger based:** GNSS receiver | laser tracker
   - In general no extra hardware
   - GPS Events (availability of UTC time stamp)
   - Release laser tracker measurement

   according to [Hesse, 2008]
Establishment of a spatial reference 6 DoF determination and realization

- 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

[Dorndorf, 2015]
6 DoF Calibration procedure

- measurement of the reference geometries
- sensor of the MSS (laser scanner)
- sensor with superior accuracy (laser tracker)
- assignment of corresponding data
- determination of plane parameters (e.g. geometries)
- adjustment of the 6 DoF
- validation of the k-TLS (reference geometries)

Fish bone diagram for measurement results of a MSS

1. Measurement results
2. Individual treatment of the whole process necessary (e.g. DIN 18709, GUM)
3. [Domdorf, 2015]
4. [Hennes, 2007; Neumann, 2012]
Validation of QA parameters
3D Lab calibration facilities @GIH

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

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

[Dormdorf, 2014]
Validation of QA parameters
Differences: Laser tracker&T-Scan vs. k-TLS based MSS

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean value [mm]</th>
<th>Sigma [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow (rectangular pipe)</td>
<td>1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Slow (curved surface)</td>
<td>0.9</td>
<td>0.5</td>
</tr>
</tbody>
</table>

[Dorndorf, 2015]

Conclusion & Future work

- 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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Dr.-Ing. Jens-André Paffenholz, Dr.-Ing. Hamza Alkhatib and Prof. Dr.-Ing. Ingo Neumann
Geodetic Institute, Leibniz Universität Hannover, Germany
paffenholz@gih.uni-hannover.de | www.gih.uni-hannover.de