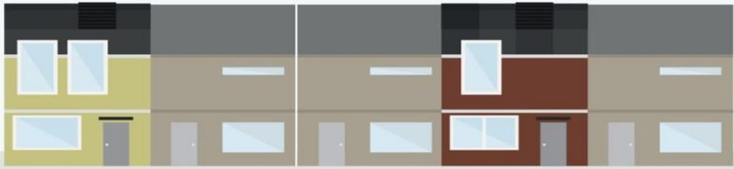
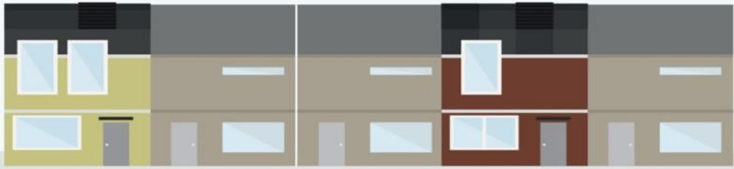
MORE—CONNECT



BIM Modelling using photogrammetry data

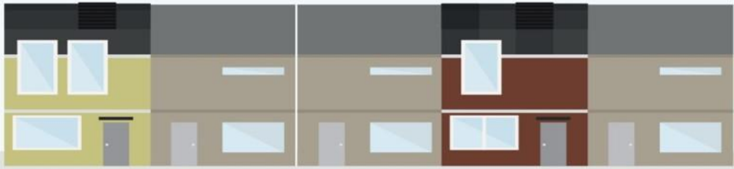
3 RD MODULE

3D scanning and BIM process



Content of presentation

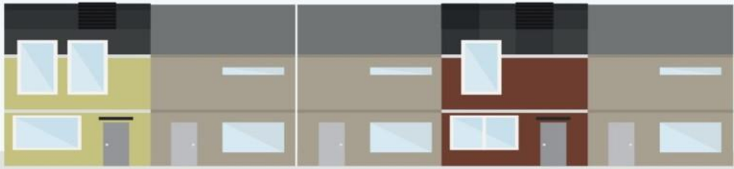
1. General information – Reality Capturing by Photogrammetry
    1. Flight planning
2. Flight and capturing image data
3. Processing photos in ContextCapture Master
    1. Setting of control points
4. BIM Modeling
5. Laser scanning point cloud data processing
    1. Data comparison
6. Converting model
7. Summary and conclusions



General Information – Reality Capturing by Photogrammetry

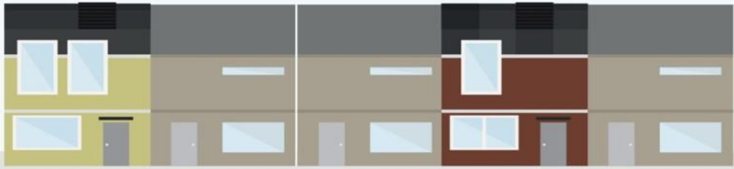
Devices and software

1) Drone Phantom 4
2) Camera DJI FC330
3) Used software:
   - ContextCapture Master
   - Acute 3D Viewer
   - Cloud Compare
   - Leica Cyclone
   - Bentley Descartes
   - AutoDesk 360 Viewer Online



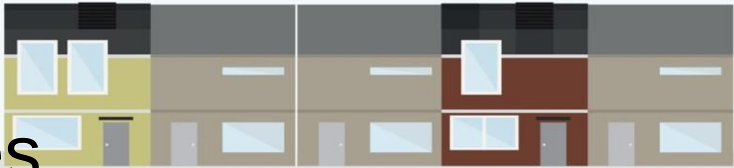
Reality Capturing – what is this?

- "Reality is merely an illusion, albeit a very persistent one." – Albert Einstein
- Probably first appearance of term: High-definition surveying (HDS): a new era in reality capture (2004) by Erwin Frei , Jonathan Kung , Richard Bukowski in: Proceedings of ISPRS Workshop Laser-Scanners for Forest and Landscape Assessment
- "The correct term is data capture. None of us are capturing reality. "Reality capture", "capture reality" - both just marketing terms. They are good marketing phrases and I just hope no one really believes them..." – Matt Young
- Reality Capturing: laserscanned or photogrammetrically 3D documented assets/environments – 3D documentation of existing reality (not virtual reality)



Modern photogrammetry

- Photogrammetry technology development during last decade:
  – Compact high resolution digital photo and video cameras
  – New algorithms for determination of correlations between pictures
  – Powerful standard computers and graphic processors
  – Lighter and more compact sensors for spatial location and orientation: GPS, micro electromechanical sensors
  - MEMS (gyroscopes, accelerometers, compasses, barometers etc.)
  – Unmanned aerial vehicles (UAV, drones) with automated flight control
- Advantages:
  – Extended digital photogrammetry application possibilities in various sectors
  – Low cost photogrammetry, which is available for non-professionals
  – Usage of drones and other mechanical vehicles in the data collection process
  – Extended real-world spatial modeling capabilities

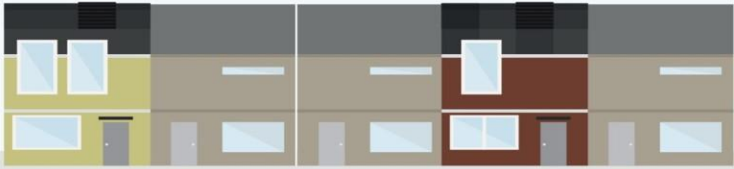


Modern Photogrammetry Features

- Data capturing
  - Usage of various digital cameras: compact, mirrorless, SLR, video, built-in
  - A variety of image capture methods: from the ground, land vehicles, from overflights, from flights around; different combinations of these methods
  - Smaller and faster preparations for field works
  - Automated mission planning and execution
- Data processing
  - Fully automated data processing with specialized desktop software (Bentley Context Capture, Pix4Dmapper, Agisoft PhotoScan) or cloud computing services
  - It is not necessary prior camera calibration •
- Data products
  - True orthophoto, 3D point cloud, digital surface model (DSM), 3D mesh model

Workflow

MORE—CONNECT



1. Images acquisition planning.

   - It based on images processing techniques requirements.
   - Flight planning can be performed with software (eg. Pix4Dcapture, DroneDeploy), which can be used to manage automatic flight.

2. Ground control points marking and surveying.

   - It is optional, but is required to ensure absolute precision.

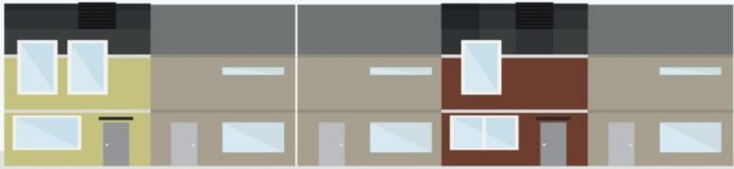
3. Data capture.

1. Automatic processing of images .

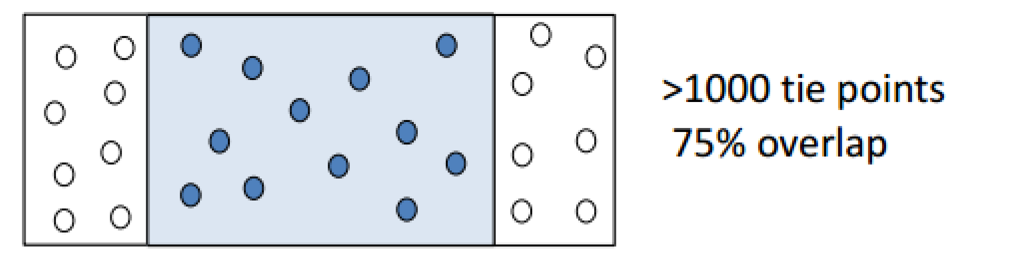
   - Bentley ContextCapture: performing aerotriangulation (tie points detection, image positioning and orientation, georeferencing), 3D model generation, generation of necessary data products (3D point cloud, orthophoto, DSM).

2. Further geoprocessing, using and publishing of results.

Images Acquisition Planning



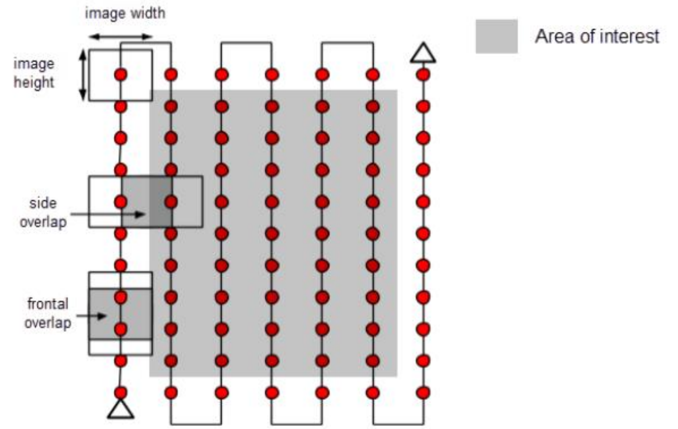
- Drastically affect image processing performance, the quality and completeness
- Goal: To ensure the greatest possible total number of tie points in images on which camera calibration, position and orientation of images can be estimated
- Unlike traditional photogrammetry it is used much larger number of tie points (> 1000) for each image pair (compared to a few tens to a few points in the traditional photogrammetry)
- The large number of tie points provides opportunities during processing to evaluate much more unknown parameters than traditional photogrammetry, including automatic calibration for your camera

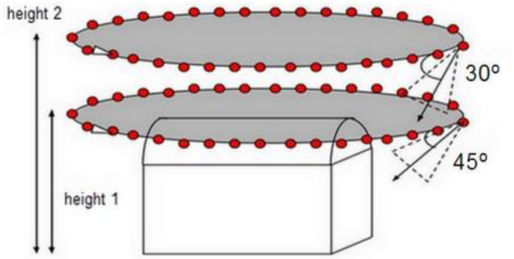


Flight plans

MORE — CONNECT

- Grid flight plan (Nadir or Oblique)
  - Optimal for areas and surfaces – Result: orthophotos, digital terrain model
  - Recommendations:
    - 75% frontal overlap
    - 60% side overlap
    - Wherever possible, a regular grid and a constant height
- Fly around plan
  - Optimal for buildings, individual objects
  - Result: point cloud, 3D model
  - Recommendations:
    - One image at every 5-10˚
    - More images at the corners of the building

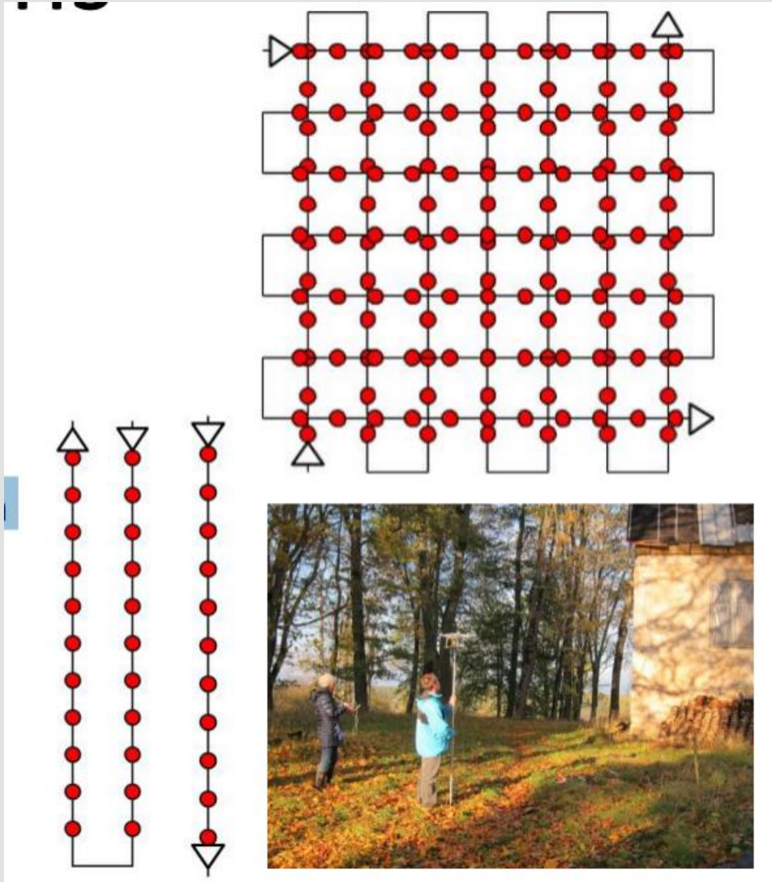




Flight plans

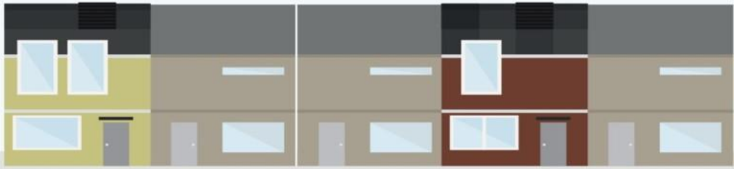
MORE—CONNECT

- Double grid flight plan
  - Optimal for urban and built-up areas
  - For reconstruction of façades reconstruction direction of camera 10-35 ° from the vertical
- Other plans
  - Corridor flight plan (roads, railways) recommends round-trip route (dual pass) with a vertical or oblique views or one-way route (single pass), but then with a 90% overlap
  - Circular or spiral routes for vertical objects (towers, chimneys, masts)
  - From ground
  - Various combination of mentioned plans



Other conditions and limitations

MORE—CONNECT



- Day time and weather:
  - Required good lighting conditions.
  - Bright sunlight gives too high contrast for images.
  - Low Sun's height above the horizon gives troublesome shadows.
  - Optimal conditions - a little cloudy day without precipitation.
- Limitations:
  - Difficulties in reconstruction of reflective and transparent surfaces, including glass.
  - Difficulties in reconstruction surfaces with a little visual content including sand, snow, waterbodies and flat walls without texture
  - A special treatment required for dense vegetation, trees and forests.
  - Specific acquisition plan is required for narrow and structured vertical objects like power and communication towers, masts, wind turbines etc.
  - Not suitable for interior modelling in bad lighting conditions.

Flight and capturing image data

Fieldwork

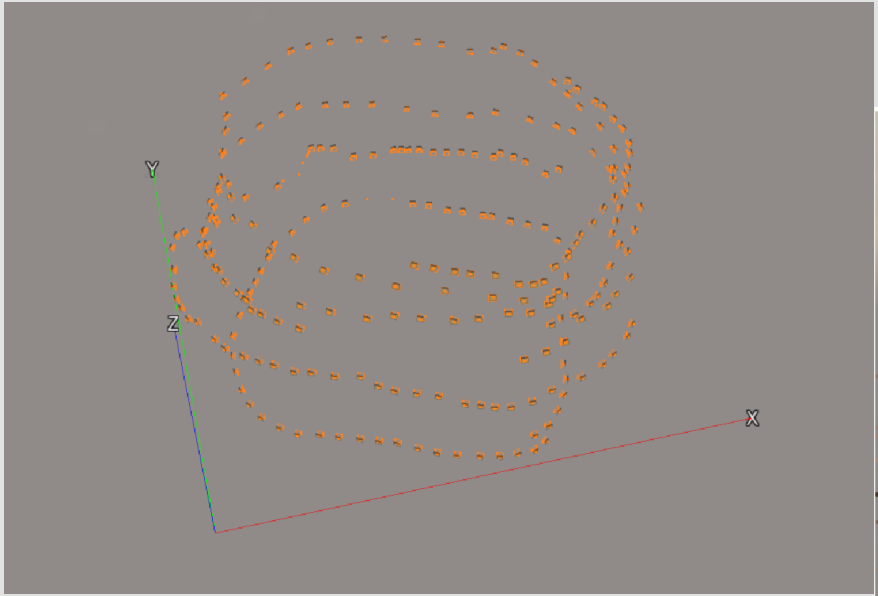
MORE—CONNECT

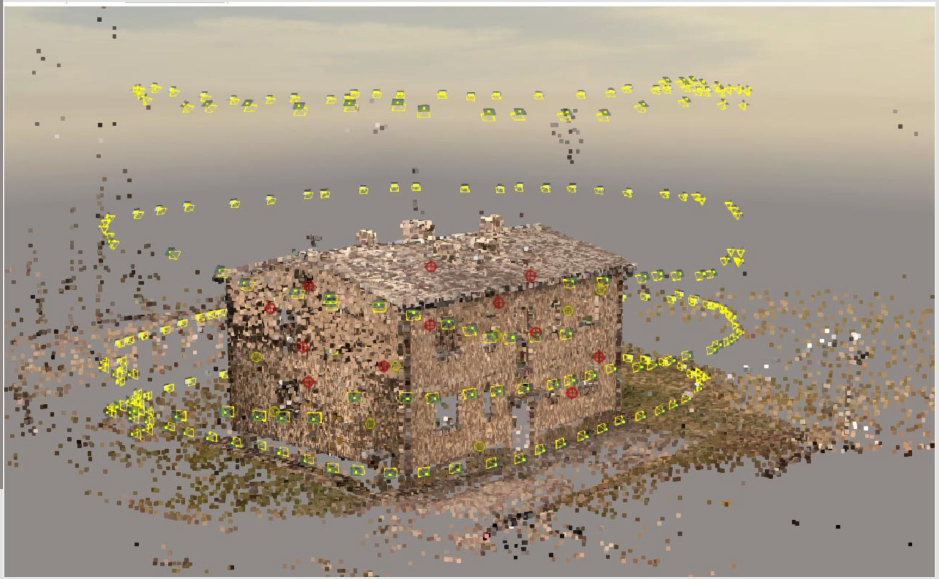
1,5 hours

Flight plan

MORE—CONNECT

- Photos taken in 4 layers - three from flight, one from ground





Flight information

MORE—CONNECT

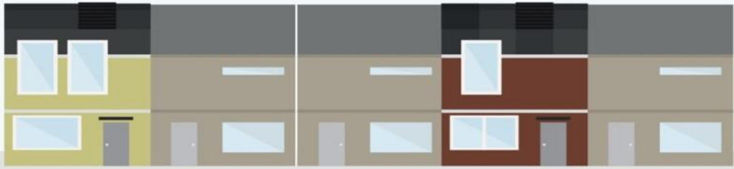
1) Photos taken in 19th April, 2017
2) Drone Phantom 4 DJI FC330
3) Weather – partly cloudy
4) Flight time - 1 hour 30 minutes
5) Number of photos - 250
6) Camera's resolution - 12.4 megapixels
7) Image format - DNG (RAW)

Camera

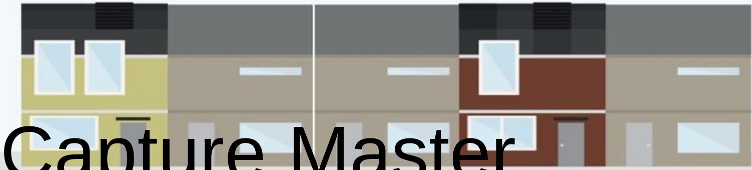
Camera maker	DJI
Camera model	FC330
F-stop	f/2.8
Exposure time	1/866 sec.
ISO speed	ISO-100
Exposure bias	-1.7 step
Focal length	4 mm
Max aperture	2.97
Metering mode	Centre Weighted Average
Subject distance	0 mm
Flash mode	No flash function
Flash energy	
35mm focal length	20

Image

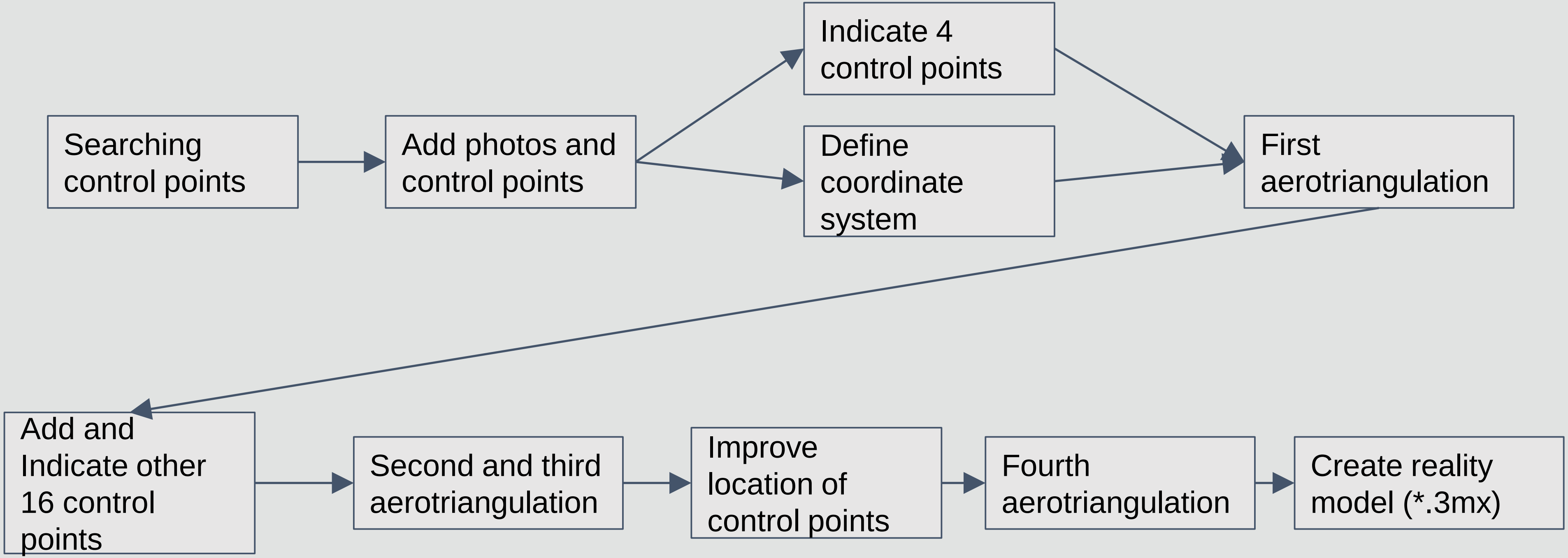
Image ID	
Dimensions	4000 x 3000
Width	4000 pixels
Height	3000 pixels
Horizontal resolution	72 dpi
Vertical resolution	72 dpi
Bit depth	24
Compression	
Resolution unit	2
Colour representation	sRGB
Compressed bits/pixel	3.80041466666666667



Processing photos in ContextCapture Master



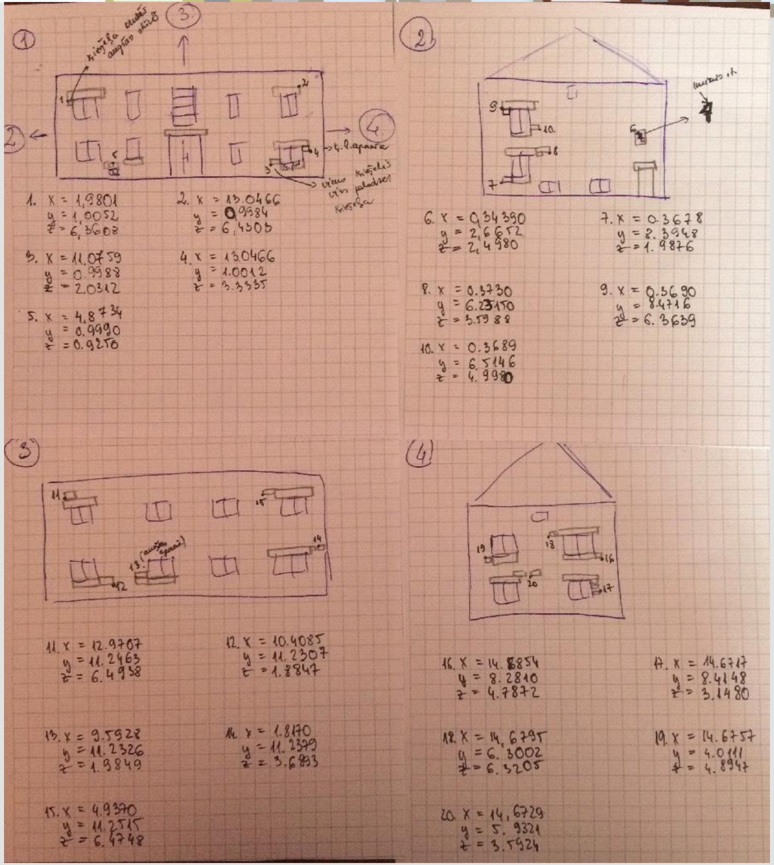
Creating reality model in ContextCapture Master



Control points

MORE—CONNECT

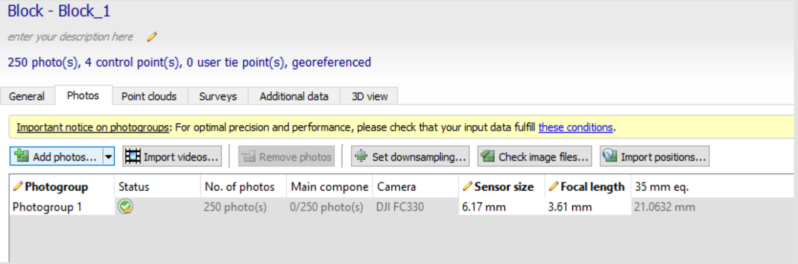
- It must be able to see one control point at least in 3 photos.
- 20 control points. 4 control points on each building wall.
- It is important that control points are positioned on both floors and in both corners of walls.
- Control points in different places better tie reality model.

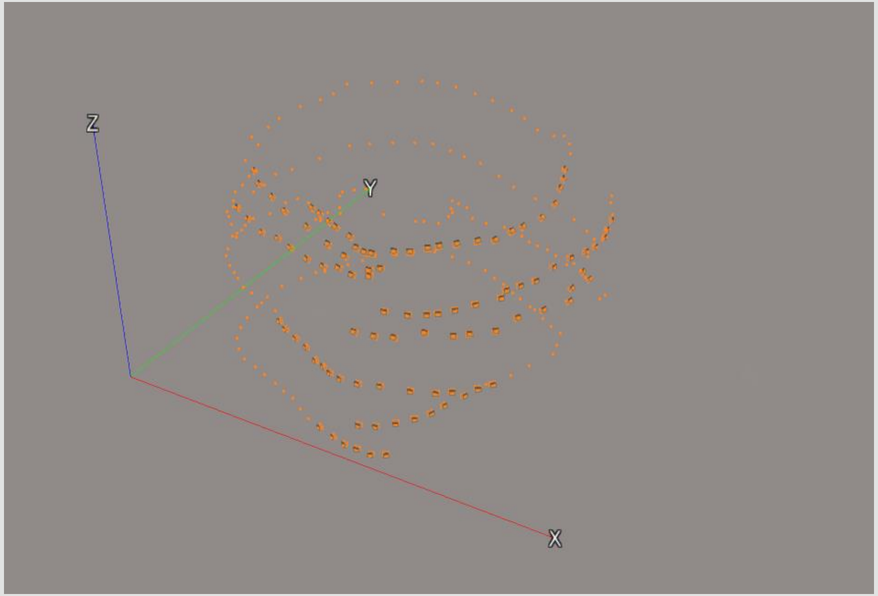


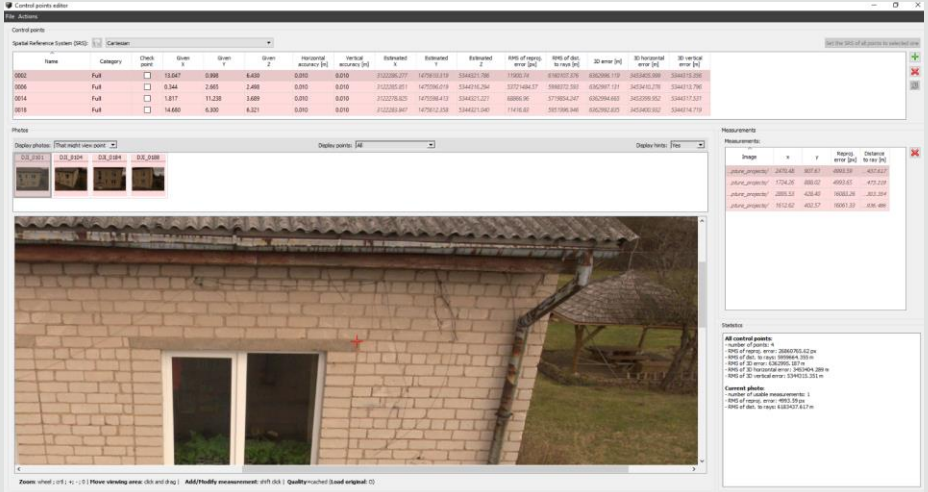
Data processing in ContextCapture Master

MORE—CONNECT

- Adding photos and control points.
- Indicate 4 control points and define coordinate system.
- Do first aerotriangulation.

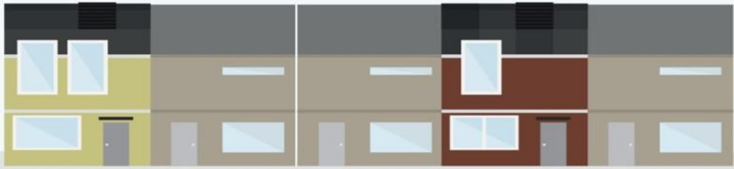


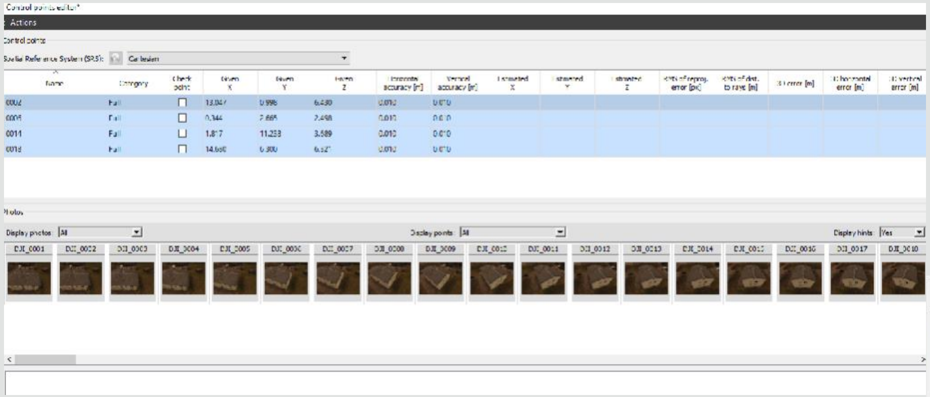


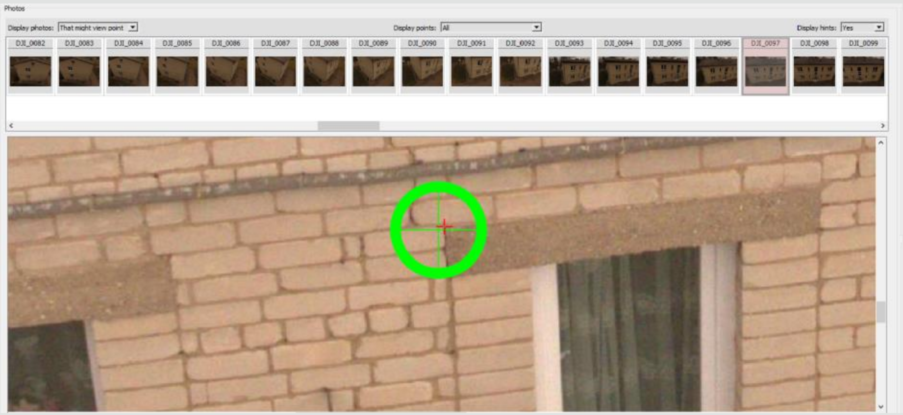


Indicating control points

MORE — CONNECT

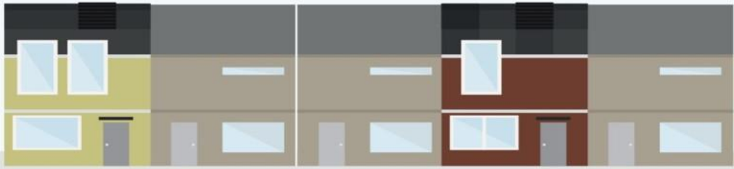






First aerotriangulation

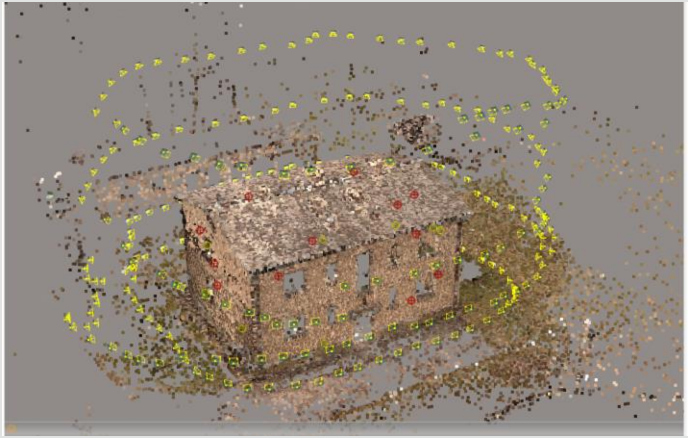
MORE—CONNECT

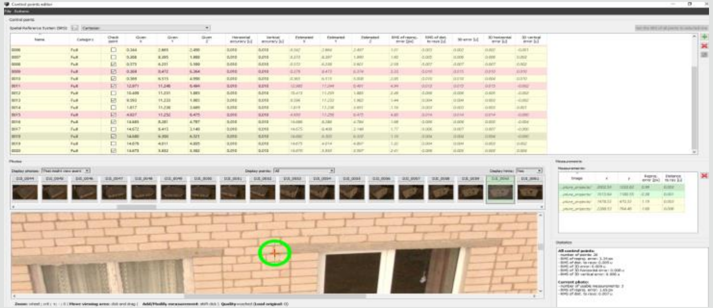


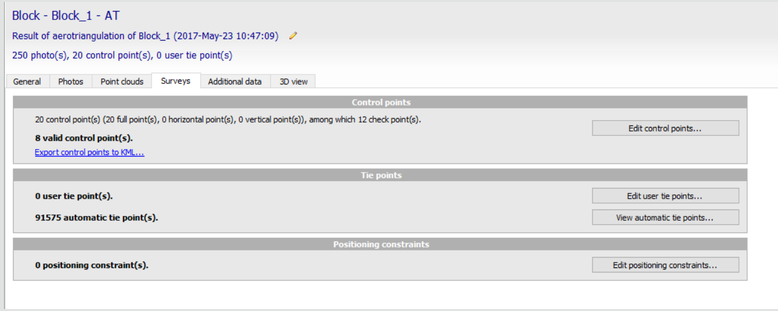
- After first aerotriangulation model is located in the correct place - it has a defined coordinate system.

- Improve location of first 4 control points.
- Add and indicate other 16 control points.
- Define photos precision - 1 cm.
- 8 of all 20 control points are pick as accurate, other 12 points are checkpoints. Checkpoints helps to evaluate reality models accuracy.

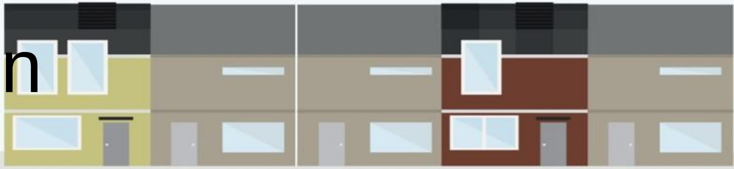
- Do second and third aerotriangulation.





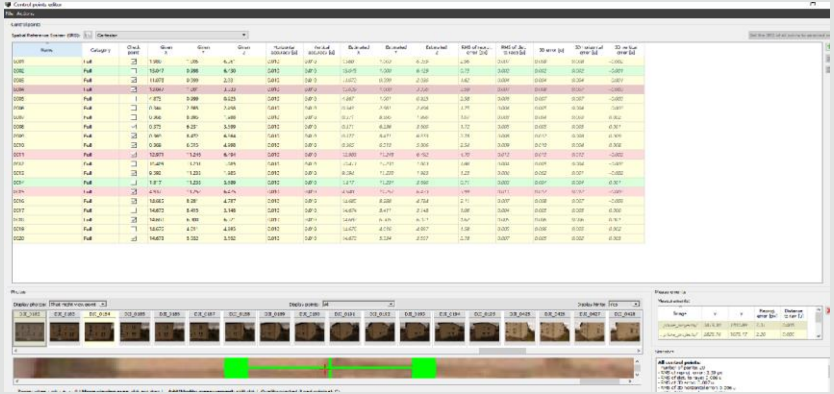


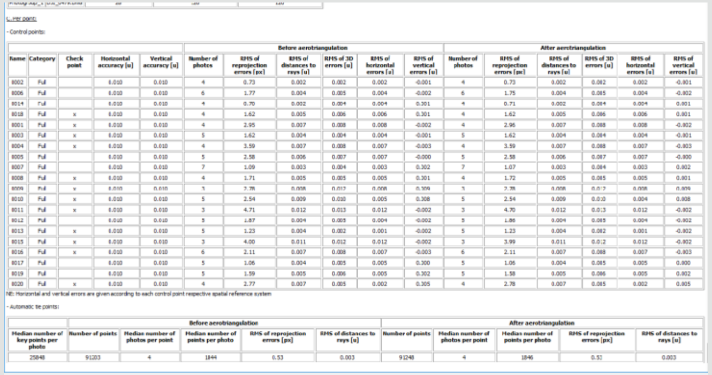
Second and third aerotriangulation



MORE — CONNECT

- Improve location of control points.
- Do fourth aerotriangulation.





C. Per point:

- Control points:

					Before aerotriangulation						After aerotriangulation					
Name	Category	Check point	Horizontal accuracy [u]	Vertical accuracy [u]	Number of photos	RMS of reprojection errors [px]	RMS of distances to rays [u]	RMS of 3D errors [u]	RMS of horizontal errors [u]	RMS of vertical errors [u]	Number of photos	RMS of reprojection errors [px]	RMS of distances to rays [u]	RMS of 3D errors [u]	RMS of horizontal errors [u]	RMS of vertical errors [u]
0002	Full		0.010	0.010	4	0.73	0.002	0.002	0.002	-0.001	4	0.73	0.002	0.002	0.002	-0.001
0006	Full		0.010	0.010	6	1.77	0.004	0.005	0.004	-0.002	6	1.75	0.004	0.005	0.004	-0.002
0014	Full		0.010	0.010	4	0.70	0.002	0.004	0.004	0.001	4	0.71	0.002	0.004	0.004	0.001
0018	Full	x	0.010	0.010	4	1.62	0.005	0.006	0.006	0.001	4	1.62	0.005	0.006	0.006	0.001
0001	Full	x	0.010	0.010	4	2.95	0.007	0.008	0.008	-0.002	4	2.96	0.007	0.008	0.008	-0.002
0003	Full	x	0.010	0.010	5	1.62	0.004	0.004	0.004	-0.001	5	1.62	0.004	0.004	0.004	-0.001
0004	Full	x	0.010	0.010	4	3.59	0.007	0.008	0.007	-0.003	4	3.59	0.007	0.008	0.007	-0.003
0005	Full		0.010	0.010	5	2.58	0.006	0.007	0.007	-0.000	5	2.58	0.006	0.007	0.007	-0.000
0007	Full		0.010	0.010	7	1.09	0.003	0.004	0.003	0.002	7	1.07	0.003	0.004	0.003	0.002
0008	Full	x	0.010	0.010	4	1.71	0.005	0.005	0.005	0.001	4	1.72	0.005	0.005	0.005	0.001
0009	Full	x	0.010	0.010	3	2.78	0.008	0.012	0.008	0.009	3	2.78	0.008	0.012	0.008	0.009
0010	Full	x	0.010	0.010	5	2.54	0.009	0.010	0.005	0.008	5	2.54	0.009	0.010	0.004	0.008
0011	Full	x	0.010	0.010	3	4.71	0.012	0.013	0.012	-0.002	3	4.70	0.012	0.013	0.012	-0.002
0012	Full		0.010	0.010	5	1.87	0.004	0.005	0.004	-0.002	5	1.86	0.004	0.005	0.004	-0.002
0013	Full	x	0.010	0.010	5	1.23	0.004	0.002	0.001	-0.002	5	1.23	0.004	0.002	0.001	-0.002
0015	Full	x	0.010	0.010	3	4.00	0.011	0.012	0.012	-0.002	3	3.99	0.011	0.012	0.012	-0.002
0016	Full	x	0.010	0.010	6	2.11	0.007	0.008	0.007	-0.003	6	2.11	0.007	0.008	0.007	-0.003
0017	Full		0.010	0.010	5	1.06	0.004	0.005	0.005	0.000	5	1.06	0.004	0.005	0.005	0.000
0019	Full		0.010	0.010	5	1.59	0.005	0.006	0.005	0.002	5	1.58	0.005	0.006	0.005	0.002
0020	Full	x	0.010	0.010	4	2.77	0.007	0.005	0.002	0.005	4	2.78	0.007	0.005	0.002	0.005

NB: Horizontal and vertical errors are given according to each control point respective spatial reference system

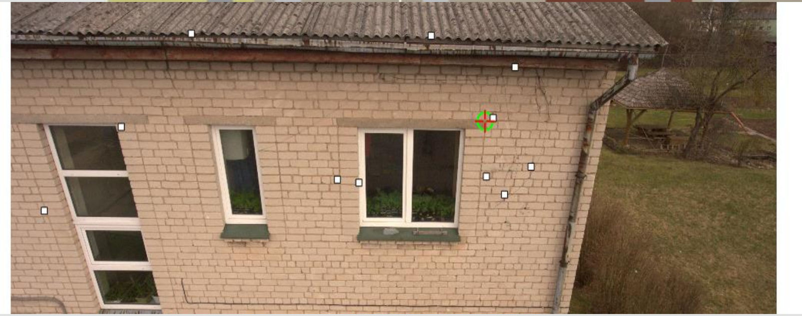
- Automatic tie points:

	Before aerotriangulation					After aerotriangulation				
Median number of key points per photo	Number of points	Median number of photos per point	Median number of points per photo	RMS of reprojection errors [px]	RMS of distances to rays [u]	Number of points	Median number of photos per point	Median number of points per photo	RMS of reprojection errors [px]	RMS of distances to rays [u]
25848	91203	4	1844	0.53	0.003	91248	4	1846	0.53	0.003

Fourth aerotriangulation

MORE—CONNECT

- Average error after fourth aerotriangulation - 0.003m.
- Creating reality model (*.3mx).



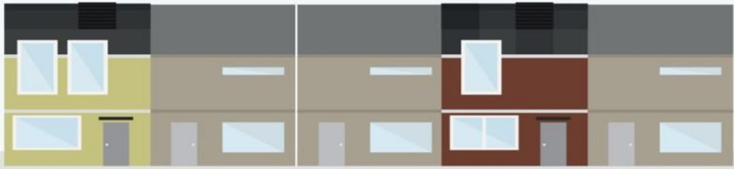
Name	Category	Check point	Given X	Given Y	Given Z	Horizontal accuracy [u]	Vertical accuracy [u]
0001	Full	☑	1.980	1.005	6.361	0.010	0.010
0002	Full	☐	13.047	0.998	6.430	0.010	0.010
0003	Full	☑	11.076	0.999	2.031	0.010	0.010
0004	Full	☑	13.047	1.001	3.333	0.010	0.010
0005	Full	☐	4.873	0.999	0.925	0.010	0.010

	Before aerotriangulation					After aerotriangulation				
Median number of key points per photo	Number of points	Median number of photos per point	Median number of points per photo	RMS of reprojection errors [px]	RMS of distances to rays [u]	Number of points	Median number of photos per point	Median number of points per photo	RMS of reprojection errors [px]	RMS of distances to rays [u]
25848	91203	4	1844	0.53	0.003	91248	4	1846	0.53	0.003

Output - reality mesh model (*.3mx)

MORE — CONNECT

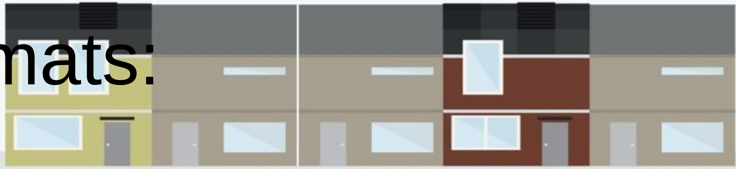
ContextCapture Master products



MORE—CONNECT

1. Point cloud
2. 3D mesh model
3. Digital terrain model
4. Orthophoto

ContextCapture Master output formats:



MORE—CONNECT

3D mesh model:

- 3MX
- Smart3DCapture S3C
- OpenSceneGraph binary (OSGB)
- Autodesk F8X
- Collada(DAE)
- StereoLithography (STL)
- ESRI i3s scene database
- LOD tree export
- Google Earth KML
- SpacEyes3D Builder layer

Point Cloud:

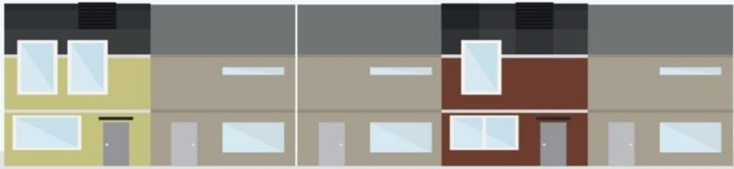
- LAS/LAZ
- POD

Ortophoto and digital terrain model:

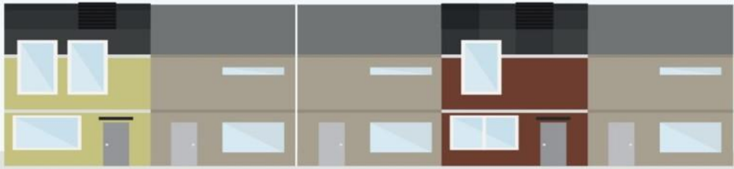
- geoTIFF
- JPEG

Time consumed

MORE—CONNECT



1. Flight planning and preparing
    - 1 hour
2. Flight and capturing images (arrival time to an object is not included):
    - 1 hour and 30 minutes
3. Processing photos in ContextCapture Master and searching for control points in Cloud Compare:
    - Searching for control points and indication (including control points area editing)
        - 3 hours
    - Creating production (reality model) -
        - 2 hours 12 minutes

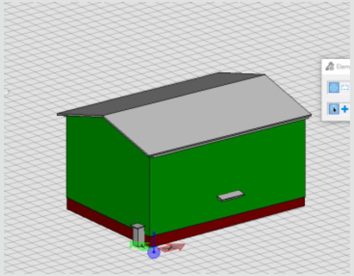


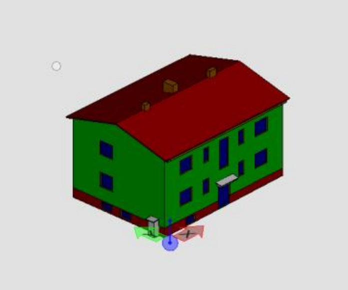
BIM Modeling

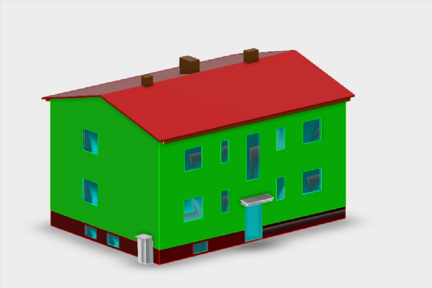
BIM Modeling in Bentley Descartes

MORE — CONNECT

*.3mx model → LOD2 modeling → LOD3 modeling → BIM model

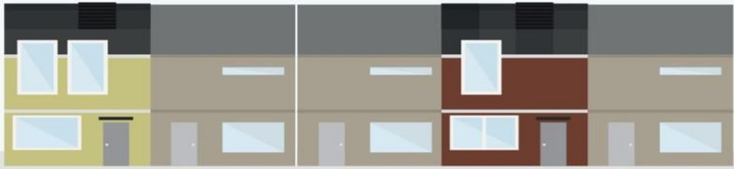






Used tools for BIM modelling

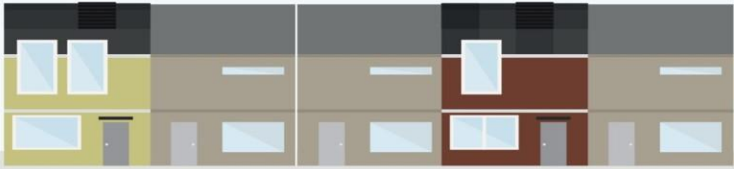
MORE—CONNECT



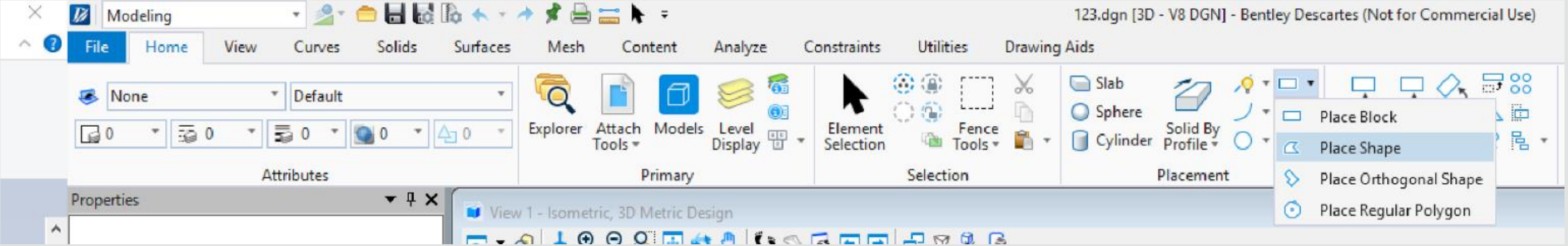
1. Software – Bentley Descartes
2. LOD2 modeling - walls, roof, basics
    - Place Shape function
    - Surfaces functions - Extend Surface; Trim Surface
3. LOD3 modeling - windows, doors
    - Fence functions
        - Place Fence
        - Delete Fence content
4. All processes in modeling are semi-automatic.

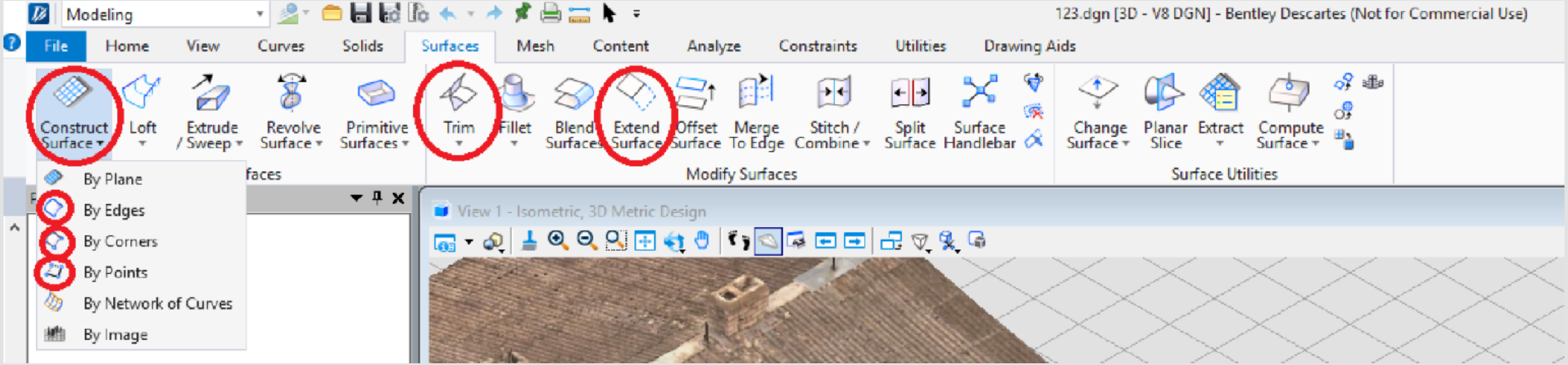
LOD 2 modeling

MORE—CONNECT



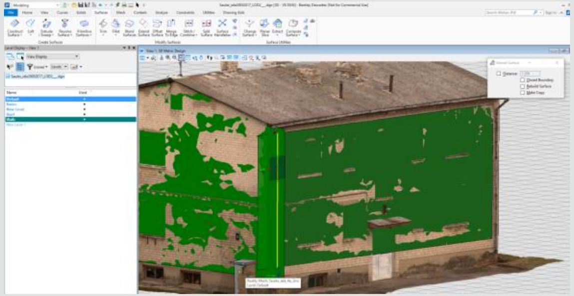
- Surfaces functions for creating walls, roof and basics



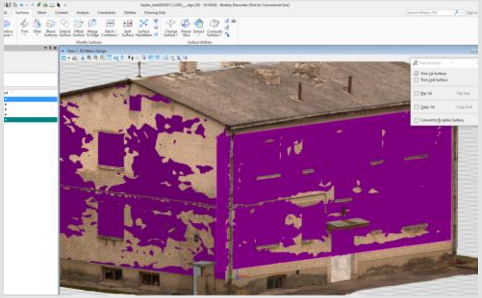


MORE — CONNECT

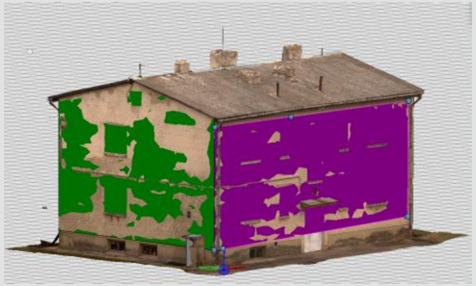
1. Place shape on the wall. (But not in the wall corners)



2. Extend 2 surfaces.

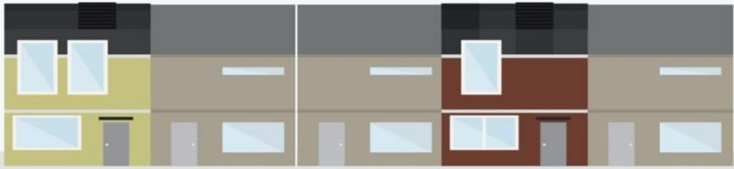


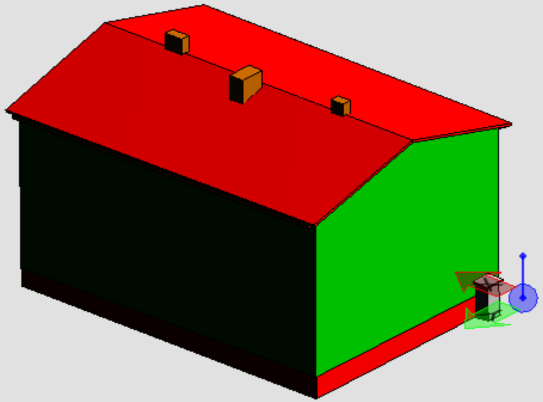
3. Show which 2 surfaces must be trimmed.

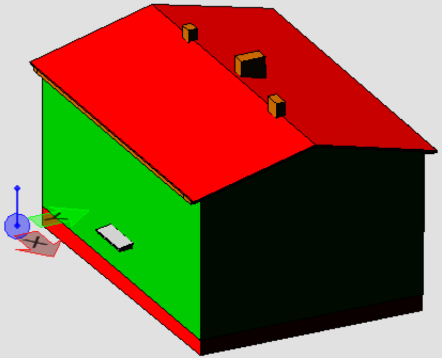


4. Both walls are crossed.

LOD2

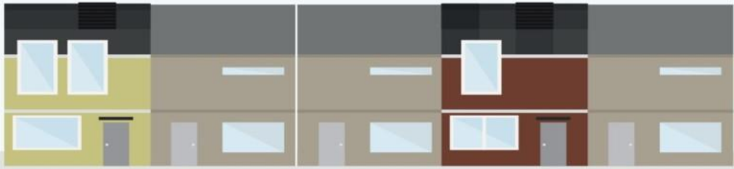




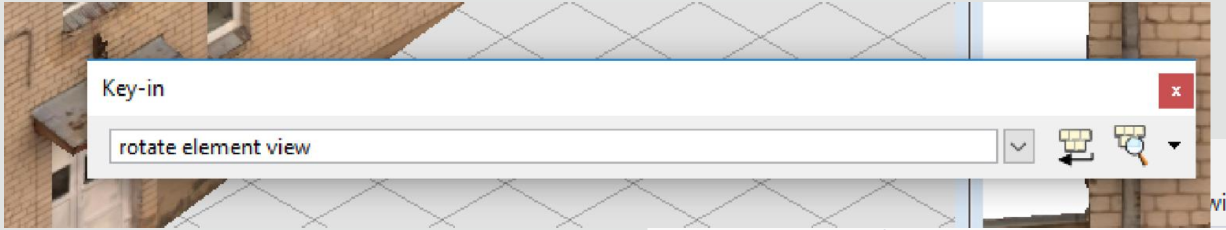


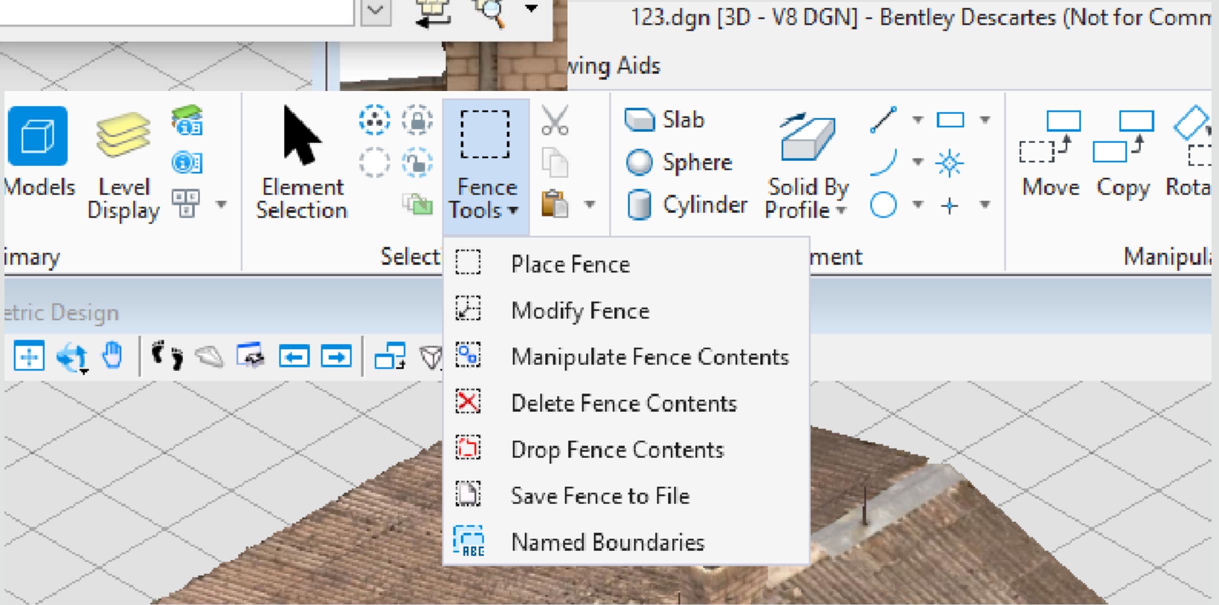
LOD3 modeling

MORE—CONNECT

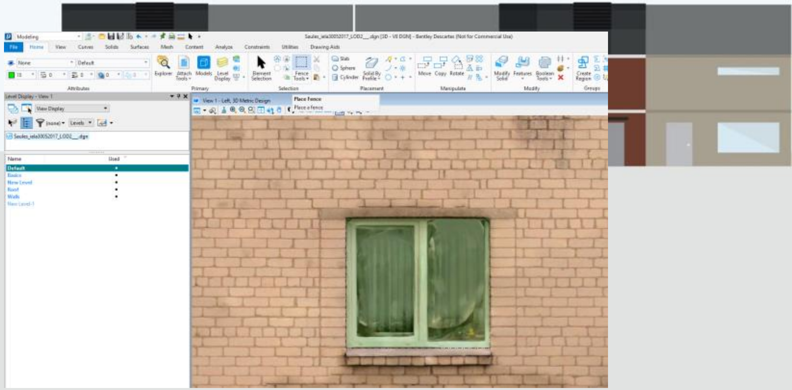


- Fence functions for creatings windows

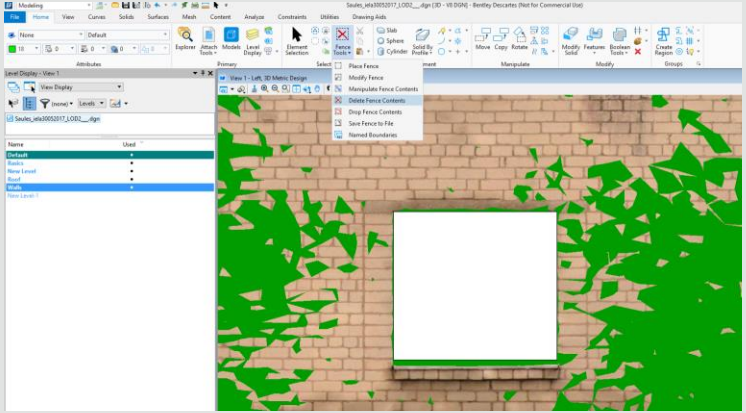




MORE—CONNECT

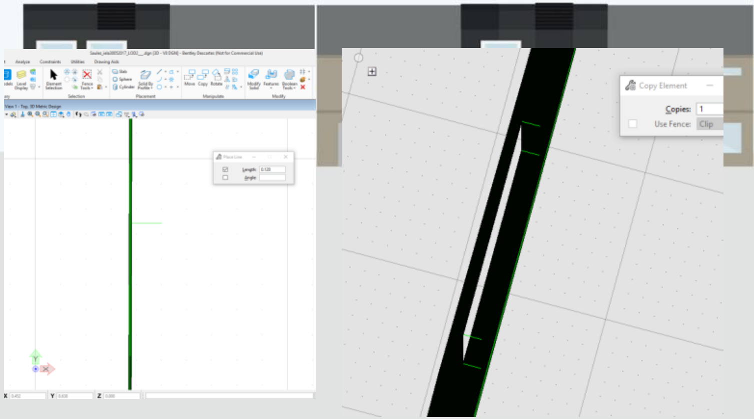


1. Turn off all levels except level with reality model. Place fence on window.



2. Turn on wall level and "Delete fence content". !!! Important to have only one wall when making window holes (if there will be 2 walls opposite each other – both of them will have window hole)

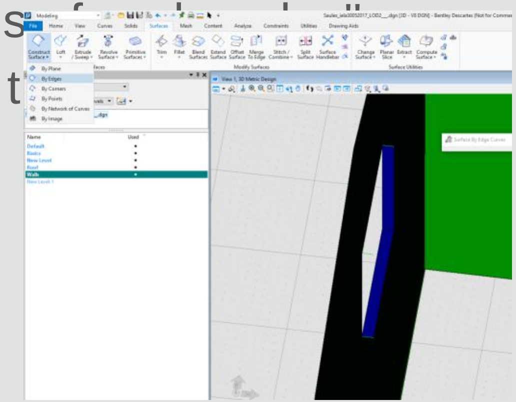
MORE—CONNECT

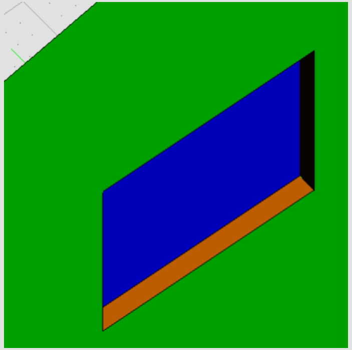


3. Then turn off reality models level and turn on top view. Place line which is perpendicular to concrete wall. Then copy it and place it on each window corner. Line is 12cm long.

4. Pick "Surfaces" function - "Create s

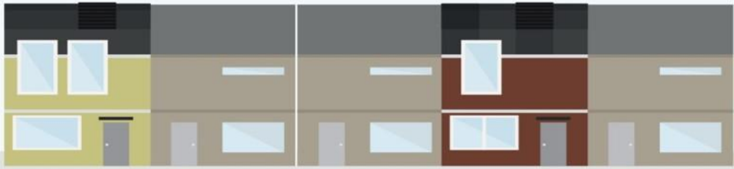
and define which lines have to make t

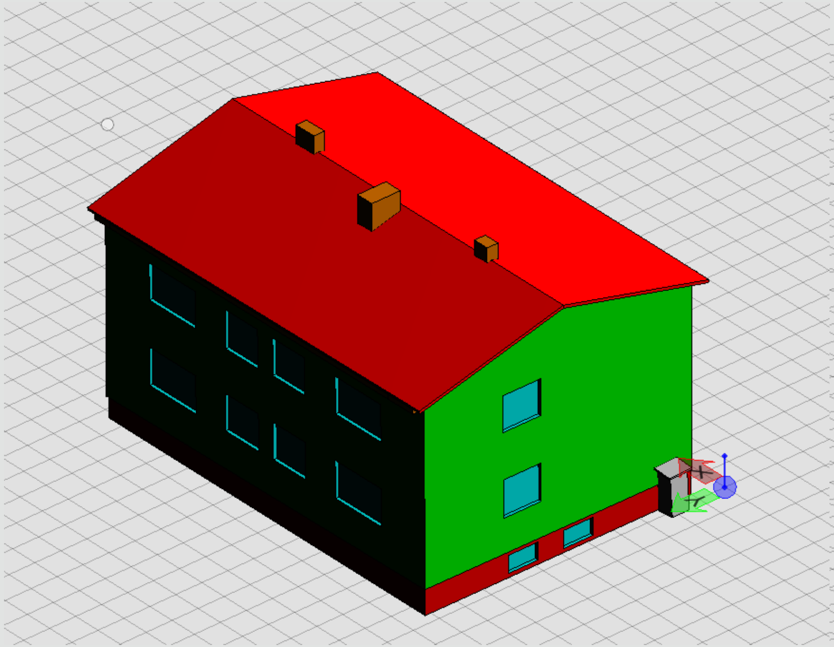


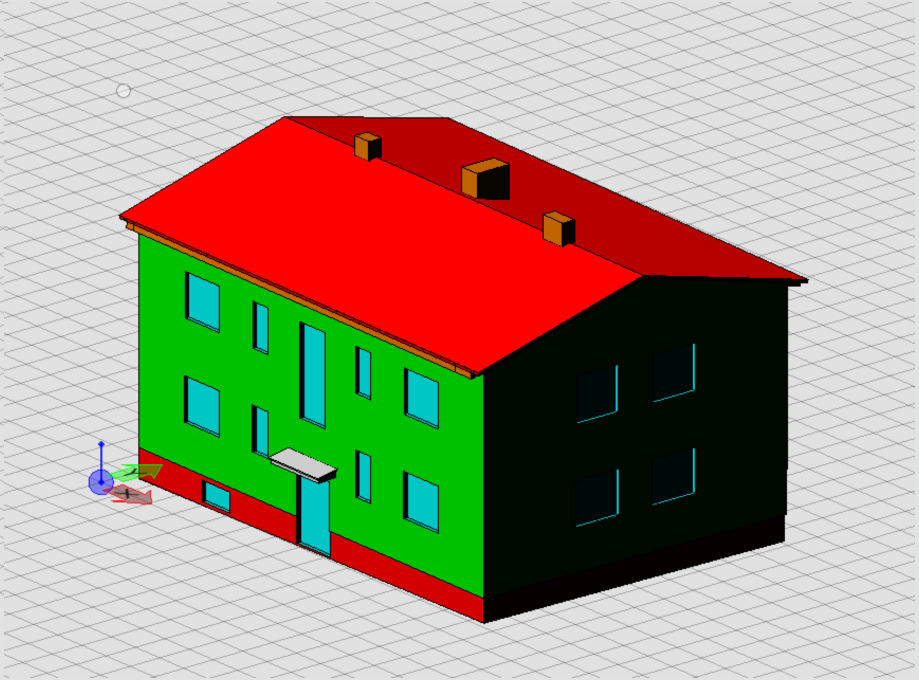


LOD3

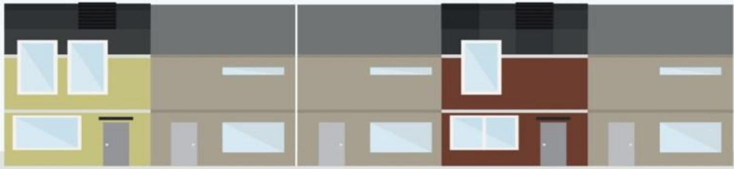
MORE—CONNECT





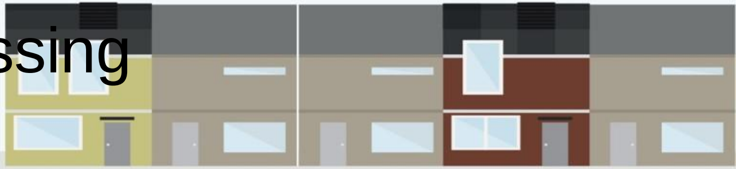


MORE — CONNECT



Point cloud data processing

Laser scanning point cloud data processing



MORE—CONNECT

1. In other cases this step is not obligatory.
2. Point cloud data is necessary for comparing reality models precision.
3. Leica Cyclone
   - Data cleanup from noises
   - One point cloud (from 8 units)
     - Data formating process from ASCII to *.e57 format
4. Cloud Compare
   - Data formating process from ASCII to *.e57 format

Photogrammetry data, BIM model and laserscanning data comparison

1. Model by Section function
   - Backward and forward view for point cloud
   - Cut view for mesh model

2. Difference between reality model and point cloud
   - Walls - fit in 1 cm *range*
   - Roof, windows *and other bottom (elements which was hard to capture)* - bigger than 1 cm.
3. Difference between model and point cloud
   - LOD2 fits in 3cm range ;
   - LOD3 fits in 3.5cm range.

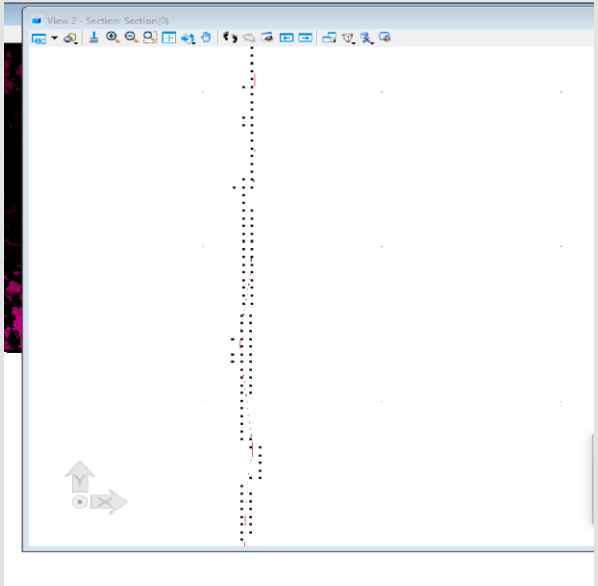
4. Difference between model and reality model

   - LOD2 fits in 3cm range;

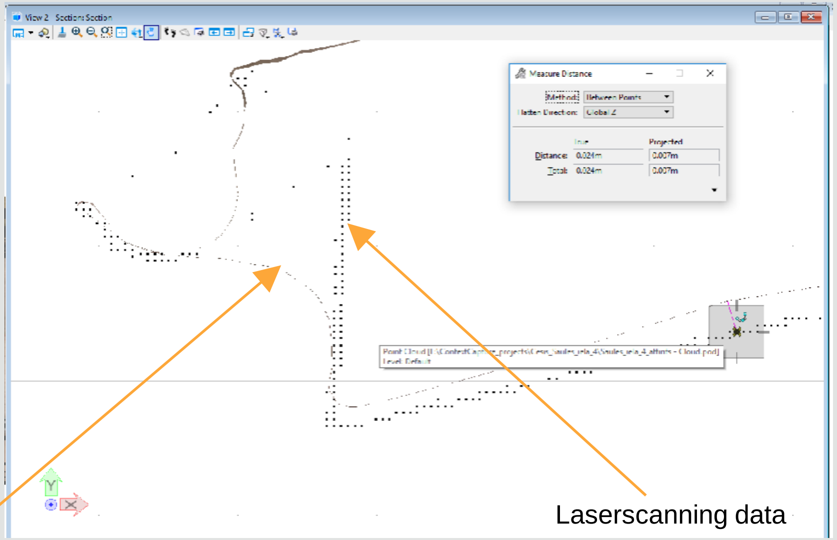
   - LOD3 - comparison is not performed because it would not be precise.

Comparison between reality model and point cloud

MORE — CONNECT



GOOD

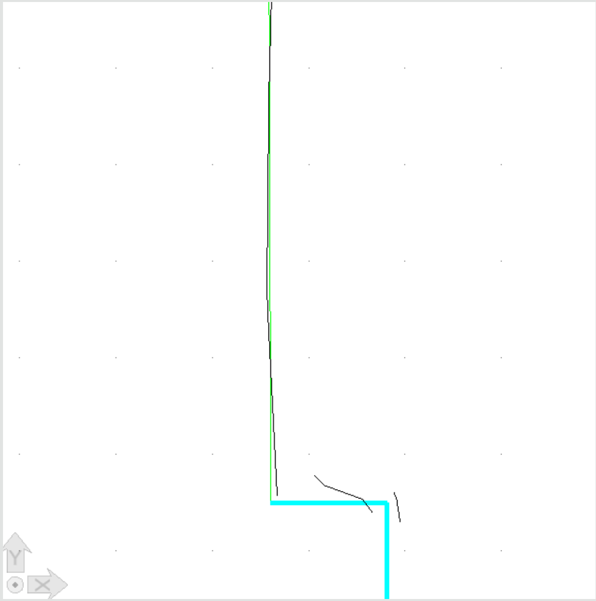


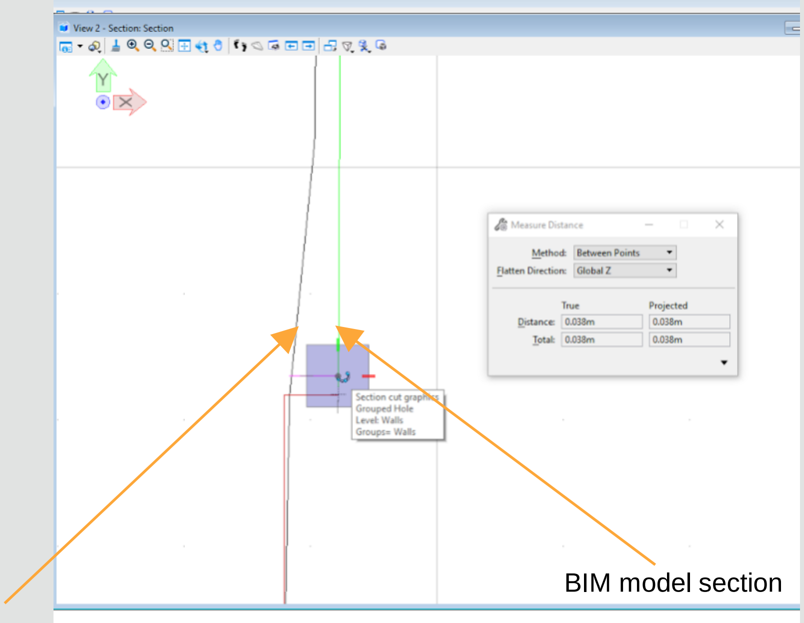
Reality model section

BAD

Comparison betweeen reality model and BIM model

MORE——CONNECT



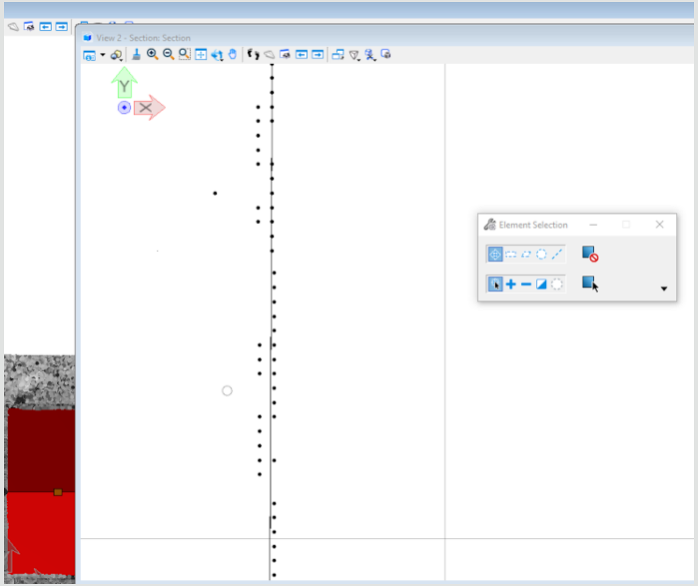


Reality model section

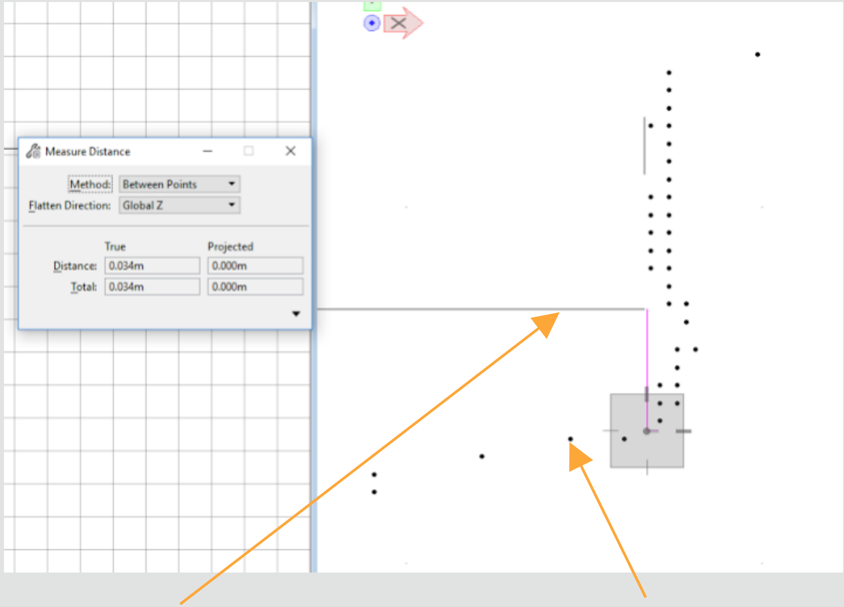
GOOD

BAD

Comparison between BIM model and point cloud



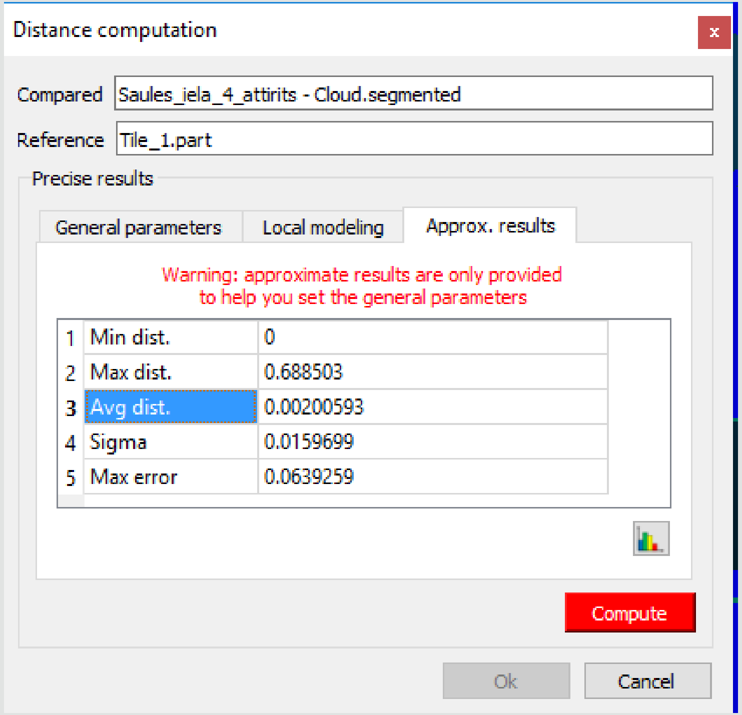
GOOD



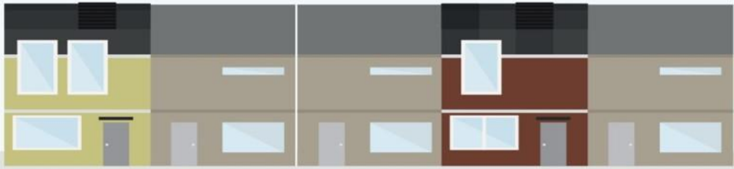
BAD

Comparing laserscanning data with photogrammetric data in Cloud Compare

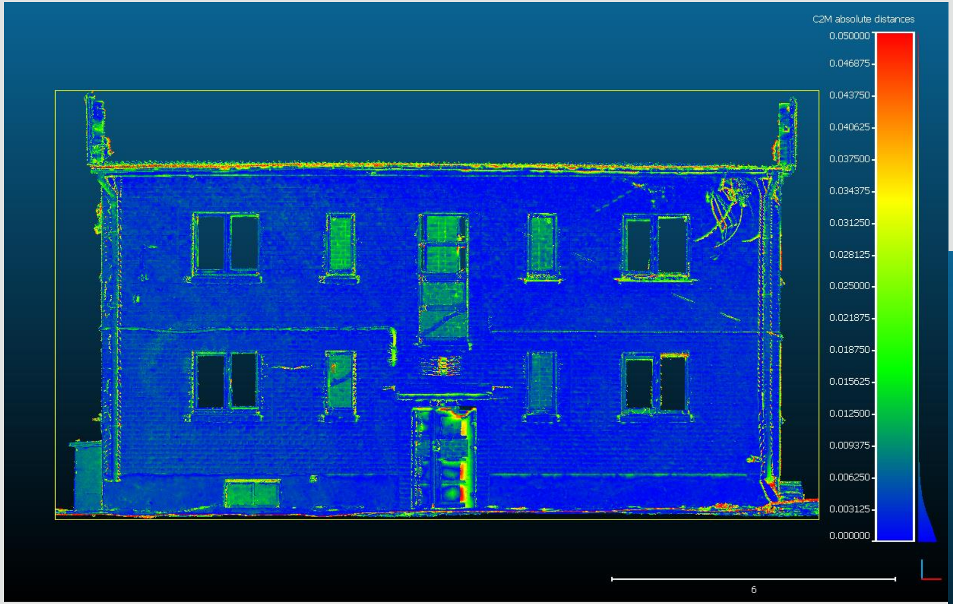
- CloudCompare
- Reality model was exported from Context Capture as *.obj format file.
- Compute cloud/mesh distance function.
- Good results:
  - Most of points are very close
  - Mostly distance between point cloud data and

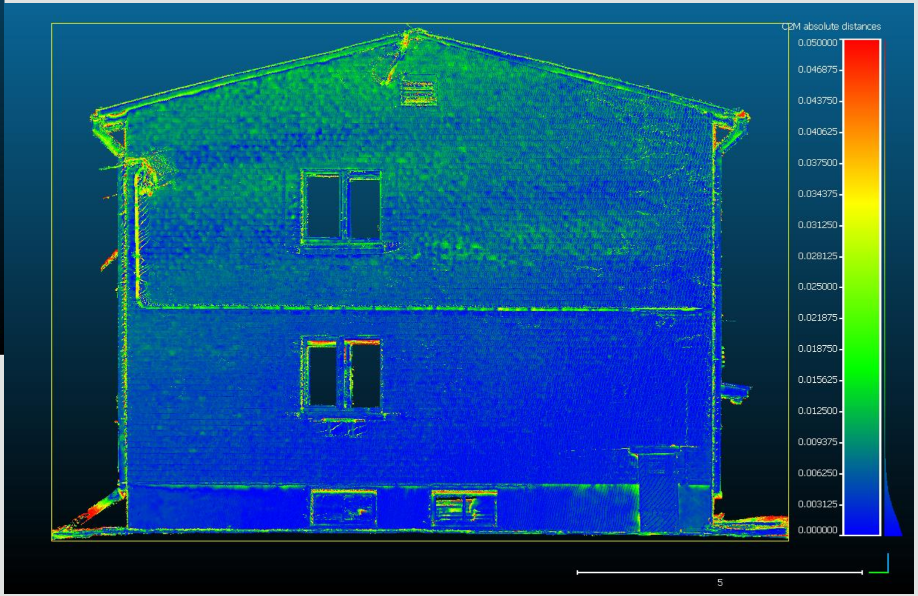


MORE—CONNECT



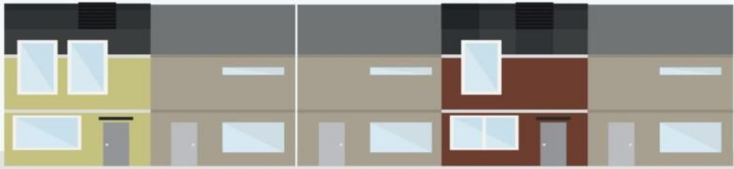
- Absolute distances between points - mostly under 1cm.

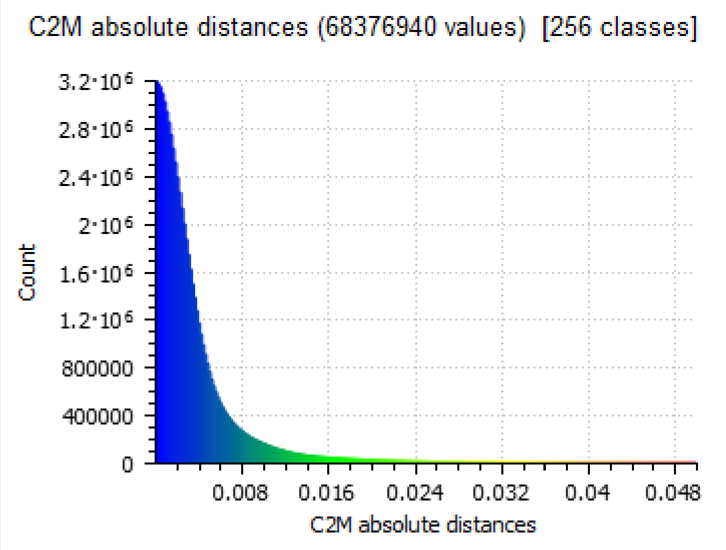


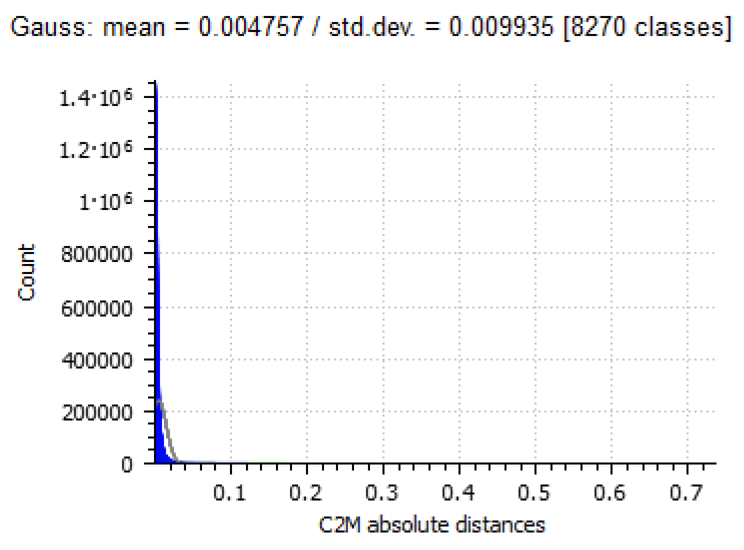


- C2M = Cloud to Mesh

MORE—CONNECT

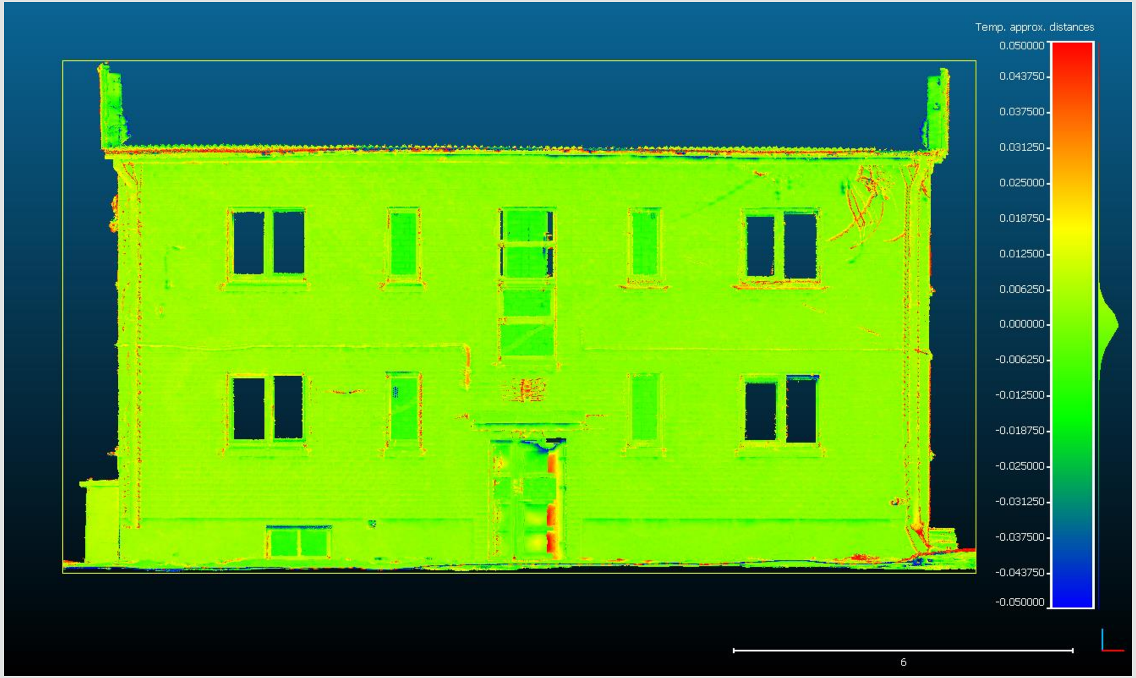


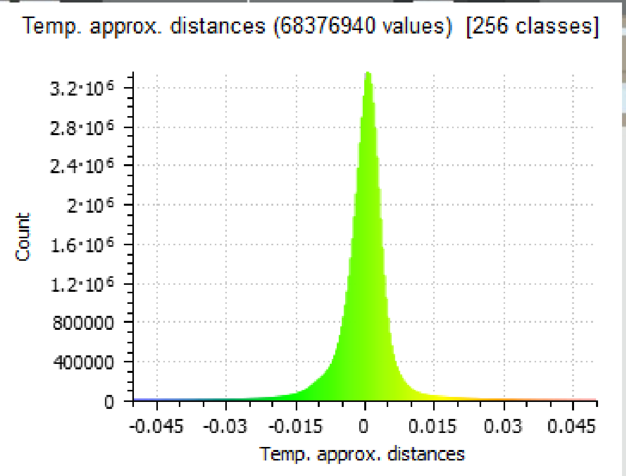


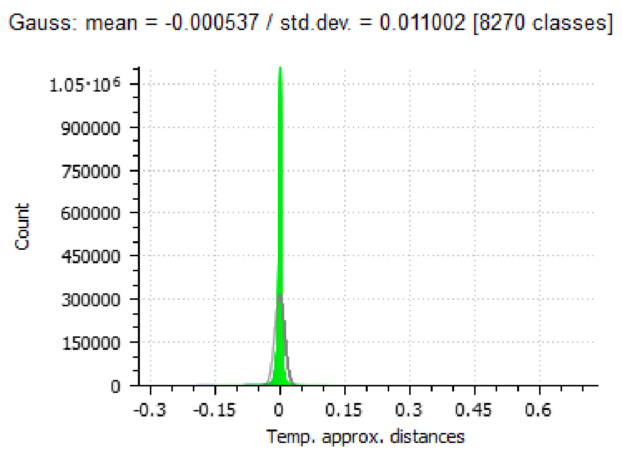


- Point amplitude

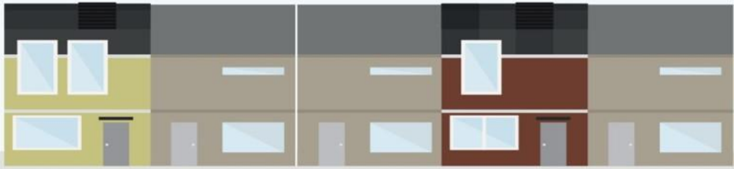
MORE — CONNECT



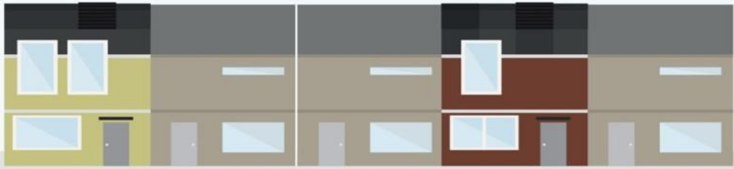




MORE — CONNECT



Converting model

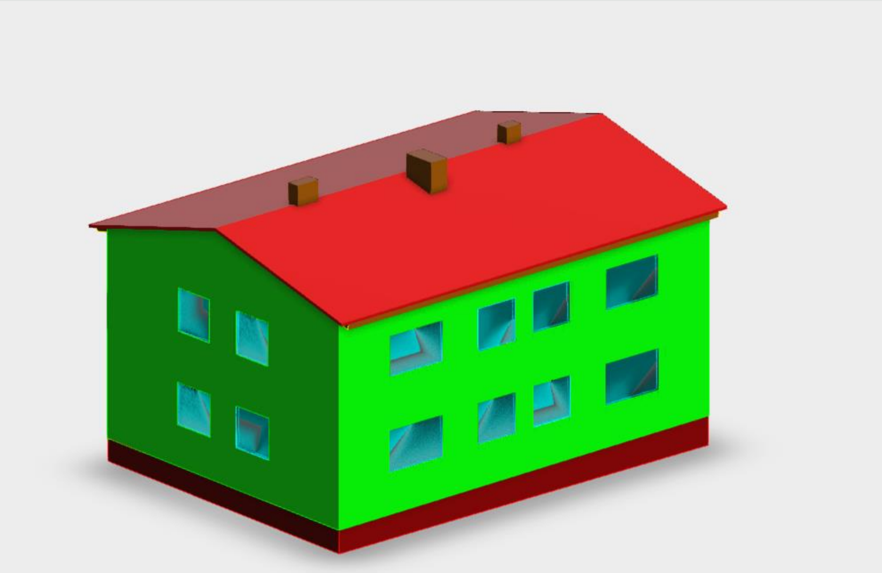


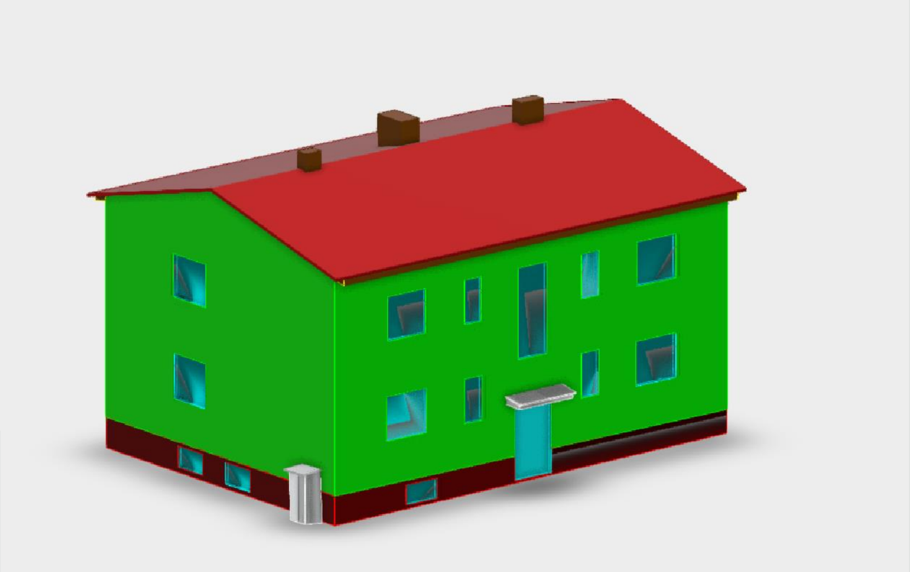
Converting model

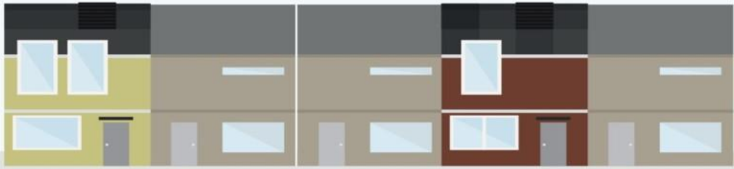
1) Converting in Bentley Descartes software
2) Output formats:
   - *.dgn;
   - *.dwg;
   - *.dxf;
   - *.dgnlib;
   - *.rdl.
3) Converting model form *.dgn format to *.dwg format
   - Checking model in AutoDesk 360 Viewer Online

Model in AutoDesk A360 Viewer online

MORE — CONNECT



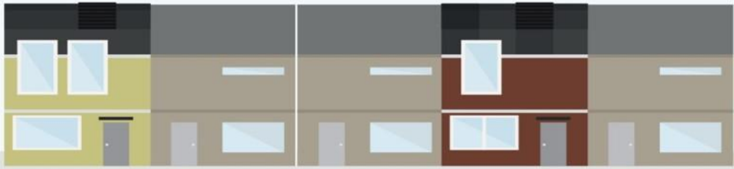




Summary and conclusions

Spent time

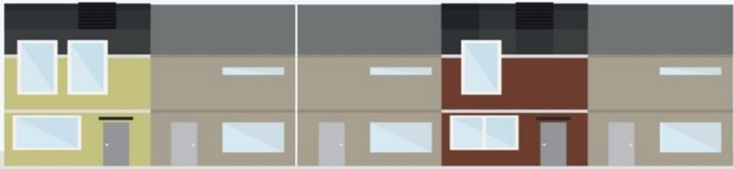
MORE—CONNECT



1) Flight planning
   - 1 hour
2) Flight and capturing images (arrival time to an object is not included):
   - 1 hour and 30 minutes
3) Point cloud cleanup and form
   - 2 hours
4) Processing photos in ContextCapture Master and searching for control points in Cloud Compare:
   - Searching for control points and indication (including control points area editing)
     - 3 hours
   - Creating production (reality model) -
     - 2 hours 12 minutes
5) Modeling:
   - ~2-3 days
6) Comparing data:
   - ~1-2 days
7) Converting and checking converted model:
   - 30 minutes

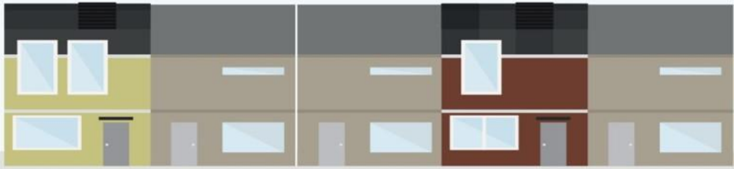
Costs

MORE—CONNECT



- Manpower - man hours costs (e.g. EUR 30)
- Drone Phantom 4 DJI FC330 with extra batteries - EUR 2000
- Software:
    - ContextCapture - EUR 6000
    - Acute 3D Viewer - free
    - Bentley Descartes - bundled with ContextCapture as ContextCapture Editor
    - AutoDesk 360 Viewer Online - free
    - Software for comparing (not obligatory):
        - Cloud Compare - free
        - Leica Cyclone - ????
- Hardware:
    - Intel Core i7 360 GHz, 64 GB RAM, GEFORCE GTX 1080TI ~ EUR 2300

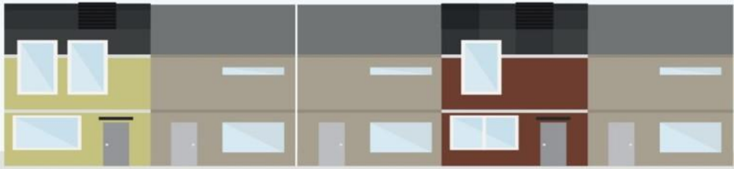
Summary and conclusions



MORE—CONNECT

1) Flight planning is very important.
2) Sunny and rainy weather is not so good as partly cloudy weather.
3) It is important to take a photos in different heights.
4) Reality model walls are pretty precise - they fit in 1 cm range.
5) Drone photogrammetry - it is a fast method for creating a 3D reality model for concrete area.
6) LOD2 model difference between reality model and point cloud is not bigger than 3cm.
7) LOD3 models windows and doors difference between point cloud is not bigger than 3.5 cm.
8) It is possible to convert LOD2 and LOD3 model from *.dgn to *.dwg format without any data loss, which is compatible for AutoCAD users.
9) Modeling takes 1-1.5 week.
10) All processes take 1.5-2 weeks.
11) It is possible to take a photos from different devices

Recommendations



1. It would be good to:
   - fly in much more layers;
   - take more photos from one position with different camera angles;
   - take more photos for elements which have a bad visibility;
   - have controlpoints in different locations on the wall;
   - make control measurements for windows depth.
2. It is very important to have a precise coordinates of control points (if it is important to have a model in concrete coordinate system).
3. *If reality model will be precise then it will be possible to create much more precise building model*