Quality assurance in building construction, based on engineering geodesy processes

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1. Motivation

- construction of high-rise buildings is getting more and more faster
- requests essential improvement of the quality assurance methods (especially for building geometry) applied directly and continuously on construction site
  → engineering geodesy processes well suited for quality assurance
  → interaction between construction and geodesy is required

Analysis and results within the DFG-project EQuiP
“Efficiency optimization and quality control of engineering geodesy processes in civil engineering”
Structure

1. Motivation
2. Construction processes
3. Quality assurance concept
4. Application
5. Summary and outlook

2. Construction processes

Theoretical reference project: climbing formwork

- Construction of a core of a typical high-rise building with a **climbing formwork**
- Special type of formwork for vertical concrete structures that rises with the building
- To raise the formwork for the production of the current wall section special platforms based on rail-suspended carriages are used
- The production process is based on repeating procedures and is set up as a working cycle
2. Construction processes

Formal model of the build process (3 hierarchy levels)

Building core
- 260 processes
- Process hierarchy based on macro and micro activity steps (REFA)
- Realized with petri nets

Total Time
- 1 week / storey

2. Construction processes

Integration of engineering geodesy processes

- An increase in quality of construction can be achieved through an optimized interface and better integration of the engineering geodesy processes
- Interaction takes place at different stages of construction
- Integration in the process model (orange transitions)

Example:
alignment of the formwork with the total station
3. Geometric quality assurance

### Quality Assurance Concept

- **Characteristics**
  - Accuracy
  - Correctness
  - Completeness
  - Reliability
  - Timeliness

- **Parameters**
  - Standard deviation
  - Tolerance correctness
  - Number of missing/odd elements
  - Condition density
  - Minimal detectable error (mde)
  - Impact of mde on parameters
  - Vulnerability to failures
  - Time delay

**Outer loop:**
- Construction of the building floor and the corresponding floor

**Inner loop:**
- Measuring formwork (alignment of the formwork)
4. Application

<table>
<thead>
<tr>
<th>Planning Phase</th>
<th>Real Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show impact of different input quantities (e.g. measurement configuration) on the results</td>
<td>parameter values are derived (a.o.) from the measurements</td>
</tr>
<tr>
<td>Quality assurance measure depends on the improvement of the measurement and construction processes</td>
<td>A quality assurance measure can be the use of alternative paths</td>
</tr>
<tr>
<td>Using Monte Carlo Method to propagate standard deviation and the tolerance throughout the processes</td>
<td>On the base of the parameters a decision is made in real time</td>
</tr>
</tbody>
</table>

Exemplary two parameters for describing the quality:

- **Standard deviation**: \( \sigma = \sqrt{\frac{\sum (x_i - \mu)^2}{n}} \)

- **Tolerance correctness**: \( t_c = \frac{1}{2} \sqrt{T^2 - T_M^2} - |l_{meas} - l_{nom}| \)

  - \( T \) – Tolerance
  - \( T_M \) – Surveying tolerance
  - \( l_{meas} \) – Measured size
  - \( l_{nom} \) – Nominal size
4. Application

- Simulation studies (in planning phase) for parameters standard deviation and tolerance correctness

<table>
<thead>
<tr>
<th>Process</th>
<th>Input / output variables</th>
<th>Input parameter values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build and Stationing</td>
<td>Input: 3 x control points, 9 observations (hz-, v-angle, distance)</td>
<td>$\sigma_{xyz}=0.005 \text{ m}$ $\sigma_{hz,v}=0.0003 \text{ gon}$ $\sigma_d=0.001 \text{ m}$</td>
</tr>
<tr>
<td>Output: 1 x station coordinates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring Formwork</td>
<td>Input: station coordinates, observations (hz-, v-angle, distance)</td>
<td>$\sigma_{xyz}=0.005 \text{ m}$ $\sigma_{hz,v}=0.0003 \text{ gon}$ $\sigma_d=0.001 \text{ m}$</td>
</tr>
<tr>
<td>Output: 2 x stake out points, 1 x tolerance</td>
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</tbody>
</table>

Parameter Output parameter values:

- $A: \sigma_x=3.2 \text{ mm} \sigma_y=3.2 \text{ mm} \sigma_z=3.1 \text{ mm}$
- $B: \sigma_x=3.1 \text{ mm} \sigma_y=3.2 \text{ mm} \sigma_z=3.1 \text{ mm}$
- $t_{c}=14.5 \text{ mm}$ ($T_m=6.6 \text{ mm}$)

→ Adaption of the process model

5. Summary and outlook

- research activities related to quality assurance in building construction
- collaborative work between civil- and geodetic engineers, which places special emphasis on the interface between construction and geodetic processes
- process model and quality assurance concept for building the inner core of a high rise building
- In real time and in the planning phase

→ Extended process model (e.g. alternative paths) to react on disturbances
Thank you for your Attention!

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