Process monitoring of construction sites by photogrammetric point clouds and 4D building information models (BIM)

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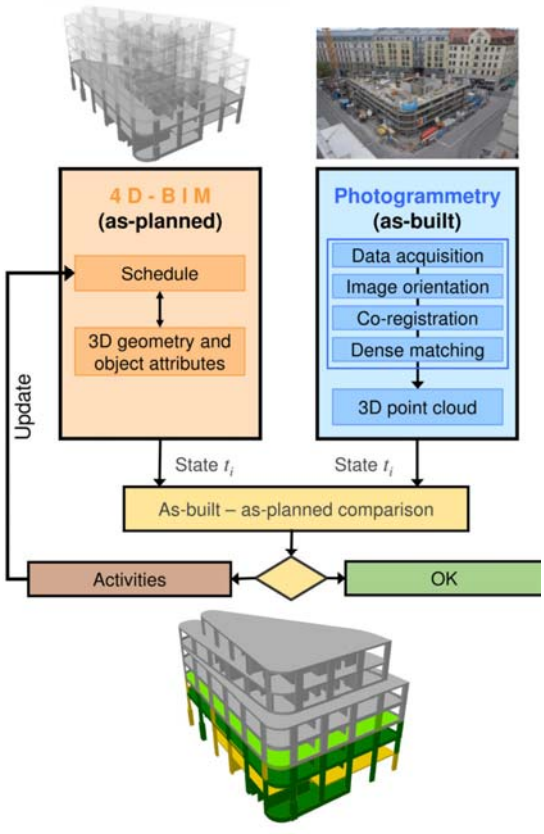
In contrast to industrial production, the processing steps on construction sites are extremely dynamic. Reasons for this are boundary conditions which are given by (i) weather, which is difficult to predict, (ii) strong dependency between single process steps and (iii) lack of strict process sequences as they exist in assembly line production. Because of multiple dependencies the actual execution of the construction work usually deviates from the planning. Therefore, monitoring of the construction process is important for recognizing delayed or premature construction steps. The deviations from the planning affect the overall organization, the schedule and the calculated costs and can lead to strong delays and a budget overrun. These effects can be mitigated by early detection of the deviations by a monitoring system.

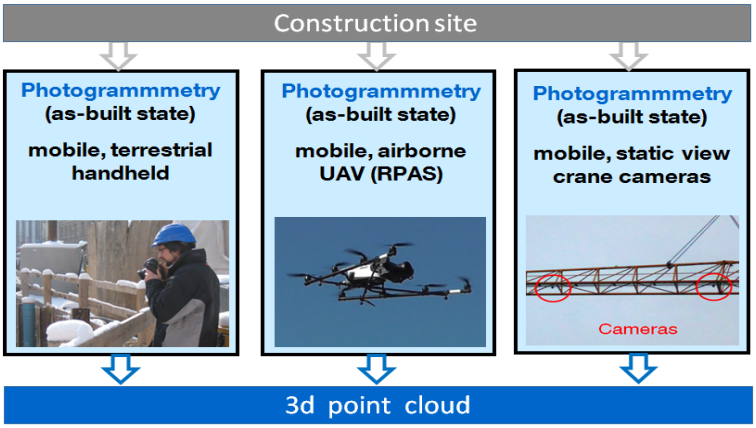
The classical manual recording of the sequential construction steps by a construction diary is time-intensive, error-prone and allows no detailed recording of the productivity. Because of this, methods for automatic area-based capturing of the changing 3D structure of a construction site over time were investigated in a DFG-funded project. The goal was the development of concepts for photogrammetric acquisitions (as-built state) and to prove the applicability of these concepts in real scenarios.

A BIM is a digital representation of a planned or built building. It contains the 3D geometry, process information and schedule, semantic classification of building elements as well as their relations. The BIM stores information for all project partners during the whole life cycle of a building from the early planning and design phase over the construction phase, the operation and maintenance phase to renovation or demolition. Furthermore, in a BIM the object-oriented 3d-model is linked to temporal information like realization periods or predicted completion dates. Additionally, quantities and costs can be modeled. Based on the BIM, several analytic and simulation tools (energy consumption, cost estimation, visualizations, structural analysis, ...) can be applied.



For automatic construction progress monitoring the BIM has to be compared to the actual state at the date of an acquisition. The **as-built state** is created from photogrammetric images, which are processed to create a 3D point cloud. The **as-planned state** of the construction is requested to a 4D Building Information Model (BIM). Based on the detected building elements, statements on the overall progress can be derived. The results are used to update the BIM, and particularly to optimize the schedule.

In the presented approach the 3D as-built state is calculated from photogrammetric images using multi-view stereo reconstruction. Different acquisition strategies and techniques, namely (i) terrestrial acquisition with a hand-held camera, (ii) aerial acquisition using a Unmanned Aerial Vehicle (UAV) and (iii) acquisition using a fixed stereo camera pair at the boom of the crane, are tested on three test sites.



Due to the different acquisition conditions for stereo reconstruction like distance, baseline, overlap, viewing angle, point matching and the different geometry of the sites, different qualities of the reconstructed 3d coordinates of points from the clouds can be expected, too. Additionally, it has to be considered that the acquisition geometry changes according to the steps of building process itself. Furthermore, on construction sites one has to cope with several difficulties like security aspects, limited accessibility, occlusions or construction activity.

Results are assessed considering the special needs for the monitoring tasks and limitations on construction sites. The three scenarios are evaluated based on the ability of automation, the required effort for acquisition, the necessary equipment and its maintaining, disturbance of the construction works, and on the accuracy and completeness of the resulting point clouds

This work was carried out in the frame of **Leonhard Obermeyer Center** (LOC) at TUM which focuses on digital methods for the build environment, see http://www.loc.tum.de .

References

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