

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

[selected slides]

Uwe Stilla, stilla@tum.de

Co-Authors: S. Tuttas, A. Braun, A. Bormann



Monitoring of building construction progress based on photogrammetric point clouds and 4d-building information models (BIM)

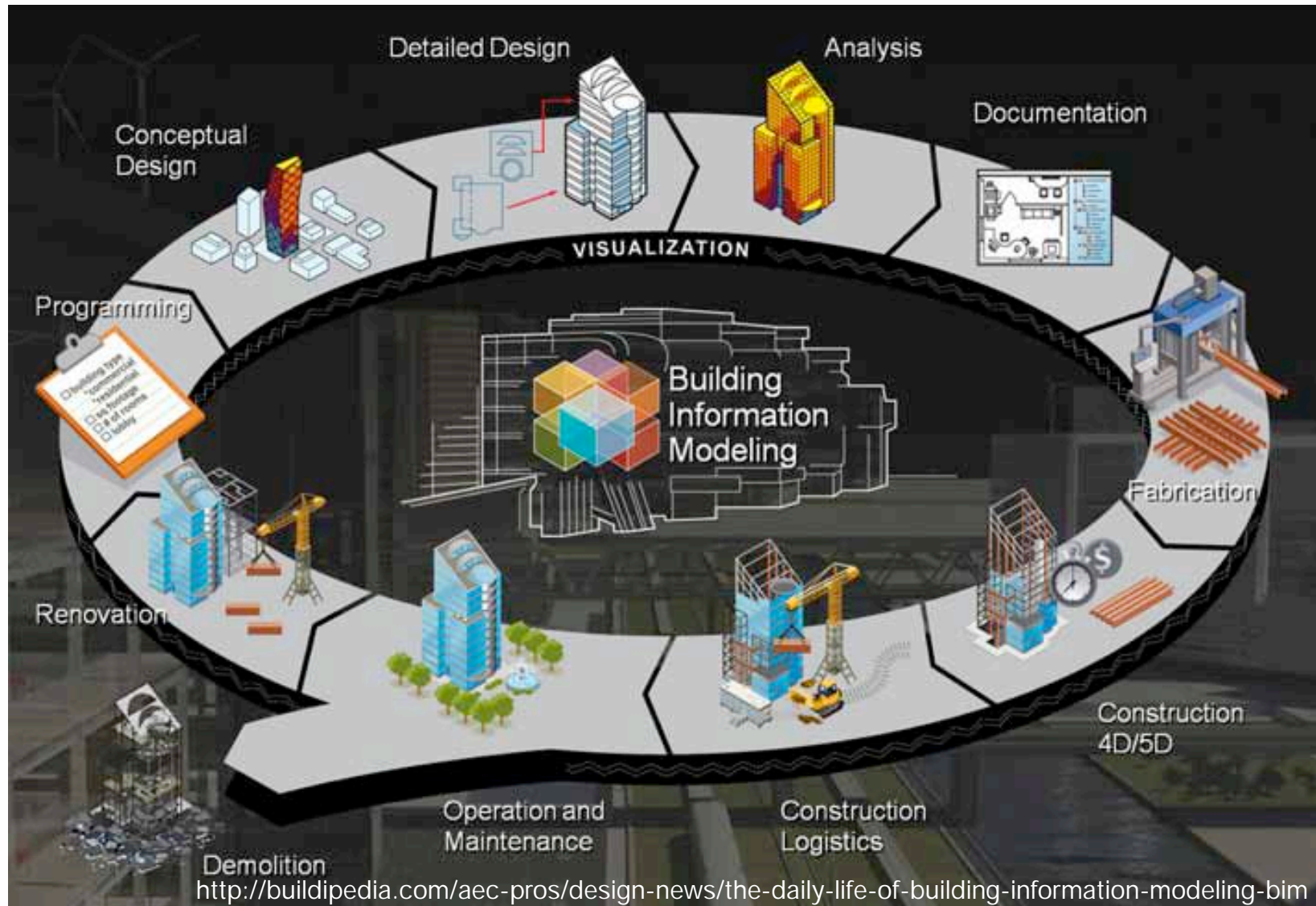
- r *ProgressTrack*: funded by German Research Foundation

- r Operating sequences of building projects are extremely dynamic
 - | difficult predictable boundary conditions (e.g. weather)
 - | strong dependency of single process steps
 - à Very often strong delays and budget overrun

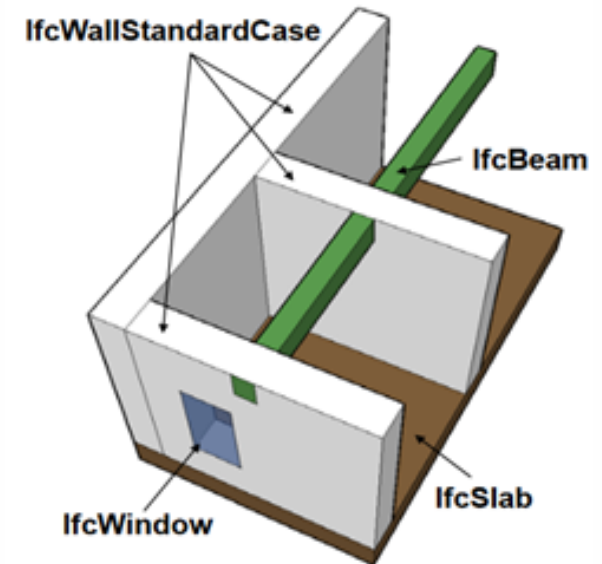
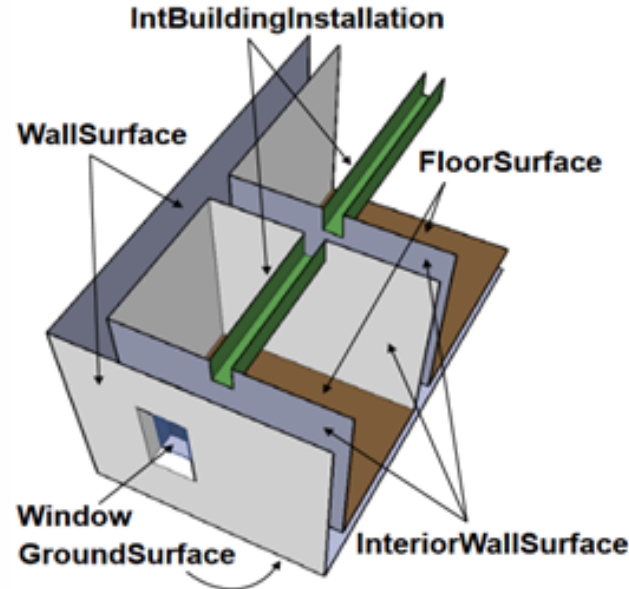
- r acquisition of the actual construction progress is essential for
 - | cost controlling
 - | organization of the further working schedule

- r up to now:
 - | manual by inspection of the site manager
 - | documentation by a handwritten construction diary
 - à planned: automatic acquisition

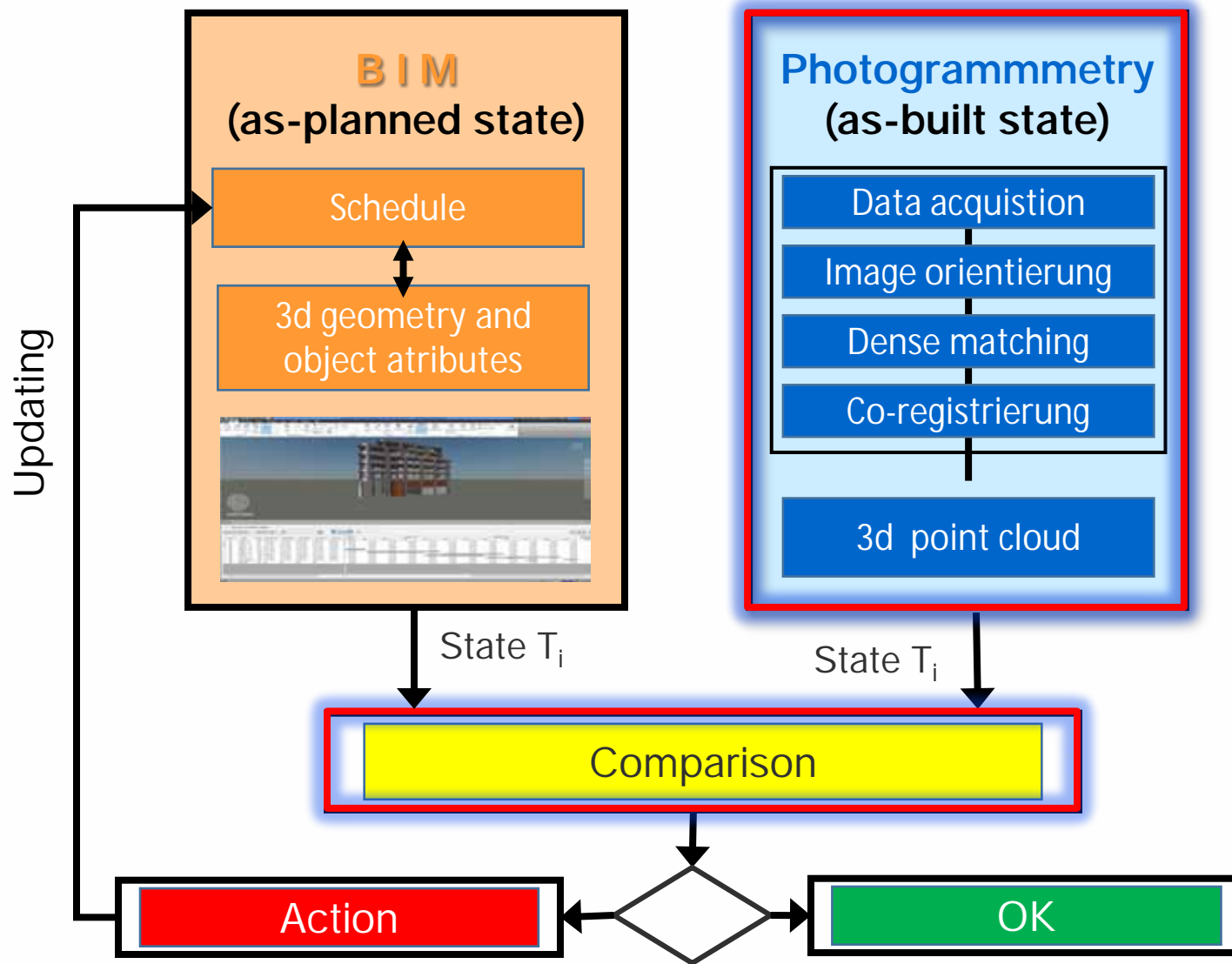
Motivation – Building Information Modeling (BIM)



	GIS	BIM
Geometry	Surface based	Volume based
Description	CityGML	IFC
Level of detail	Five levels	None
Semantics	Boundary surfaces	Building elements



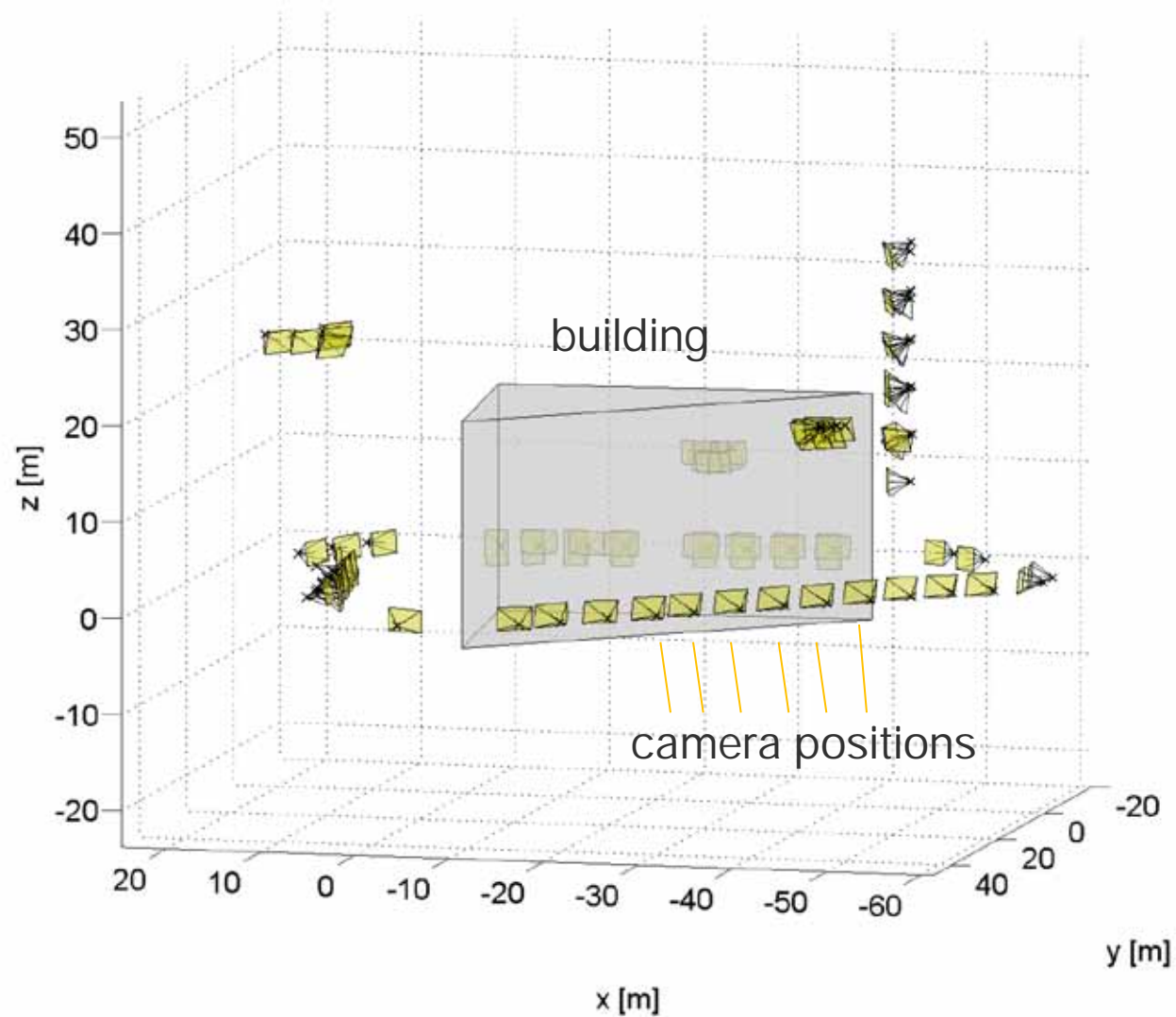
(Gröger et al., 2012)
(Nagel et al., 2009)











Different positions of aquisition



Positions of acquisitions JUN-27



Positions of acquisitions JUN-12

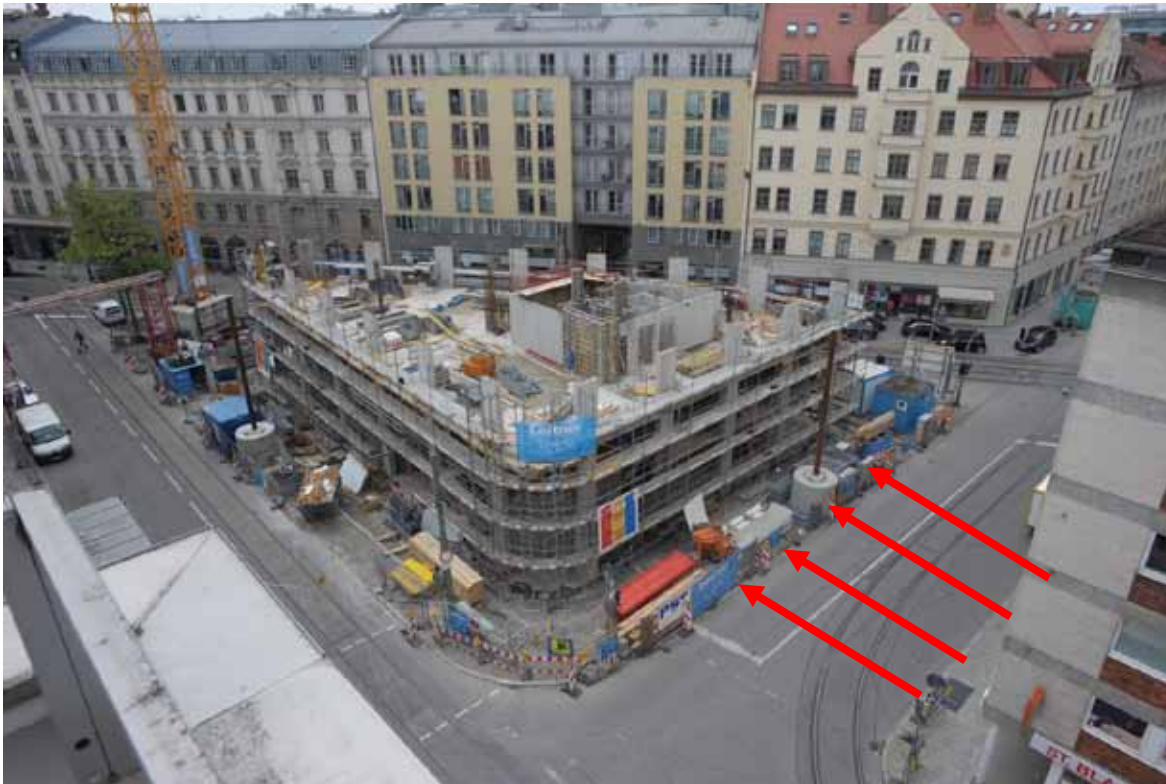


Image orientation – corresponding points



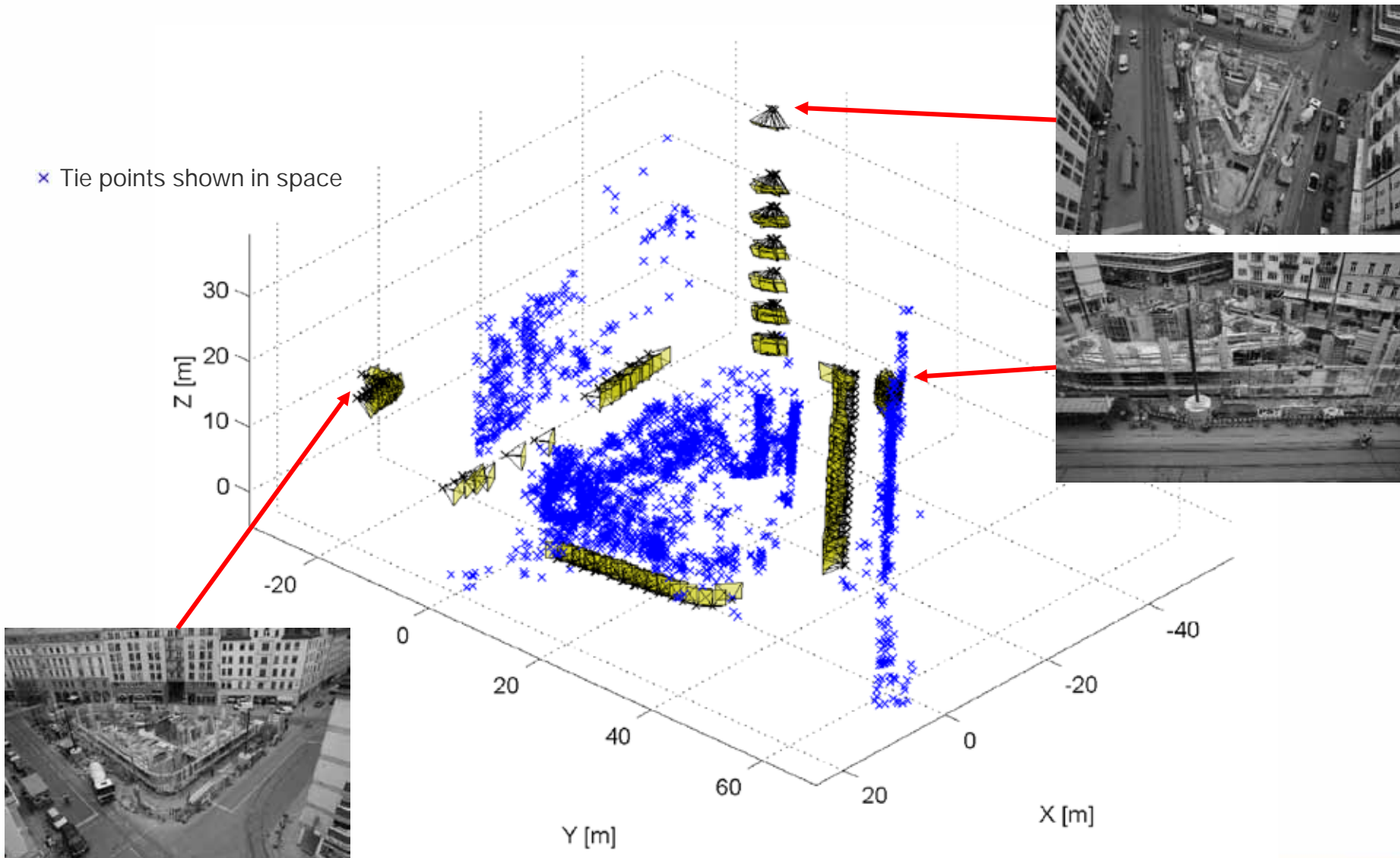
● Ground Control Points

— Tie points (Features)

Ground Control Points – points having known coordinates



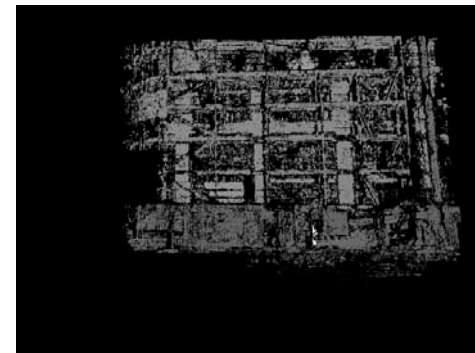
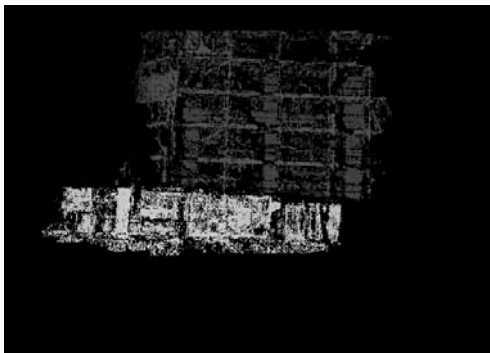
Tie points – corresponding image points



Selection of appropriate stereo pairs

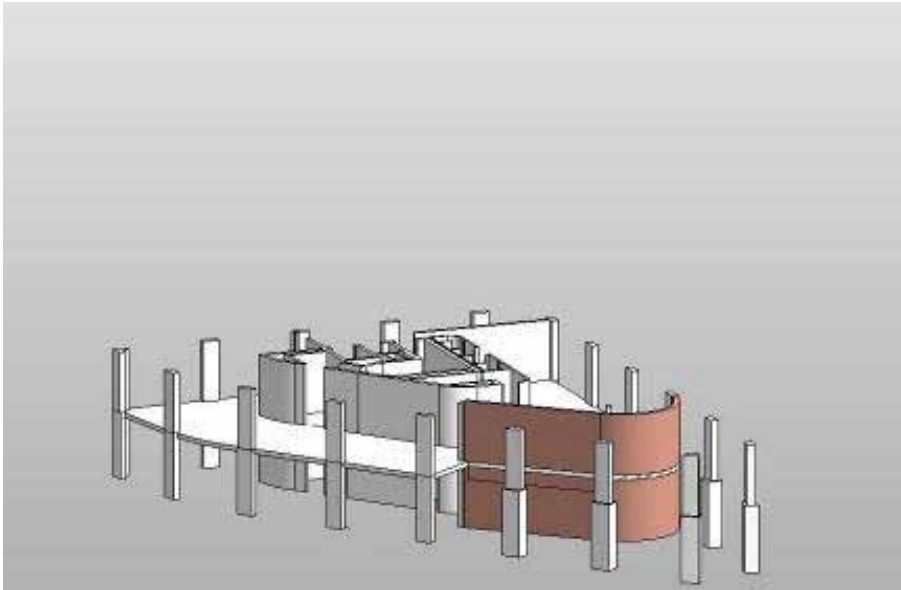


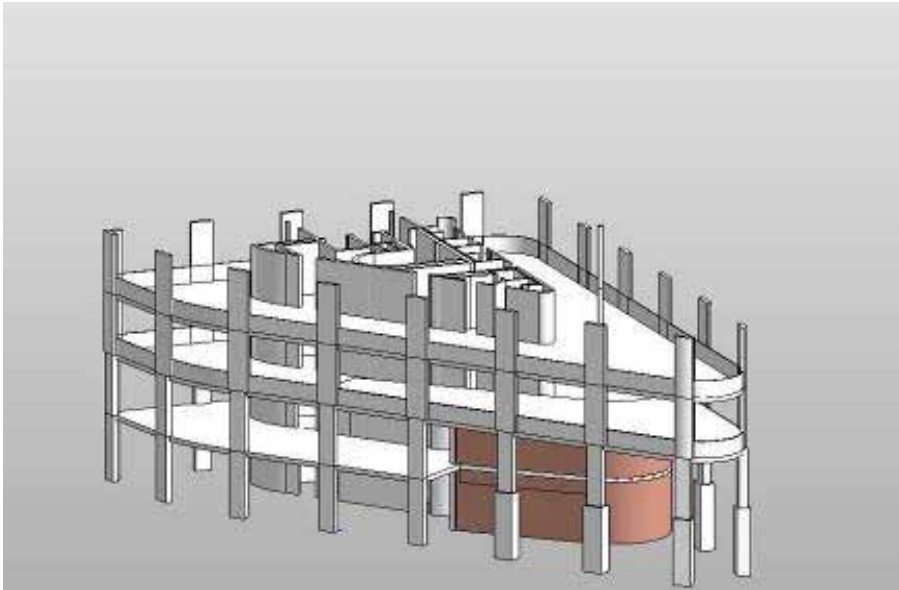
Depth value for each pixel by Dense-Stereo-Matching



Fusion of depth maps ® Triangulation of 3d points

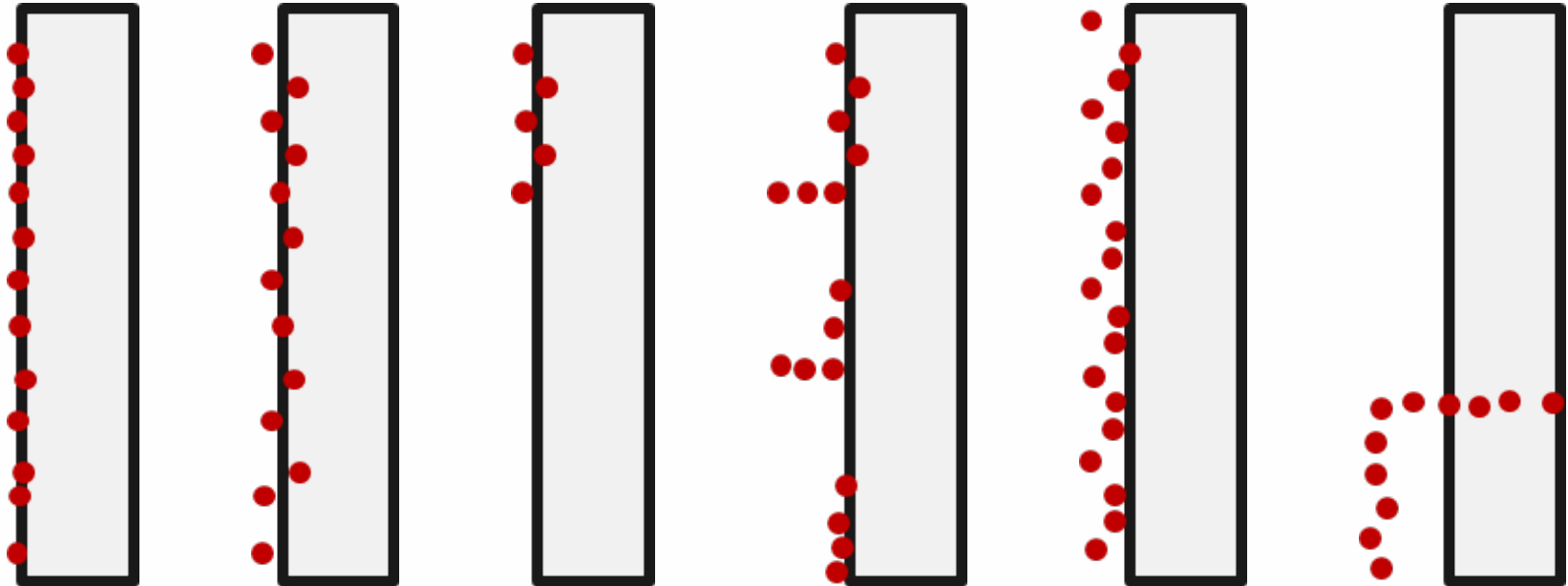












r Punkte auf Bauteiloberfläche

a) bei guter Tiefengenauigkeit,

b) bei schlechterer Tiefengenauigkeit,

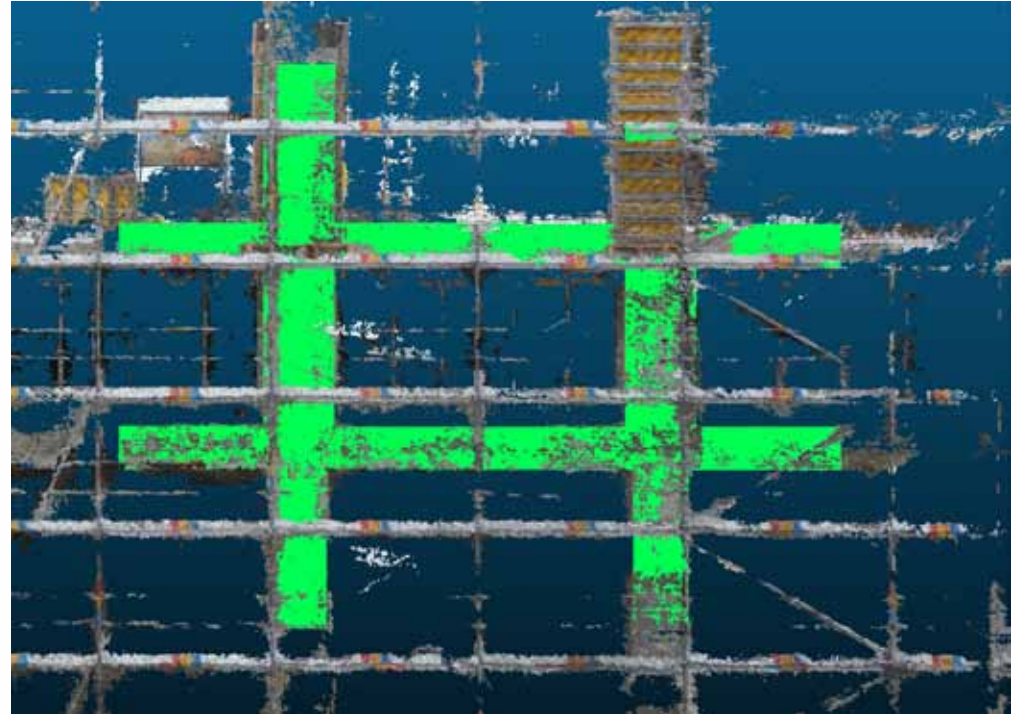
c) bei Verdeckung des unteren Bereiches;

d) Bauteil mit Verdeckungen und Punkte vom Gerüst;

e) Bauteil mit Verschalung;

f) nicht vorhandenes Bauteil bei vorhandenem temporären Objekt

- r Which construction parts are verified by the points?
- r Extraction of points around the object parts.
- r Rasterization of object planes (10 cm)
- r Check for every raster cell if the points confirm the presence of the construction object.



- r Measure which considers amount of points, accuracy (s) and distance (d) of points to plane:

$$M = \frac{1}{m_d} \times \sum_i \frac{1}{d_i \times s_d} \quad \text{mit} \quad d_i = \begin{cases} d_i & \text{für } d_i > d_{\min} \\ d_{\min} & \text{für } d_i \leq d_{\min} \end{cases}$$

- r Values for thresholds:

$$\begin{aligned} p_d &= 2 \text{ cm} \quad \text{“Point density”} \\ d_i &= 2 \text{ cm} \\ s_d &= 1 \text{ cm} \\ d_{\min} &= 0.5 \text{ cm} \end{aligned}$$

All results are available in the BIM !

progressTrack Viewer

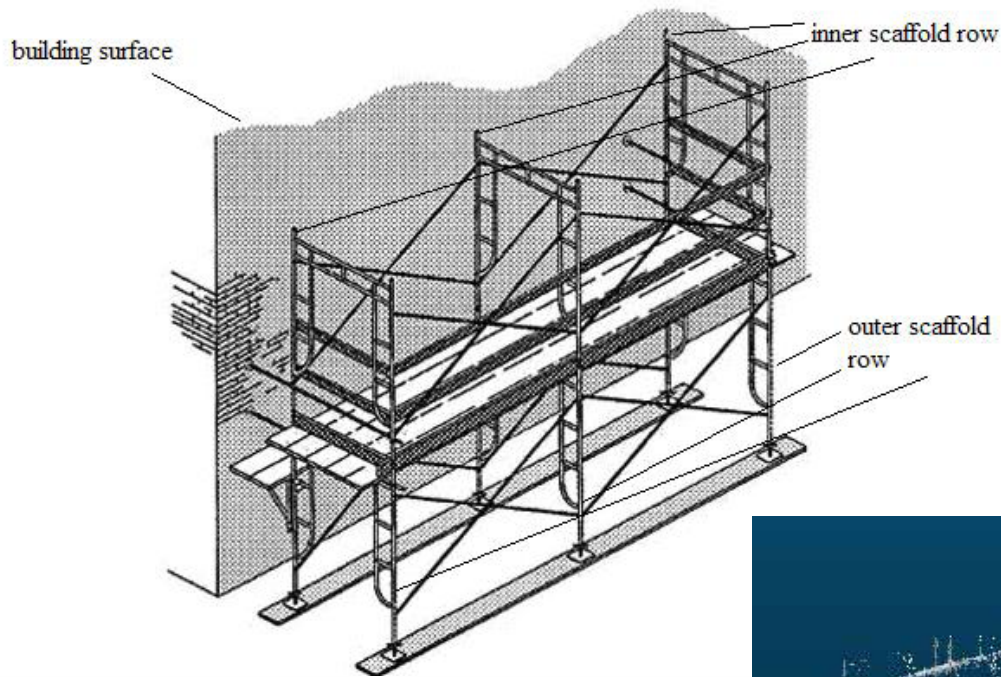
System	Model	Processes	Tag	ID	Name	Material	Tr
1	(2 item(s))						
380879	0uDYMG6uClBewbCIBEt	Basic Wall	MW	17.5	380879	Mauerwerk - Zie	F
384309	0jdHoqTj5KA21381efmZ	Basic Wall	STB	25.0	384309	Stahlbeton - Ort	F
385172	0jdHoqTj5KA21381efmC2	Basic Wall	STB	20.0	385172	Stahlbeton - Ort	F
386721	0jdHoqTj5KA21381efmKt	Basic Wall	STB	20.0	386721	Stahlbeton - Ort	F
387193	0jdHoqTj5KA21381efm0l	Basic Wall	STB	20.0	387193	Stahlbeton - Ort	F
387476	0jdHoqTj5KA21381efm02	Basic Wall	STB	25.0	387476	Stahlbeton - Ort	F
389209	1LoGWnNV97PeZmeR_e0X	Basic Wall	MW	17.5	389209	Mauerwerk - Zie	F
389626	1LoGWnNV97PeZmeR_e0X	Basic Wall	MW	17.5	389626	Mauerwerk - Zie	F
391053	1LoGWnNV97PeZmeR_e0X	Basic Wall	MW	17.5	391053	Mauerwerk - Zie	F
391866	1LoGWnNV97PeZmeR_e0X	Basic Wall	STB	20.0	391866	Stahlbeton - Ort	F
392613	1LoGWnNV97PeZmeR_e0X	Basic Wall	STB	20.0	392613	Stahlbeton - Ort	F
393750	1LoGWnNV97PeZmeR_e0X	Basic Wall	STB	20.0	393750	Stahlbeton - Ort	F
394801	1_CjpcU318bxd9a3waK9B9	Basic Wall	STB	25.0	394801	Stahlbeton - Ort	F
396284	1_CjpcU318bxd9a3waK9Y4	Basic Wall	STB	20.0	396284	Stahlbeton - Ort	F
396767	1_CjpcU318bxd9a3waK9ad	Basic Wall	STB	25.0	396767	Stahlbeton - Ort	F
420199	1wJQc75lv2LxK9245ed_O	Basic Wall	STB	25.0	420199	Stahlbeton - Ort	F
420962	1wJQc75lv2LxK9245edgT	Basic Wall	STB	20.0	420962	Stahlbeton - Ort	F
424626	2VC_q08Ebf_RcD8cooc5w	Basic Wall	MW	17.5	424626	Mauerwerk - Zie	F
425263	2VC_q08Ebf_RcD8cooc5a	Basic Wall	STB	25.0	425263	Stahlbeton - Ort	F
426889	2VC_q08Ebf_RcD8coocJU	Basic Wall	STB	25.0	426889	Stahlbeton - Ort	F
428958	2VC_q08Ebf_RcD8coocL	Basic Wall	STB	25.0	428958	Stahlbeton - Ort	F
432250	2jly2Pr0r69H_dglL0RLB9	Basic Wall	MW	17.5	432250	Mauerwerk - Zie	F
432341	2jly2Pr0r69H_dglL0RLAc	Basic Wall	MW	17.5	432341	Mauerwerk - Zie	F
433340	1C13E2IBH8P8IFBuh7Fu0r	Basic Wall	STB	30.0	433340	Stahlbeton - Ort	F
434773	1C13E2IBH8P8IFBuh7Fncv	Basic Wall	STB	30.0	434773	Stahlbeton - Ort	F
434977	1C13E2IBH8P8IFBuh7FnyC	Basic Wall	STB	30.0	434977	Stahlbeton - Ort	F
435531	1C13E2IBH8P8IFBuh7Fnxb	Basic Wall	STB	30.0	435531	Stahlbeton - Ort	F
436101	1C13E2IBH8P8IFBuh7Fnkc	Basic Wall	STB	25.0	436101	Stahlbeton - Ort	F
436483	1C13E2IBH8P8IFBuh7FnKc	Basic Wall	STB	25.0	436483	Stahlbeton - Ort	F
443460	3nn8XZBL7zQF5y5kvZ3a	Basic Wall	STB	25.0	443460	Stahlbeton - Ort	F
444152	3nn8XZBL7zQF5y5kvZaO	Basic Wall	STB	25.0	444152	Stahlbeton - Ort	F
444750	3nn8XZBL7zQF5y5kvZQk	Basic Wall	STB	25.0	444750	Stahlbeton - Ort	F
455378	1VWCL1KGH48vE2UddRC	Basic Wall	STB	25.0	455378	Stahlbeton - Ort	F
456189	1VWCL1KGH48vE2UddRC	Basic Wall	MW	17.5	456189	Mauerwerk - Zie	F
457887	2MxJ3BtX9NQk5v3nr63Y	Basic Wall	STB	25.0	457887	Stahlbeton - Ort	F
459641	2MxJ3BtX9NQk5v3nrPy4	Basic Wall	MW	17.5	459641	Mauerwerk - Zie	F
460352	2MxJ3BtX9NQk5v3nrPez	Basic Wall	MW	17.5	460352	Mauerwerk - Zie	F
461068	2MxJ3BtX9NQk5v3nrPLn	Basic Wall	MW	17.5	461068	Mauerwerk - Zie	F
461252	2MxJ3BtX9NQk5v3nrPM	Basic Wall	MW	17.5	461252	Mauerwerk - Zie	F
540893	2bmQJFV0zWp6nKDWpvc	Basic Wall	MW	7.5	540893	Mauerwerk - Zie	F
541007	2bmQJFV0zWp6nKDWpvc	Basic Wall	MW	7.5	541007	Mauerwerk - Zie	F

- As planned model
- As planned process
- Detected, in-time
- Detected, ahead of time

Photogrammetric Observations | Gantt Chart | Precedence Relationships

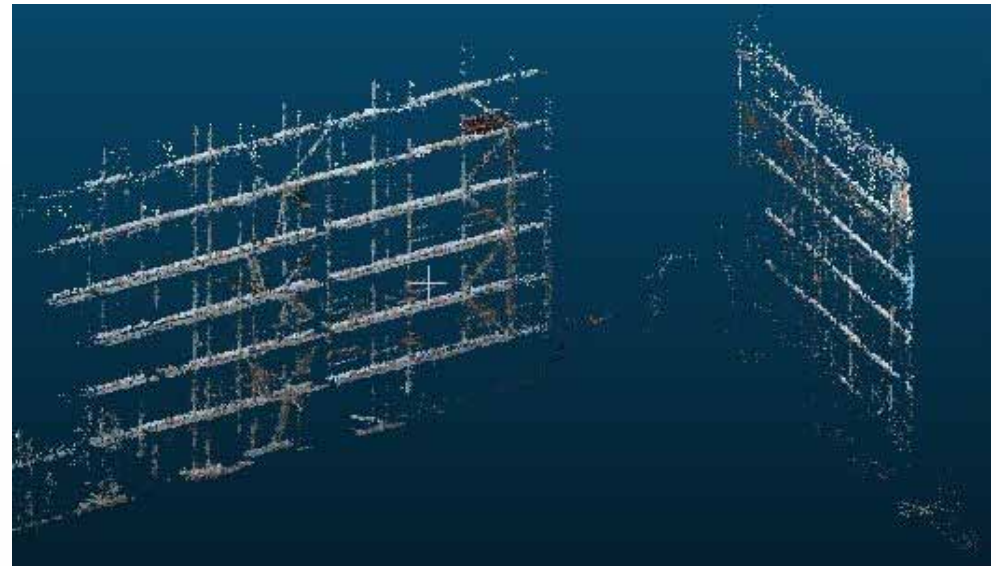
ID	Date
2	5/15/2013 12:00:00 AM
1	8/27/2013 12:00:00 AM

karlstrasse



Assumption:

Standard parts of a scaffold are known (e.g. length and diameter of the poles)





RPAS

r ASCTEC

┆ Falcon

Camera

r Sony NEX-7

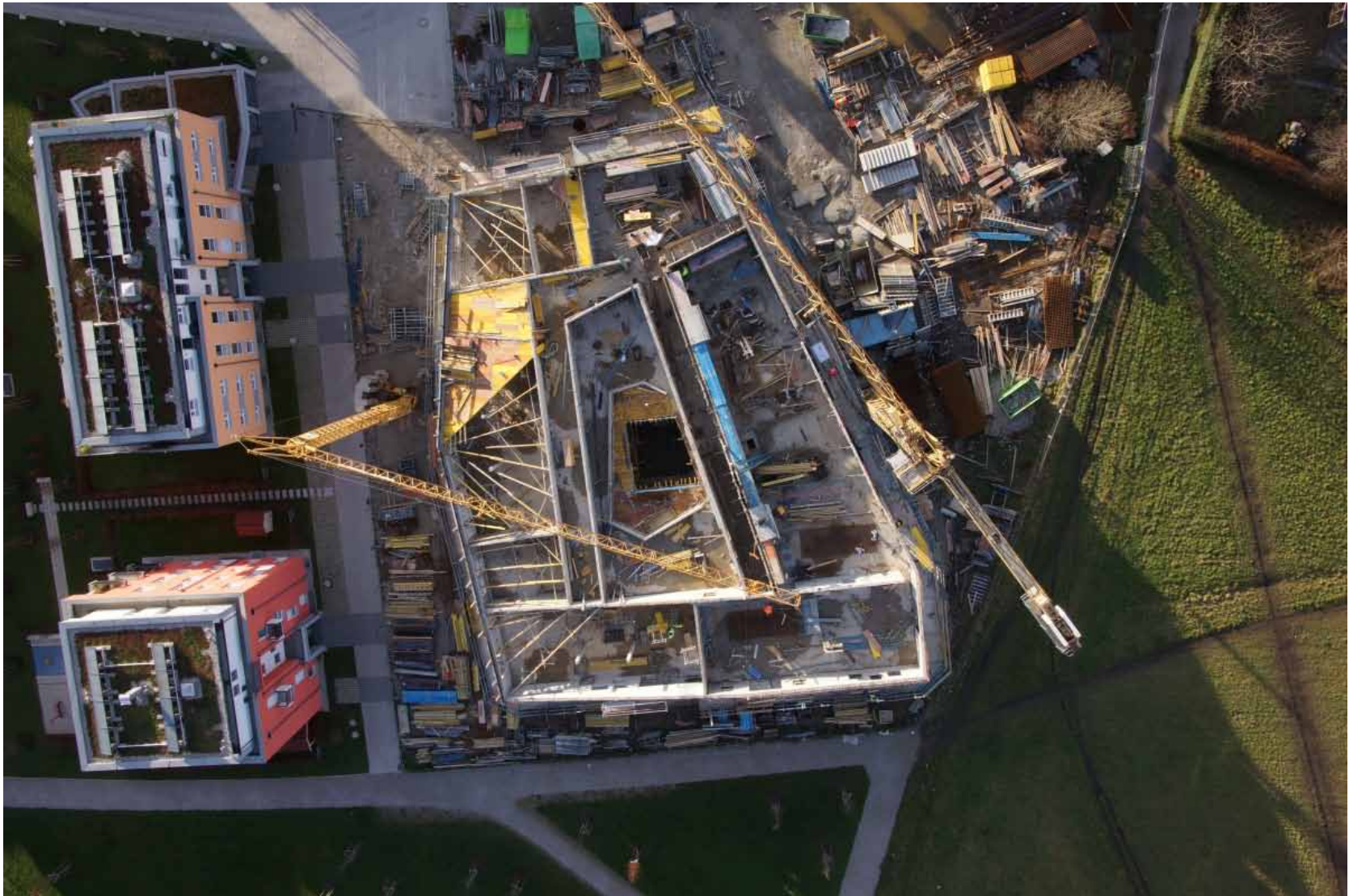
r RGB

r 6000 x 4000 pix

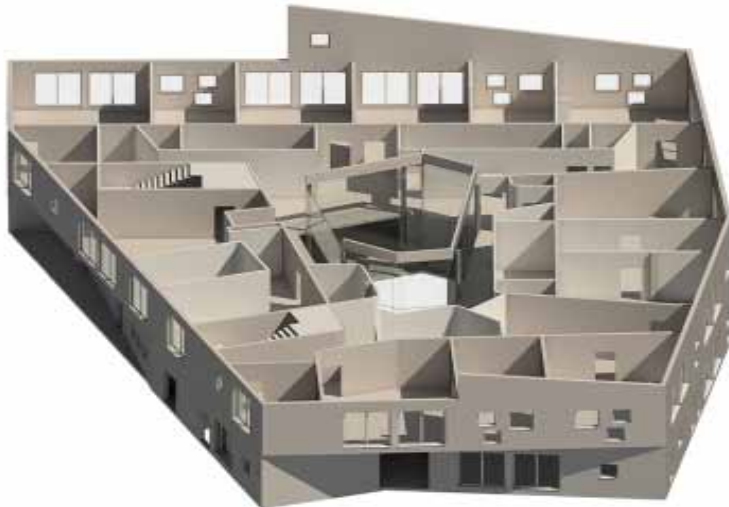
r Wide angle lens





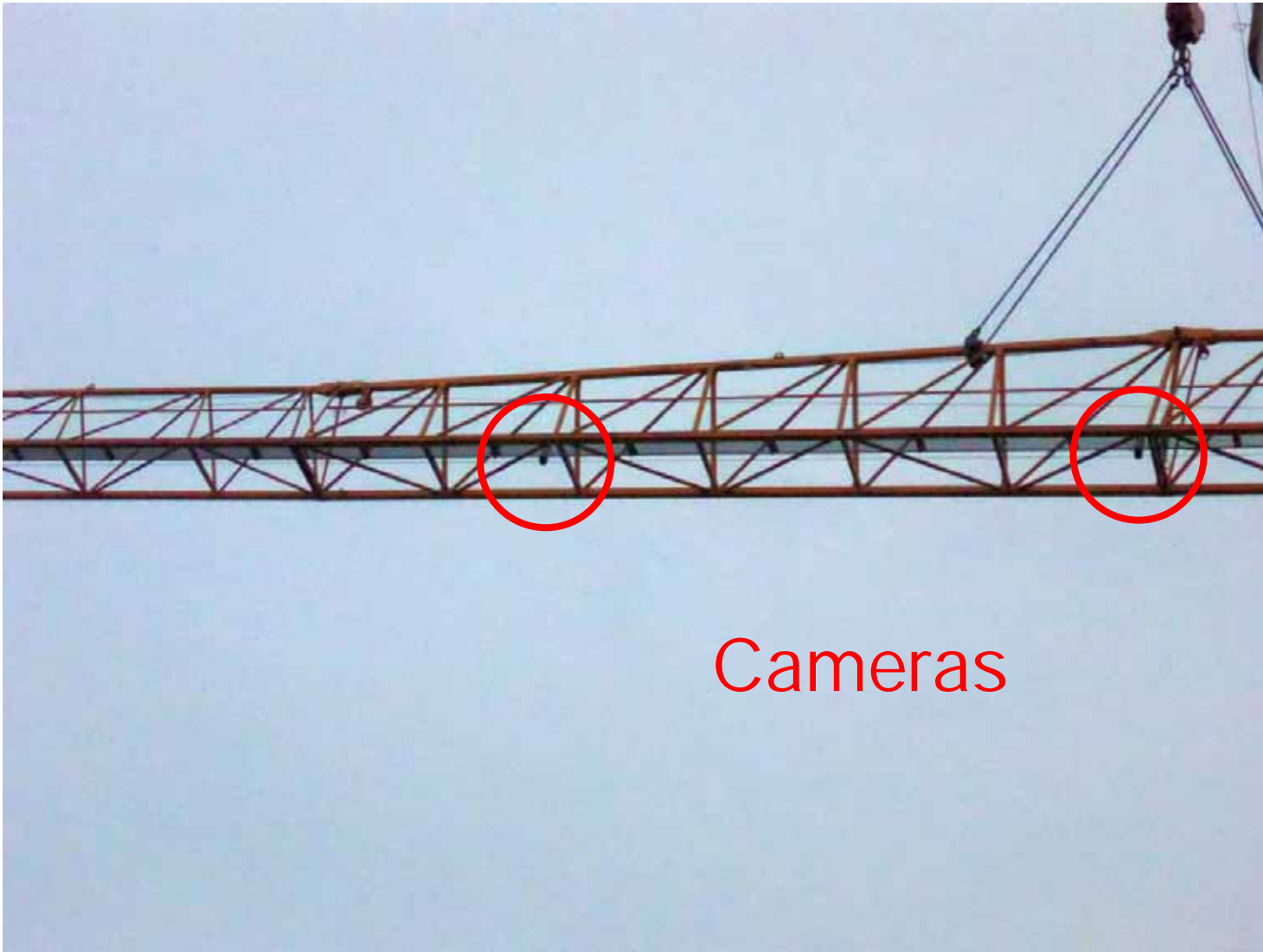




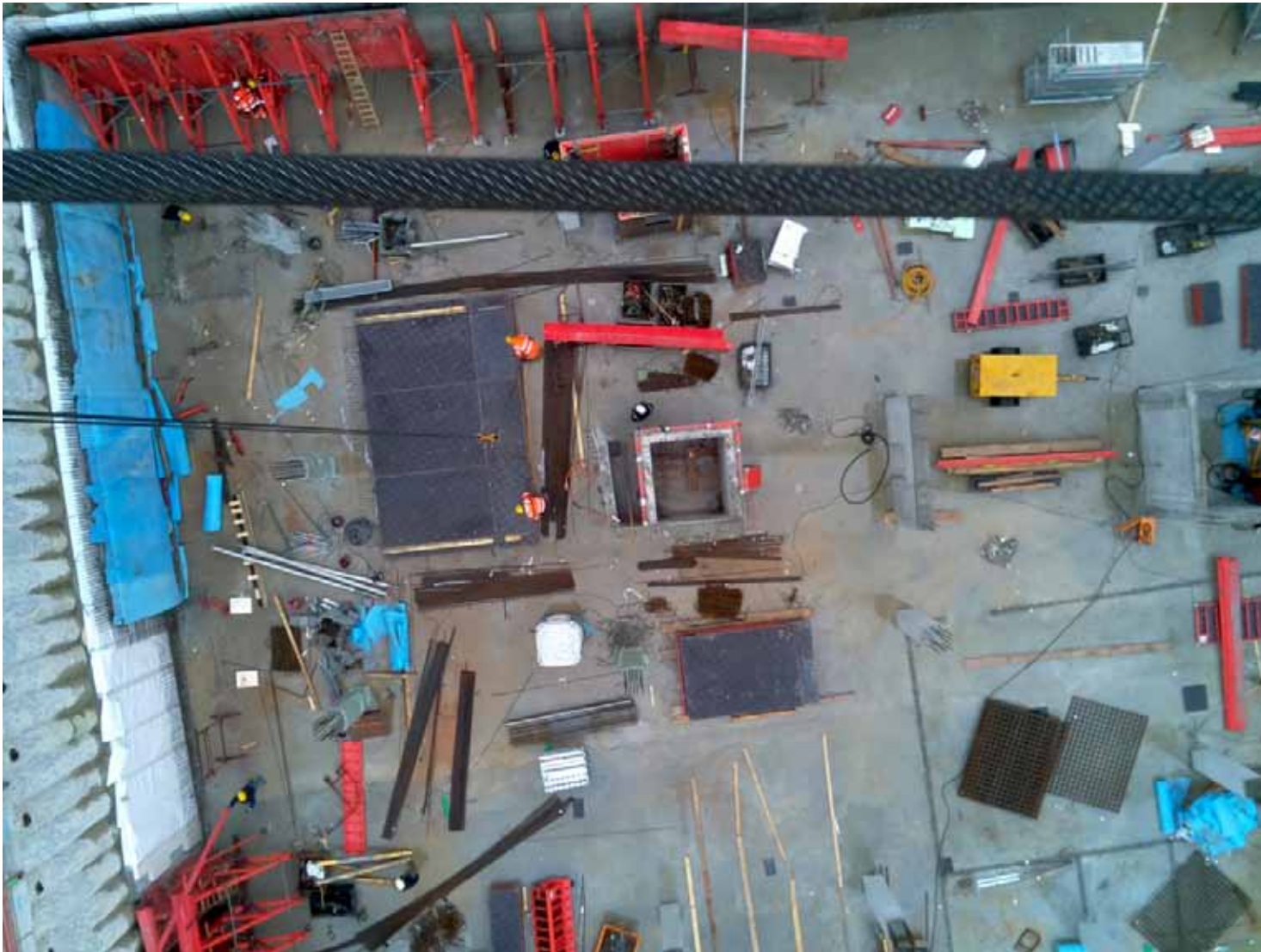


Cameras mounted on the crane jib

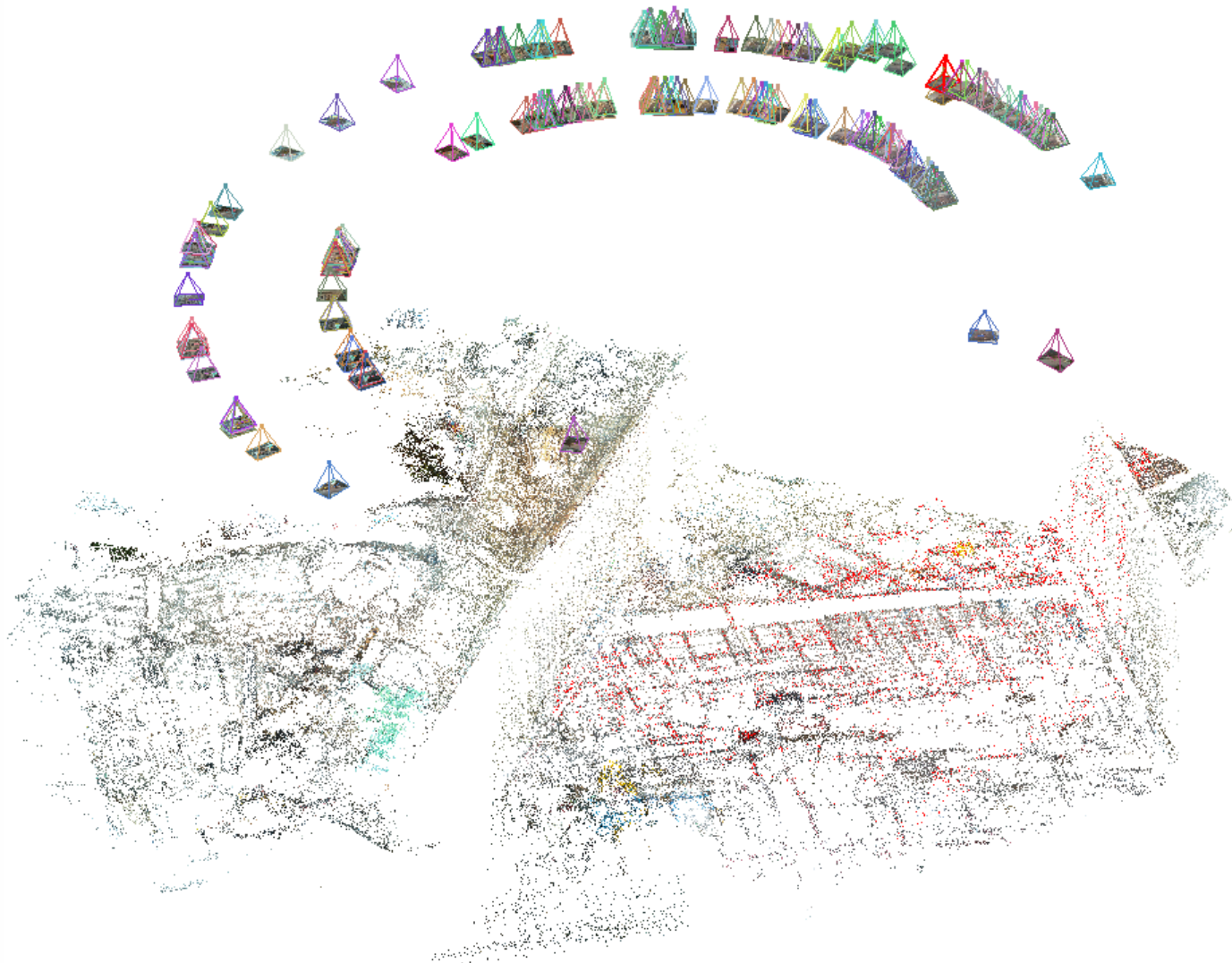


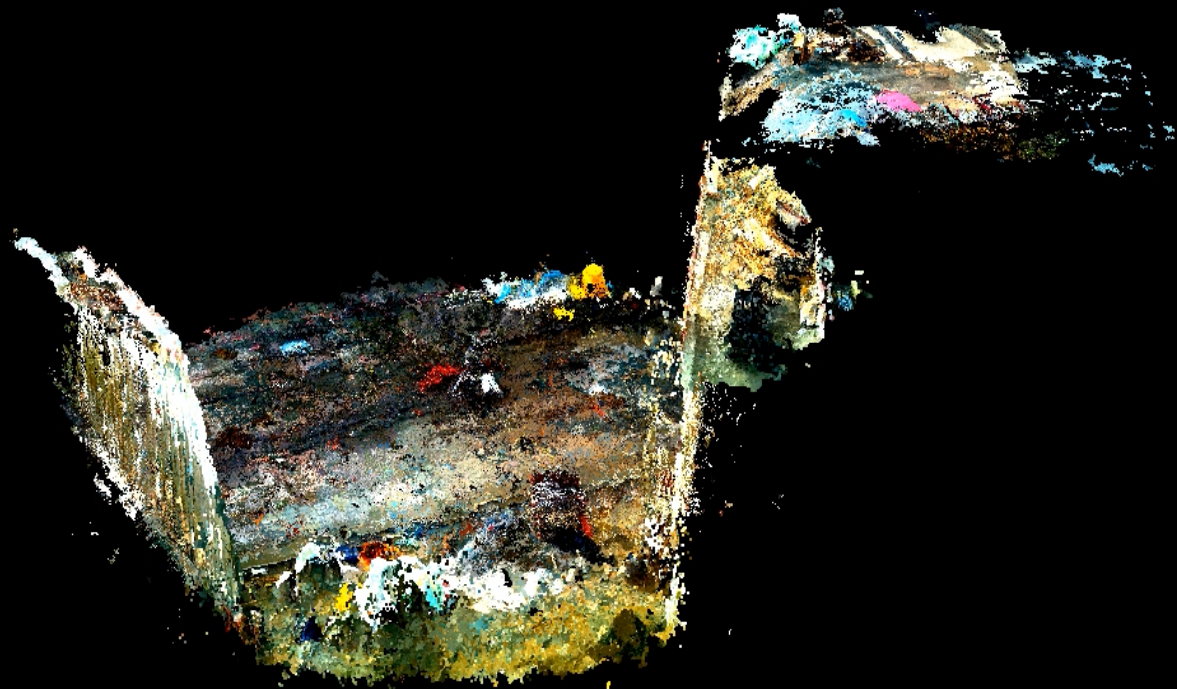




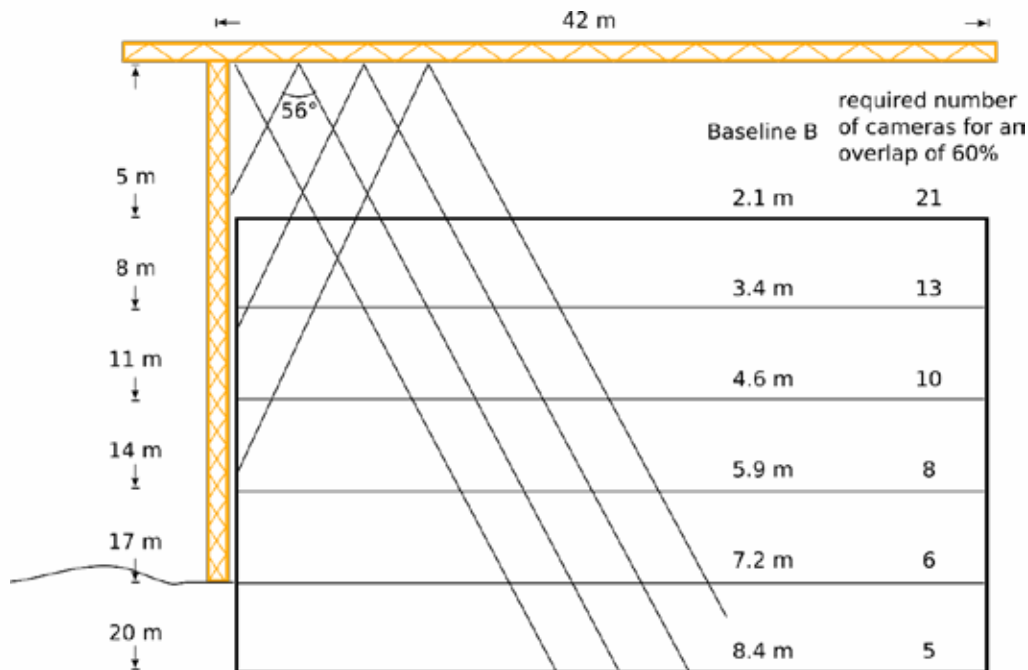


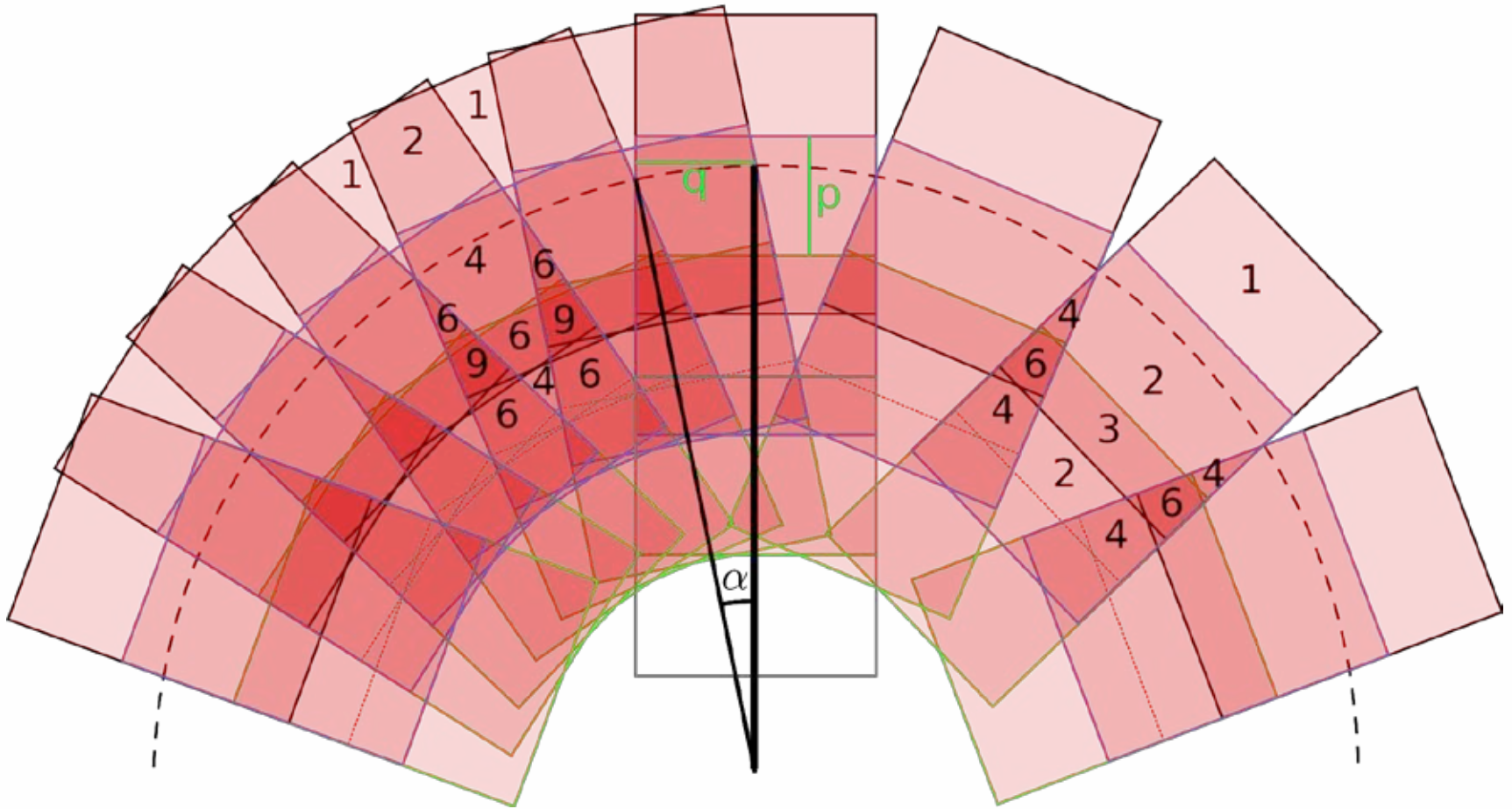


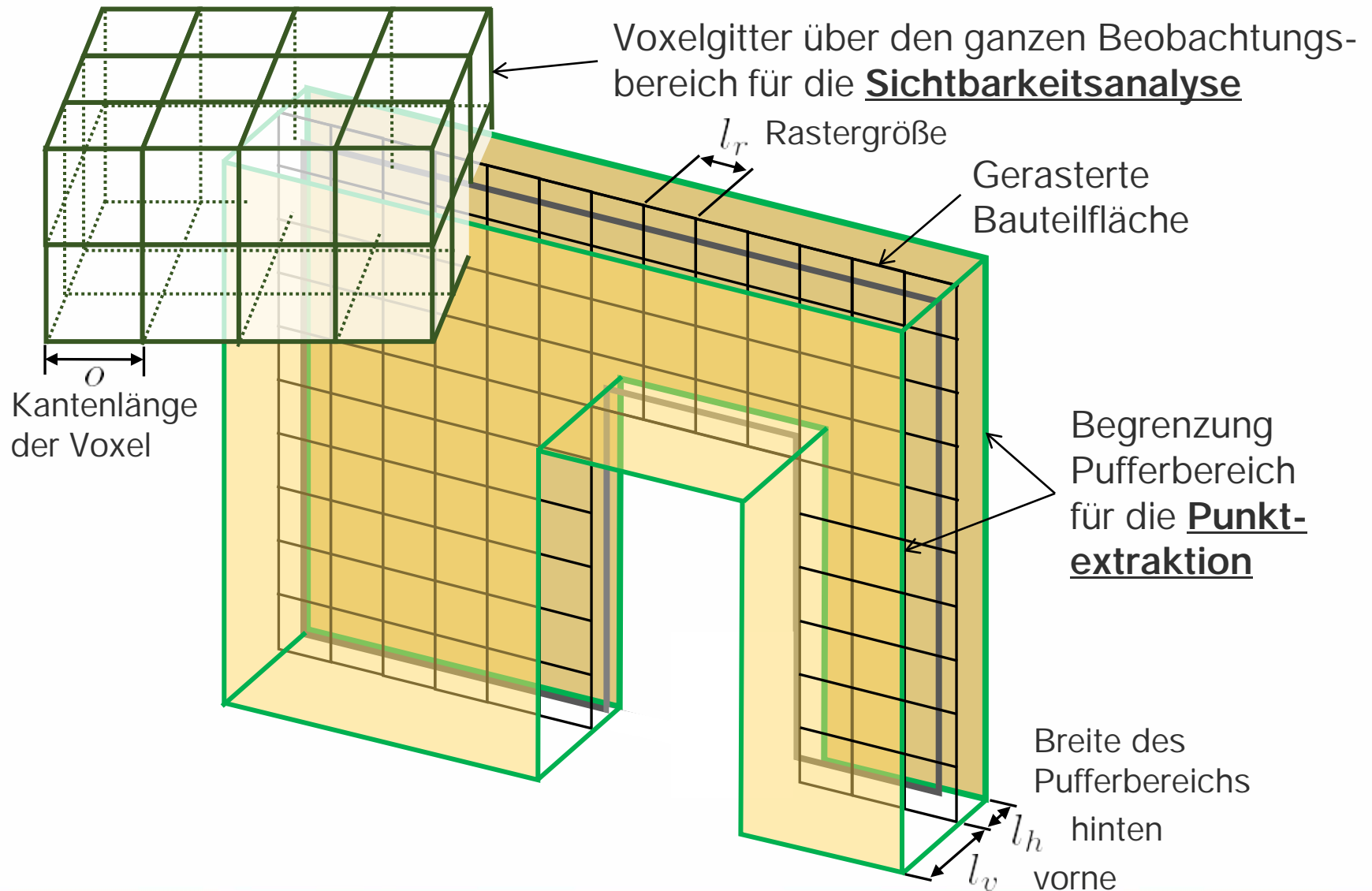




- r Usually all areas can be reached by the cranes.
- r The higher the building the more cameras are necessary.
- r A controlled crane movement is necessary to ensure full coverage.
- r Trolley and hoisting rope may be in the view.







- r Unterscheidung von Bauteilen
 - (1) sichtbar und vorhanden
 - (2) sichtbar und vorhanden
 - (3) definitiv nicht vorhanden – da (2) sichtbar
 - (4) keine Aussage möglich – da nicht sichtbar

