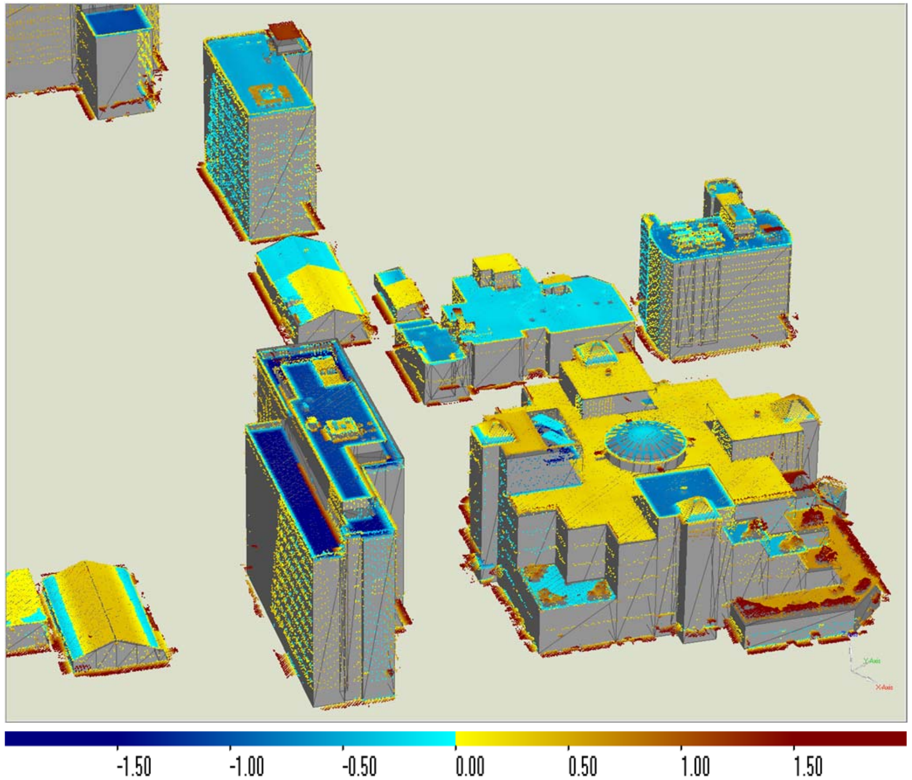

Fast Quality Control of 3D City Models

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Introduction – 3D building modeling

• 3D city models are in high demand.

• **Fully automated** methods still cannot satisfy the practical user needs.
This fact led to substantial research on the **semi-automated methods**.
E.g. CyberCity Modeller (*Gruen and Wang, 1998*).

• While the performance of the methods is improving,
the **quality evaluation of 3D building data** has become an important issue.

Introduction – Quality assessment methods in the literature

• Quality metrics using **pixels,** based on 2D projections (*Henricsson and Baltsavias, 1997; Ameri, 2000; Suveg and Vosselman, 2002; Boudet et al., 2006*),

• Quality metrics using **voxels**, considering buildings as volumetric data (*McKeown et al., 2000; Schuster and Weidner, 2003; Meidow and Schuster, 2005*),

• **Qualitative and visual** evaluation (*Rottensteiner and Schulze, 2003; Durupt, Taillandier, 2006*),

• **Error propagation** applied to the stochastic properties of input (road) data (*Elberink and Vosselman 2007*),

• Detailed reviews in *McKeown et al*. (2000) and *Sargent et al.* (2007).

Introduction – Goal

• '**Quality Assessment of 3D Building Data**' is a cooperative project between
Chair of Photogrammetry and Remote Sensing of **ETH Zurich,**
Research department of **Ordnance Survey, (UK)**.

• **Goal** is to calculate **metrics** for the **quantitative evaluation** of 3D buildings.

• These **metrics**,
+ correspond to customers' requirements (of Ordnance Survey),
+ independent of the method of data capture.

Data

• **Input data:**
3D building models provided in a vector 3D model format.

• **Verification (reference) data:**
Airborne laser scanning (ALS) point cloud data
or
another 3D model given at a higher quality level.

Quality assessment by 3D surface matching

• In fact, 3D building data is in **surface** form.

• Our proposal is to work directly on 3D surface elements (**surfels**).
The input model is co-registered to the verification data
by **Least Squares 3D surface matching** (**LS3D**, *Gruen and Akca, 2005*).

• The **LS3D surface matching method**

+ rigorous algorithm for the matching of overlapping 3D surfaces,
+ estimates 3D transformation parameters,
+ min → Sum(Sqr (EuclideanDistance)),
+ using Generalized Gauss-Markoff model,
+ internal quality control,
+ multi-quality & multi-resolution data.

• The LS3D method evaluates the Euclidean distances between the verification and input data sets. **The Euclidean distances** give appropriate metrics for the 3D model quality.

Quality criteria - generated by the LS3D method

• **Reference system accuracy**
Due to production techniques, input & verification reference frames may differ.
LS3D method calculates 7DOF, 6DOF, 3DOF, etc., differences.

• **Positional accuracy**
Each element-to-element correspondence is a 3D Euclidean vector.
Assuming that verification data at a higher quality level,
Euclidean distances are the positional accuracy of the surfels (of input surface).

• **Completeness**
Assuming that verification data complete, accurate and dense,
missing correspondences show the completeness.

Quality assessment strategy

Three procedural steps were followed in the experiments.

• **Step 1. Computation of initial (spatial) disagreement**
Only 3D spatial distances calculated (without any transformation).
This step shows the initial misalignment.

• **Step 2. Co-registration**
Run of the LS3D surface matching with the transformation computation.
Acc. to preliminary tests, only translations (3DOF) between both data sets.
The estimated 3D transformation parameters applied to test data sets.
Thus, the reference system errors isolated from the building's positional errors.

• **Step 3. Comparison**
Again, only 3D spatial distances calculated (without any transformation).
This final step shows the positional accuracy of buildings and completeness.

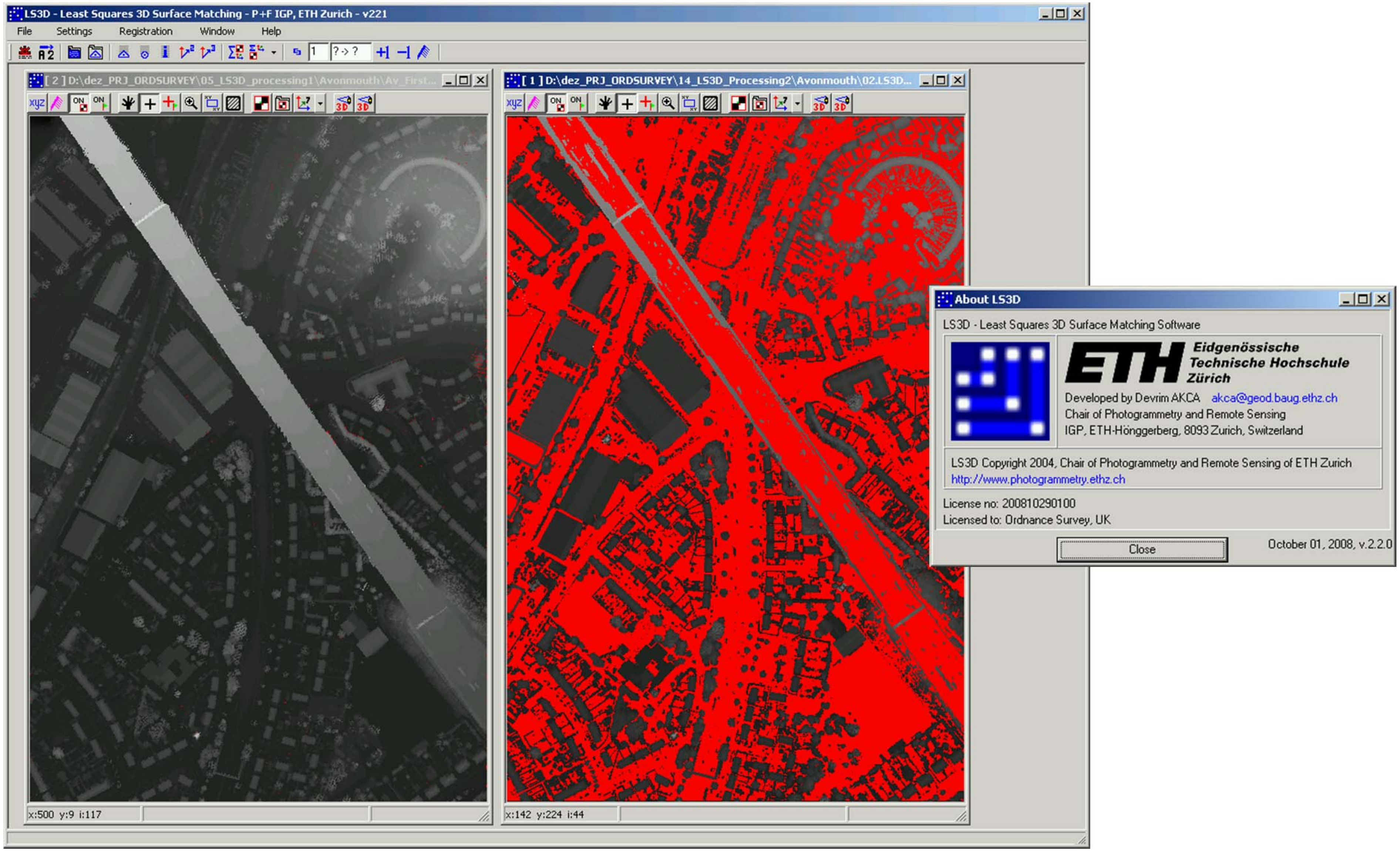
Experimental work – test sites

Two test sites in UK,
• Avonmouth (**AV**)
• Bournemouth test area 2 (**BO2**).

Input data:
• 3D building data (in V3D format),
• generated using CC-Modeler,
• measured through DMC imagery.

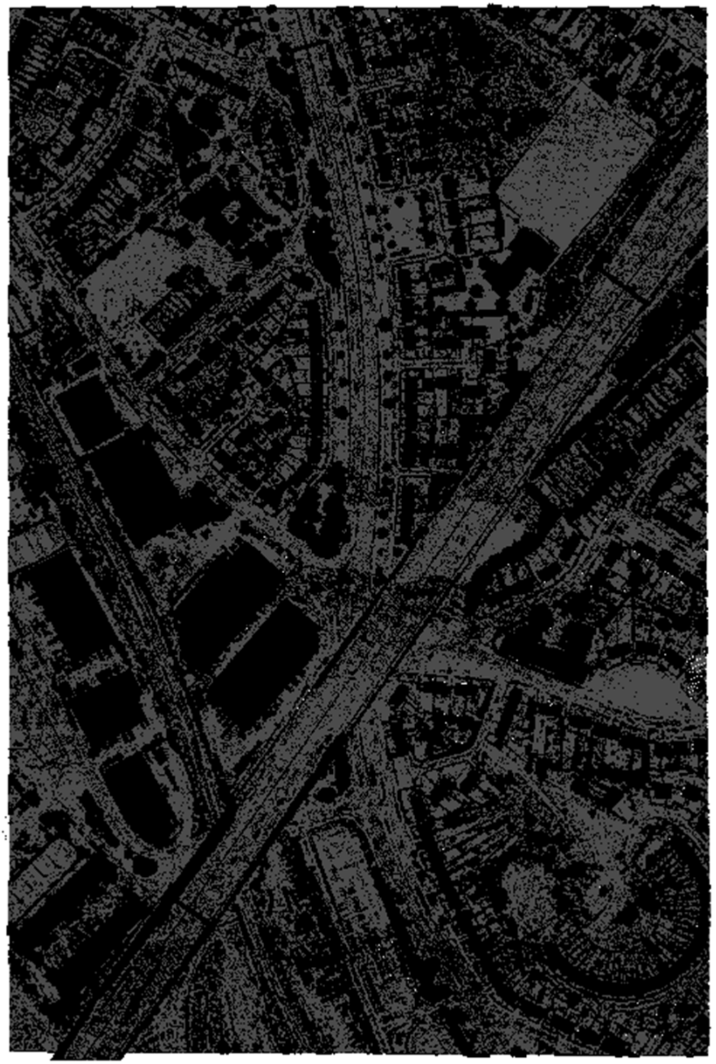
Verification data:
• LIDAR point clouds,
• acquired by Airborne 1 Corporation using a Bravo 50K ALTM system carried on a helicopter platform,
• 25 point/m^2 density.

Experimental work – LS3D Software



Results of test site AV

Verification LIDAR Data



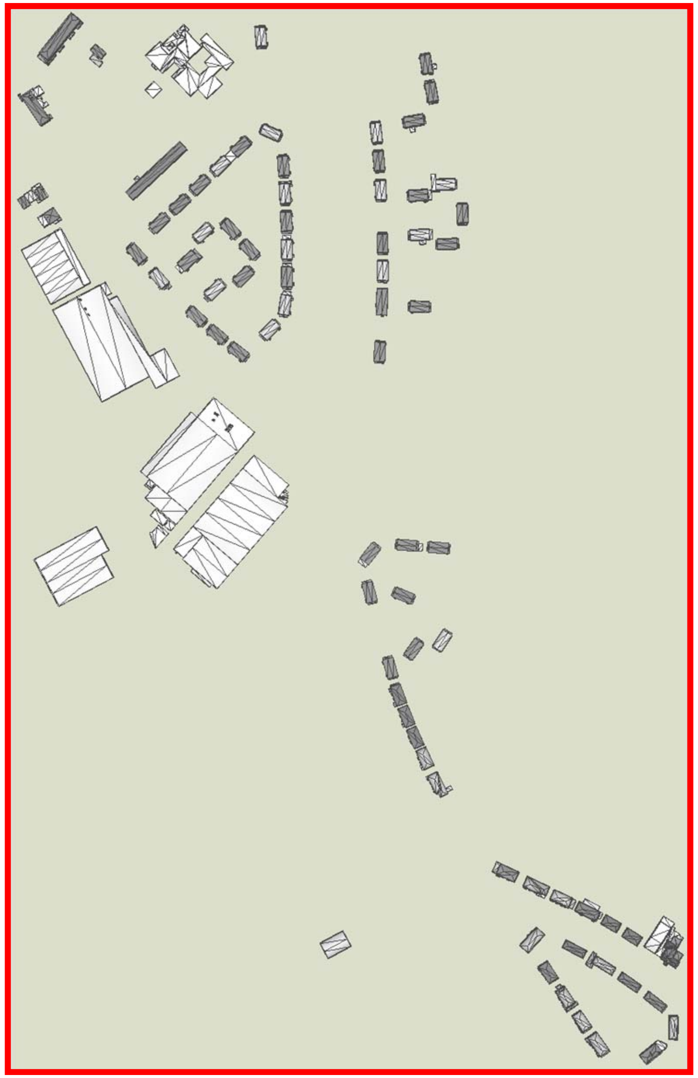
SCOP++ Filtering

Unclassifiable
Building
Hi-Vegetation
Med-Vegetation
~~Low Vegetation~~
~~Ground~~
~~Below~~

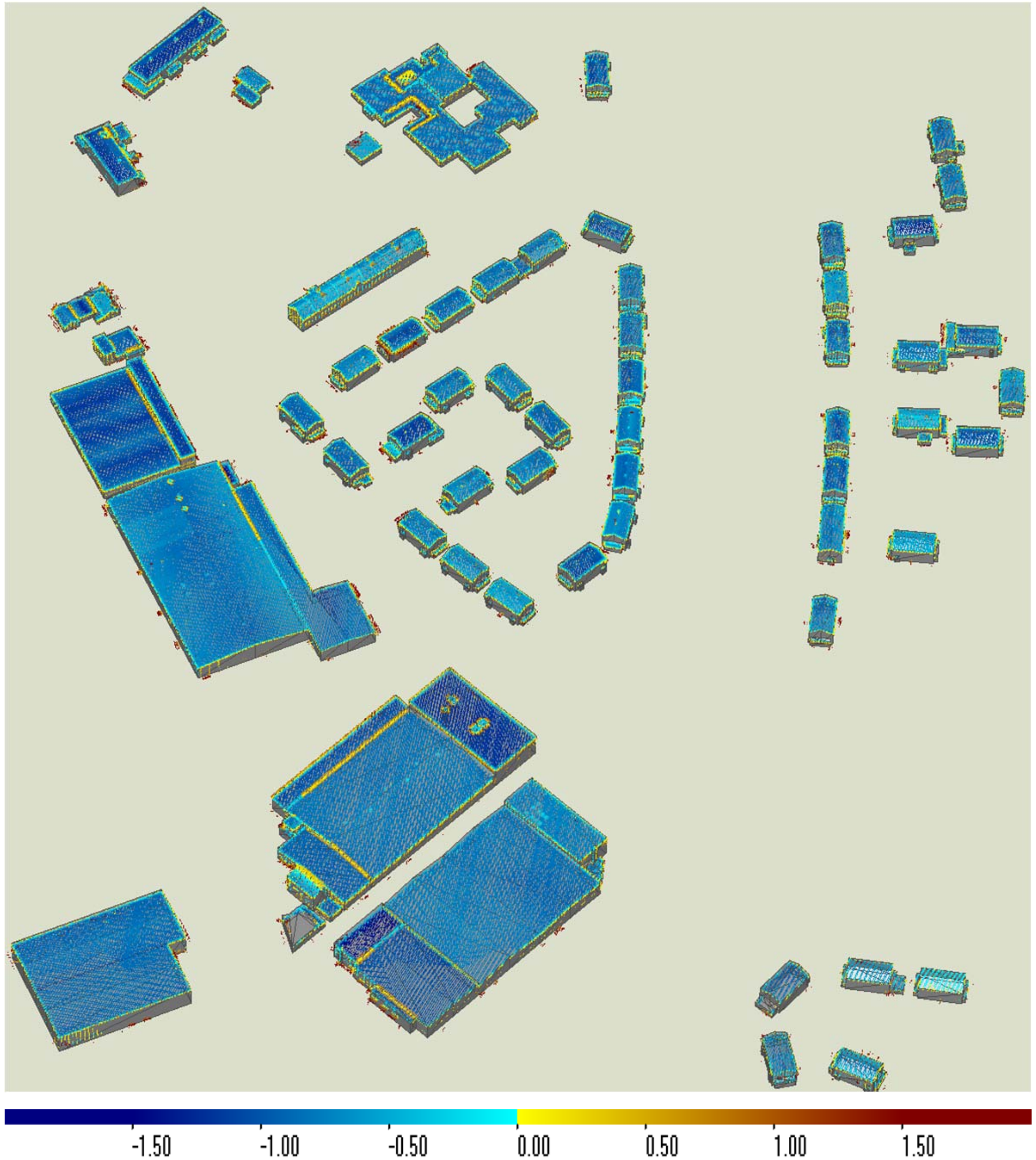
Results of test site AV

Verification LIDAR Data

Input 3D Building Data



Results of test site AV



Step 1:

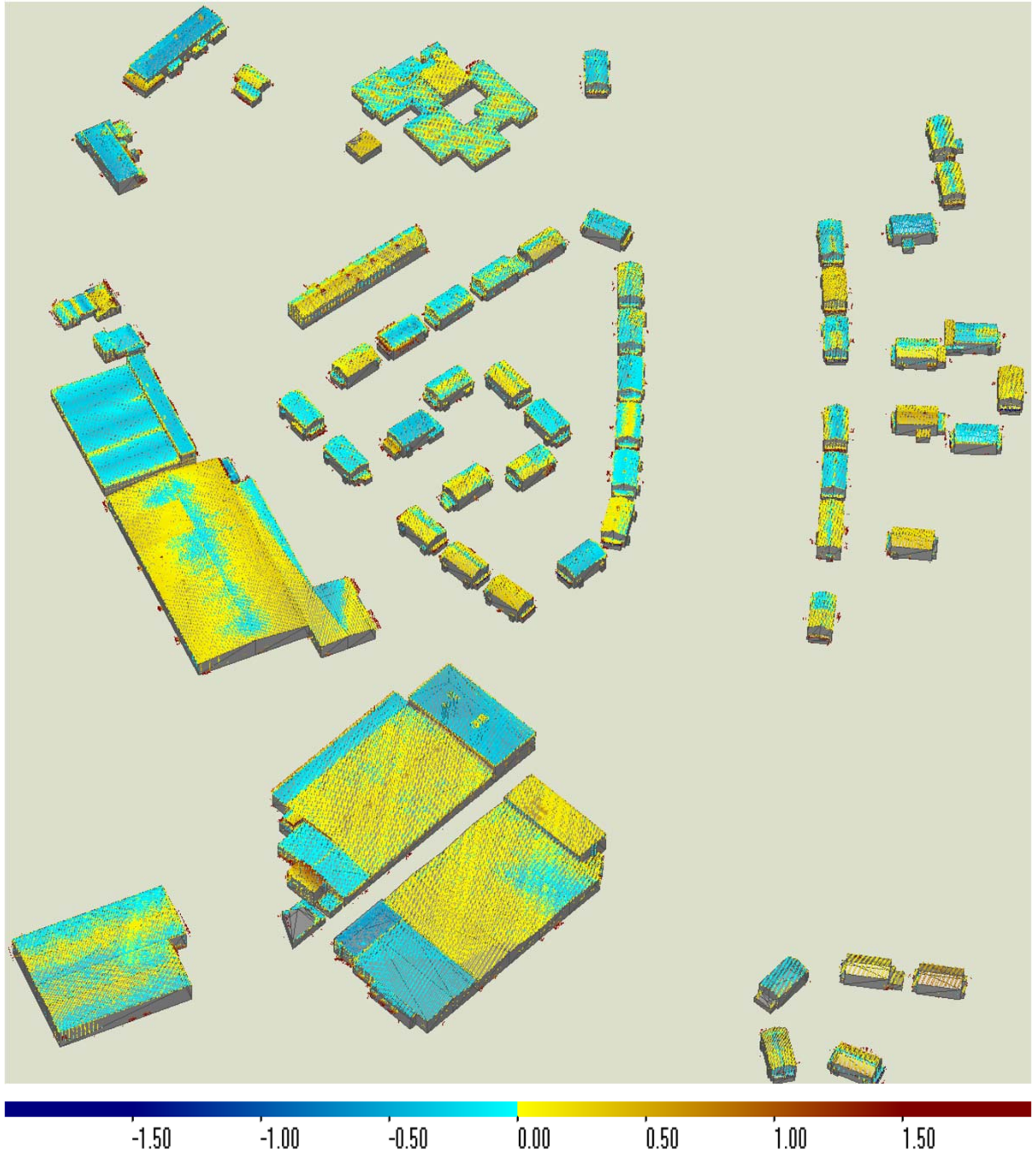
- Only the Euclidean distances, without transformation.
- 3D Building data is **above** the LIDAR pointcloud.
- Sigma0^ = **± 0.77 m**

Step 2:

- Full LS3D run, computation of 3D transformation.
- 3D Translation vector:

X= **+0.06 m**
Y= **+0.05 m**
Z= **−0.85 m**

Results of test site AV



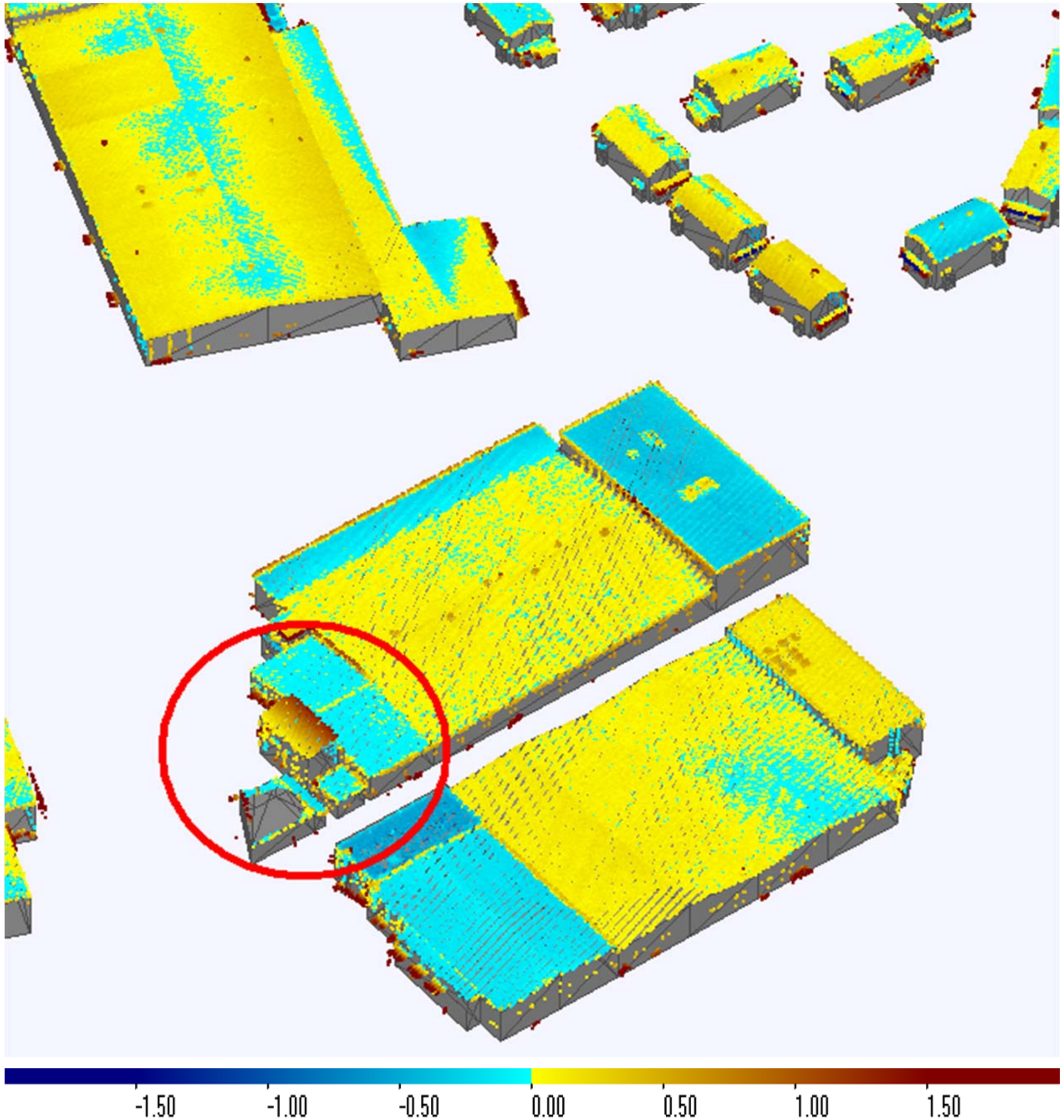
• The translation vector is applied.

Step 3:

• Only the Euclidean distances, without transformation.

• Sigma0^ = **± 0.30 m**

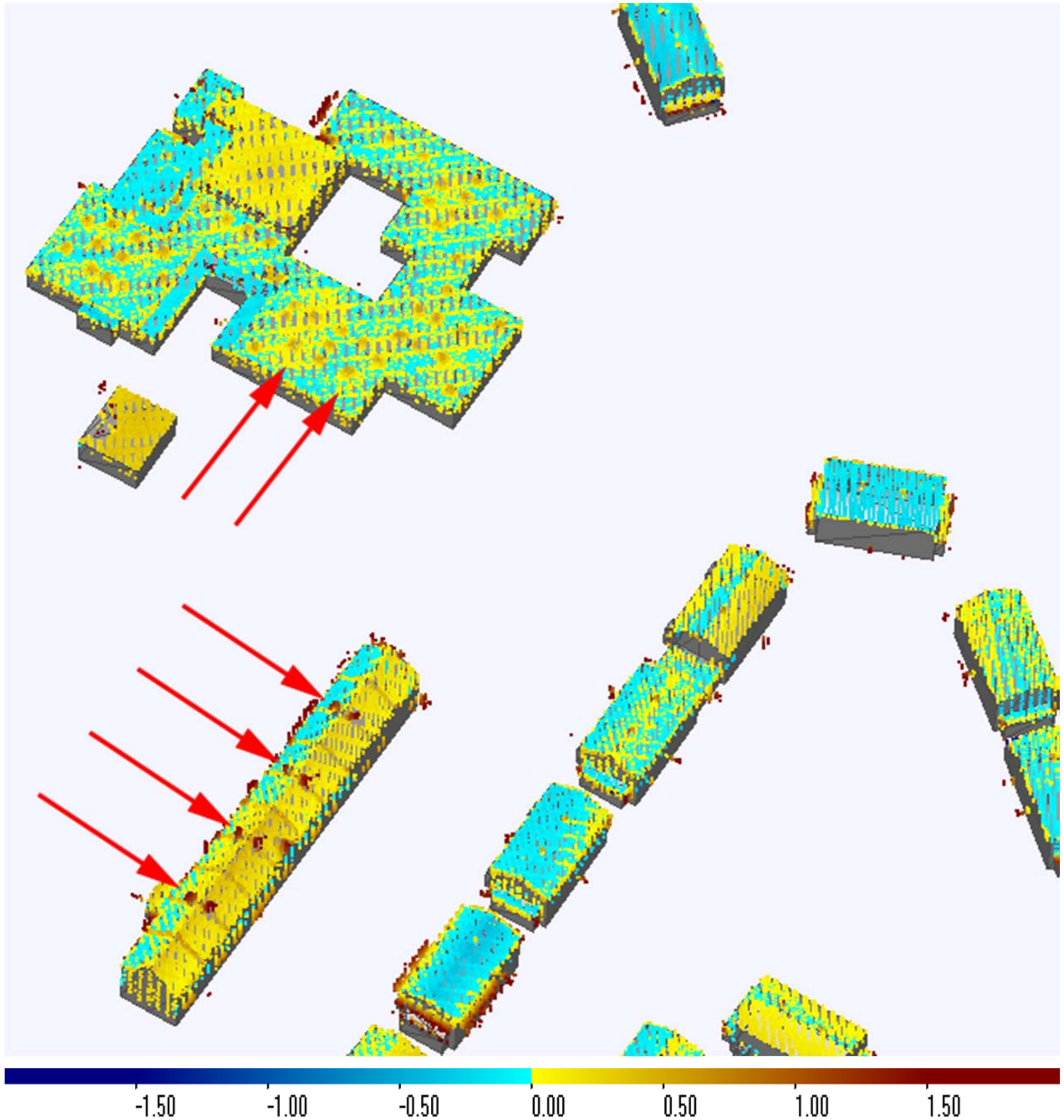
Results of test site AV – Zoom In



Positional Accuracy:

- **The red circle** shows a part of a building which has a large measurement error.

Results of test site AV – Zoom In

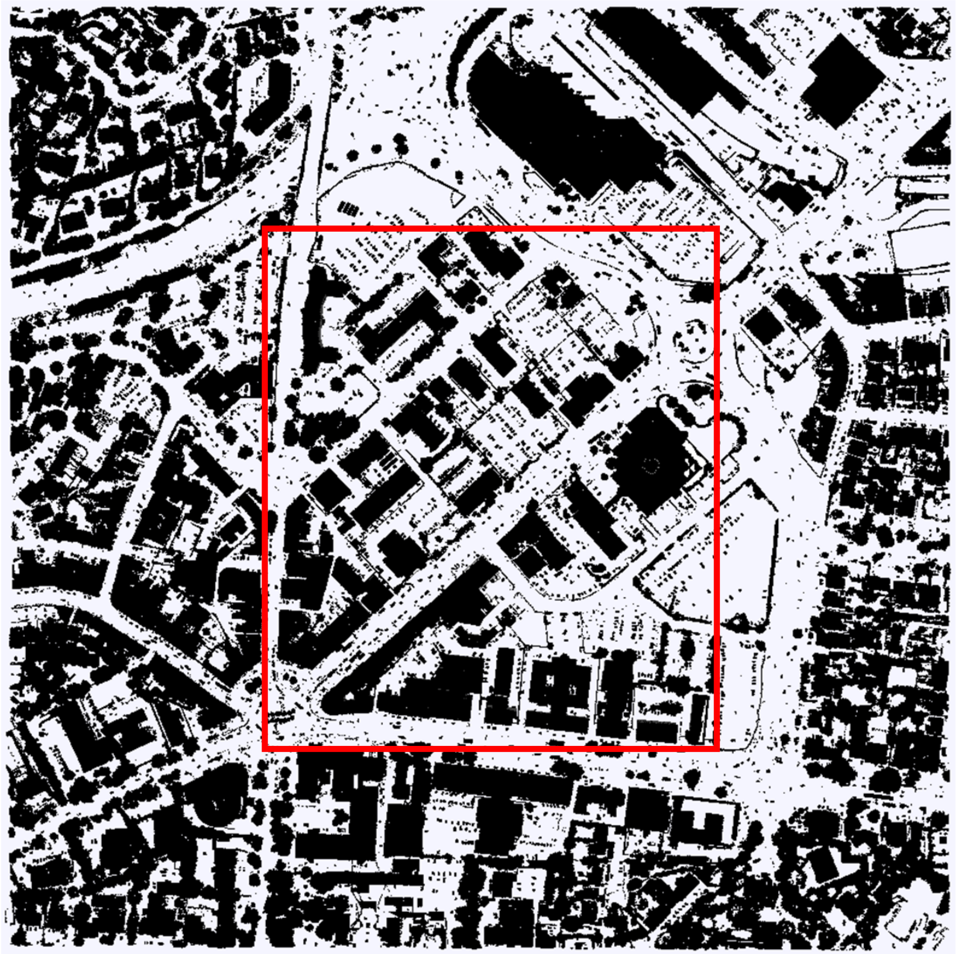


Completeness:

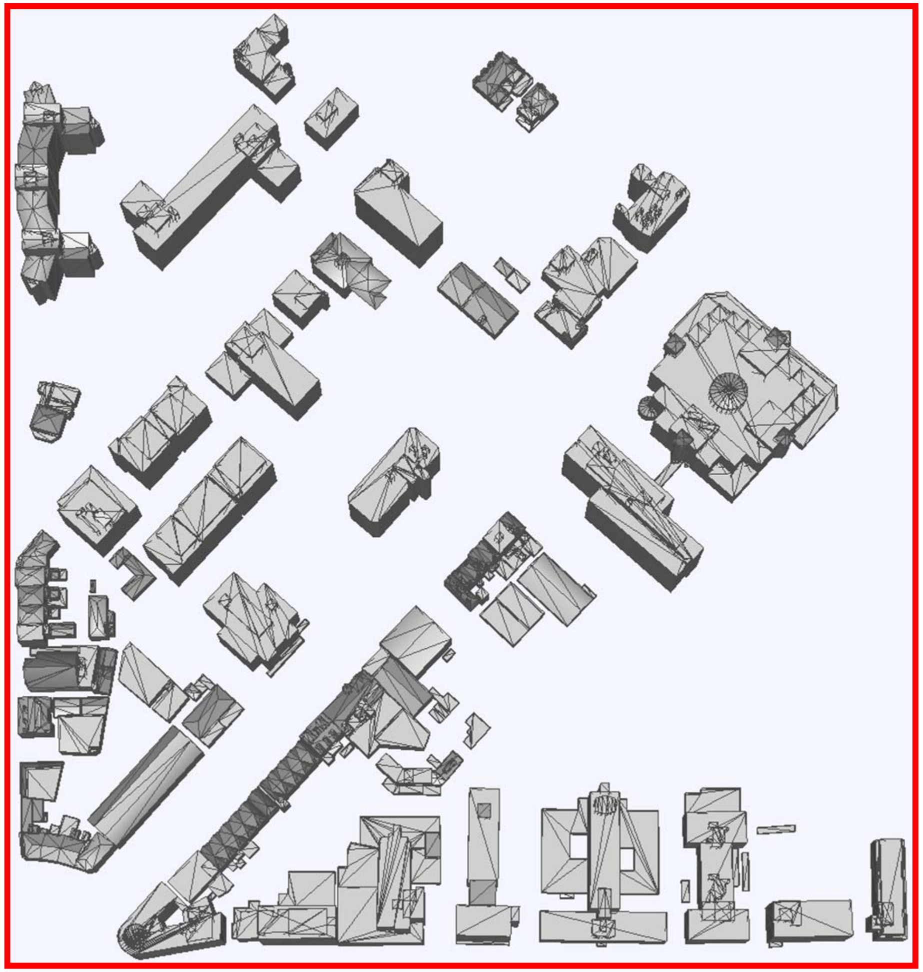
- **Red arrows** show the missing chimneys and dormers in 3D building data.

Results of test site BO2

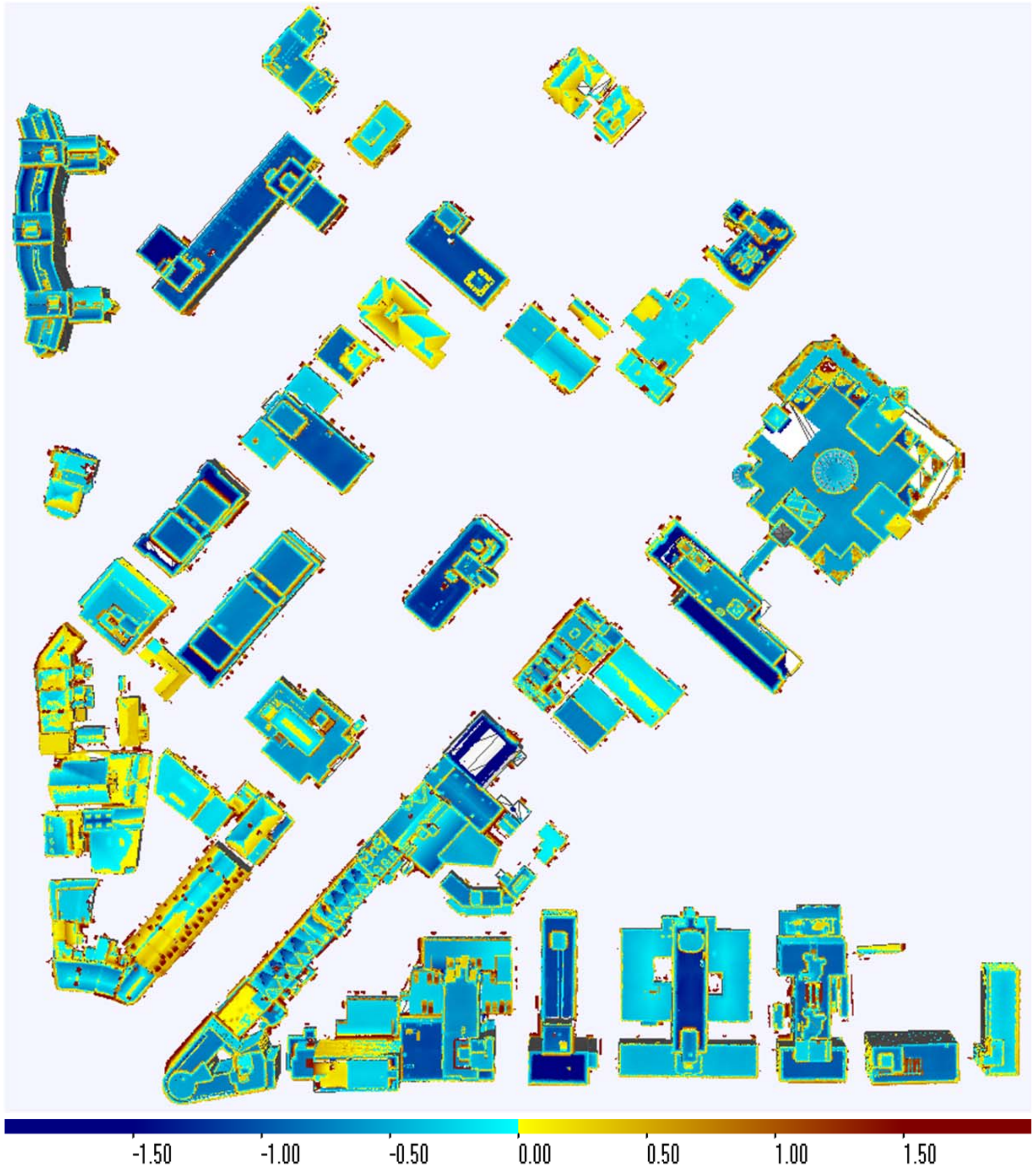
Verification LIDAR Data



Input 3D Building Data



Results of test site BO2



Step 1:

• Only the Euclidean distances, without transformation.

• 3D Building data is mostly **above** the LIDAR pointcloud.

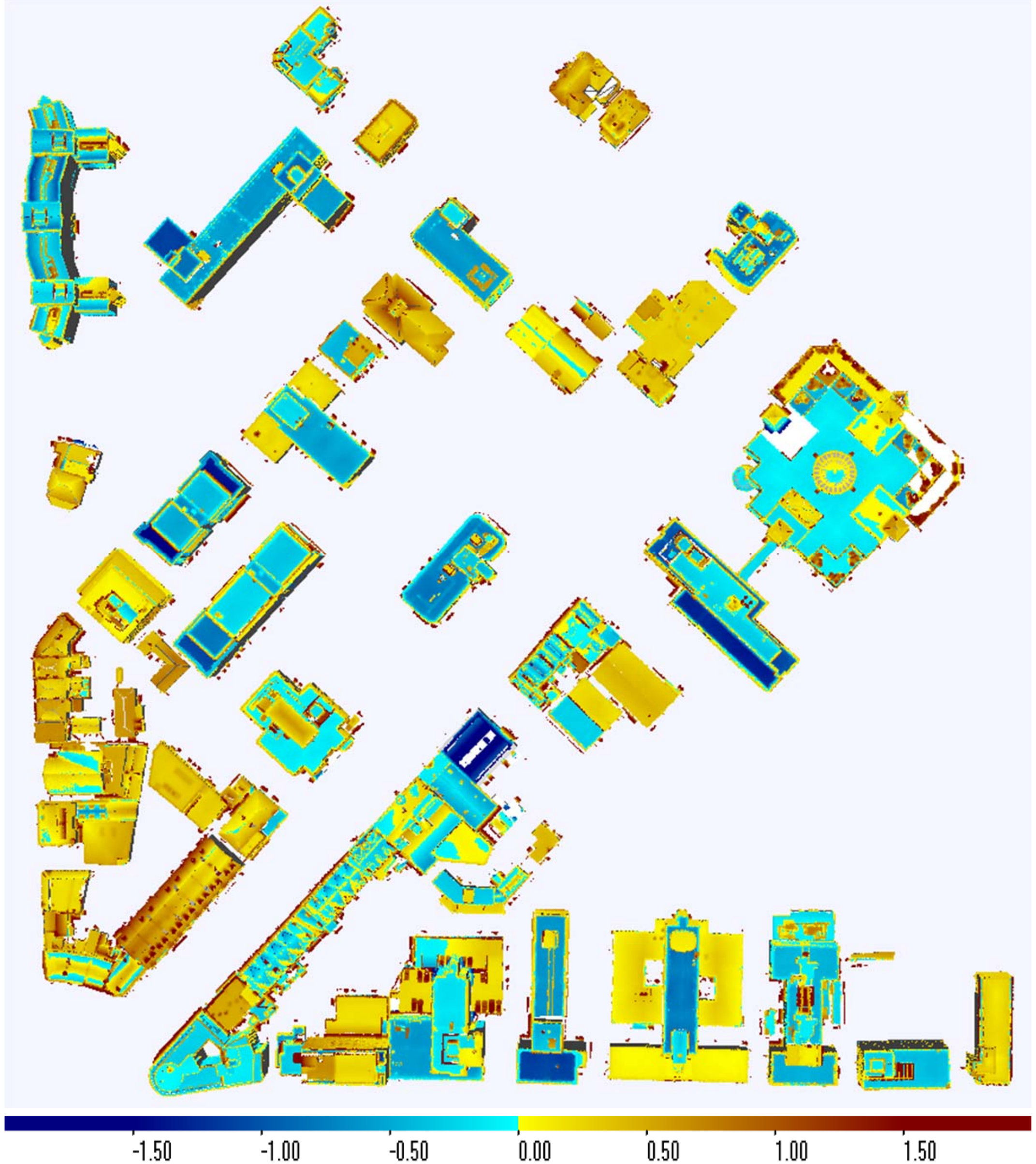
• Sigma0^ = **± 0.65 m**

Step 2:

• Full LS3D run, computation of 3D transformation.

• 3D Translation vector:
X= **+0.24 m**
Y= **−0.24 m**
Z= **−0.49 m**

Results of test site BO2

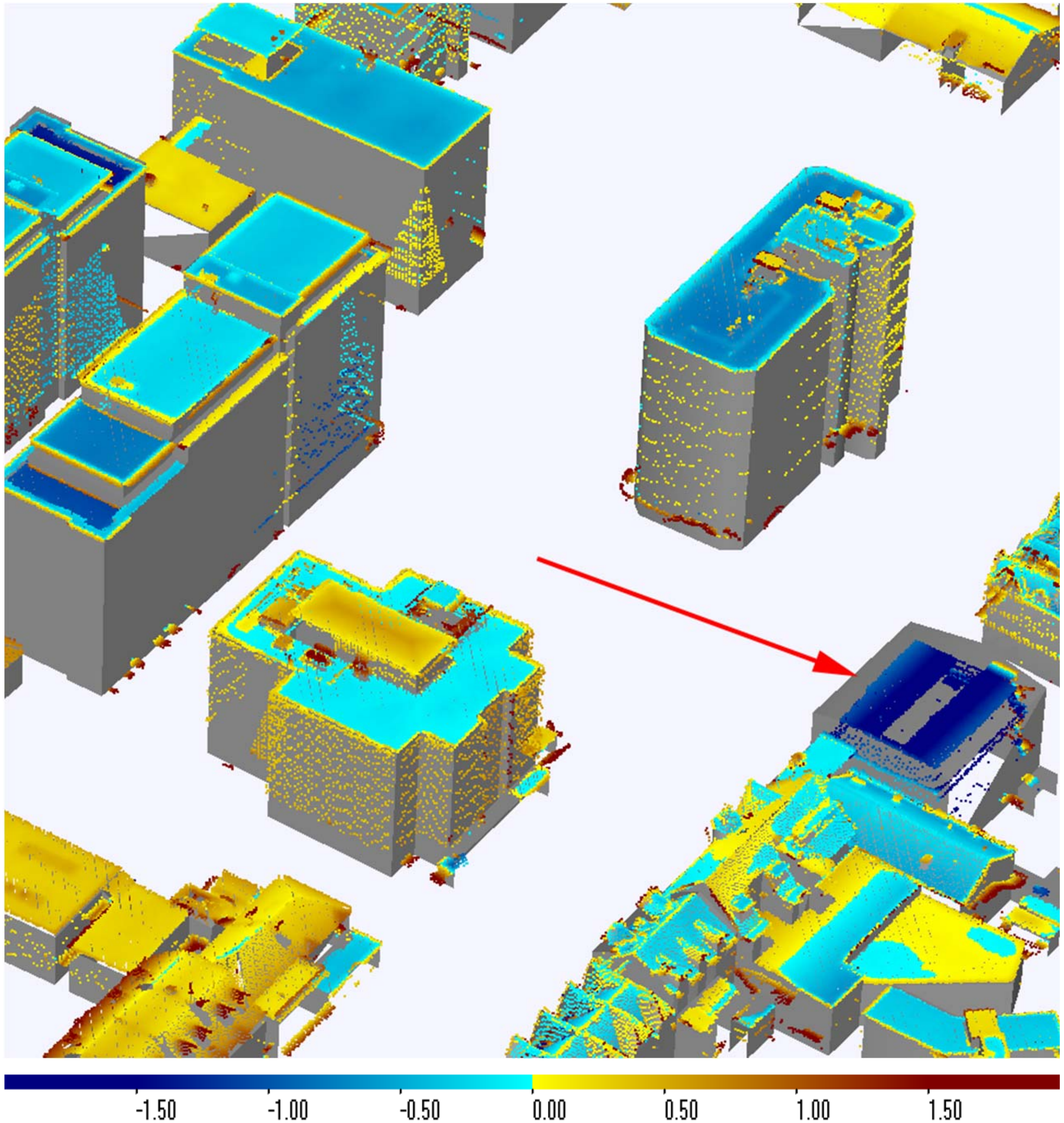


- The translation vector is applied.

<u>Step 3:</u>

- Only the Euclidean distances, without transformation.
- Sigma0^ = **± 0.54 m**

Results of test site BO2 – Zoom in

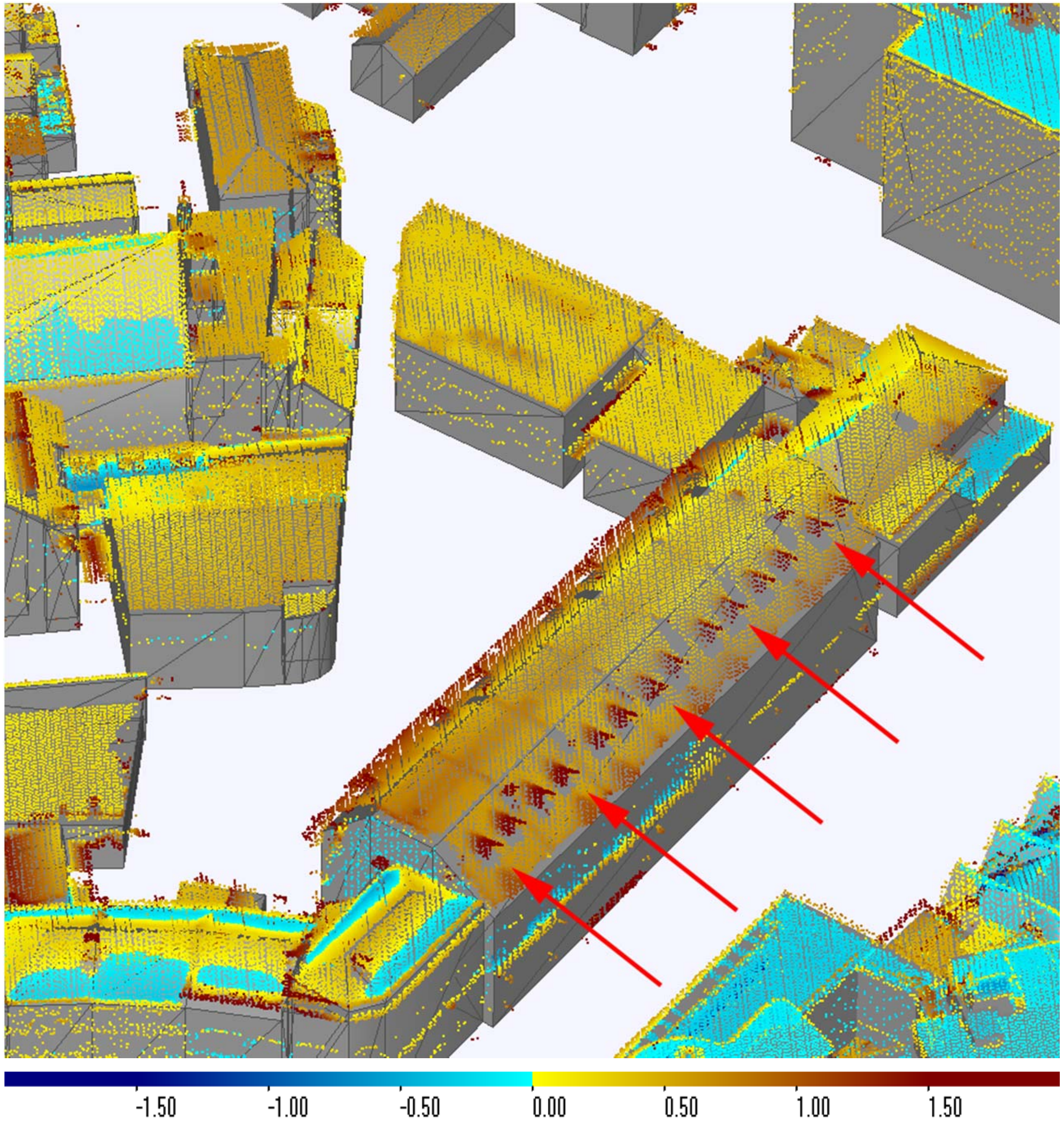


Positional Accuracy:

- **The red arrow** shows a roof of a building with large differences between the model and verification data.

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Results of test site BO2 – Zoom in



Completeness:

- **Red arrows** show the missing dormers of the building.

Conclusions

• We developed a practical method together with a GUI based C/C++ software.

• Our method can successfully assess the 3D building data in terms of

+ **gross errors** (outliers)

++ type I errors (completeness)

++ type II errors,

+ **systematic errors**

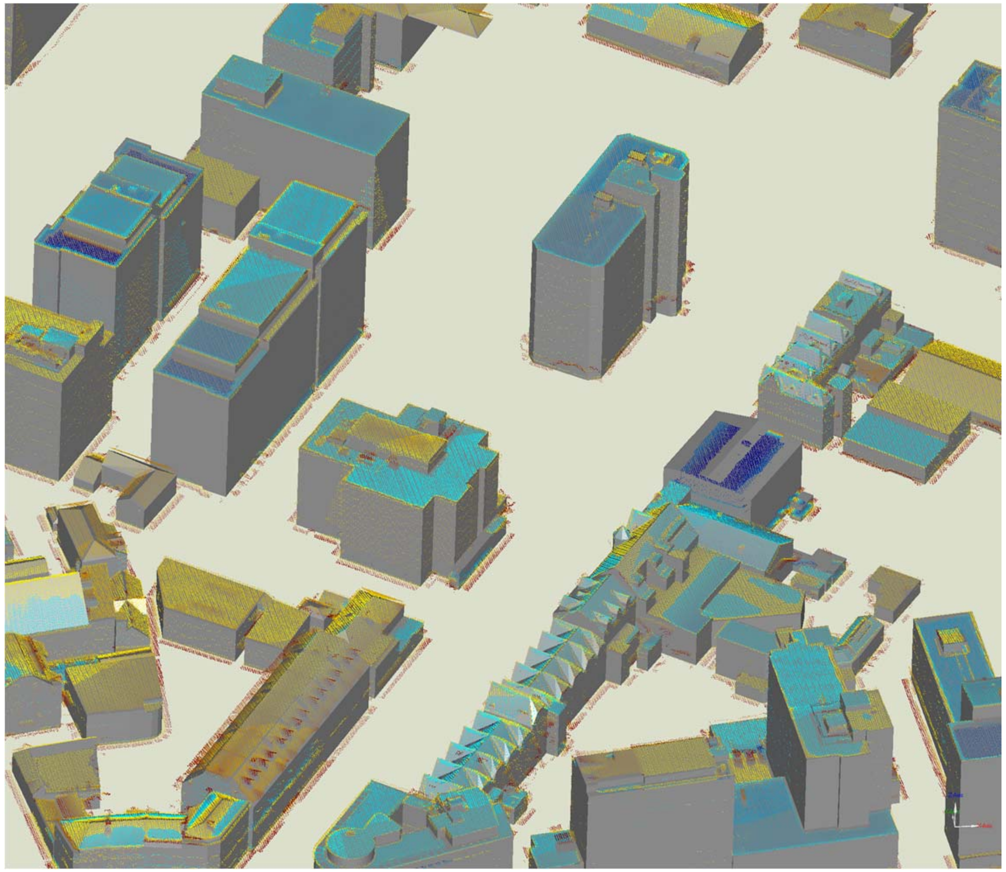
++ errors due to reference system differences

++ systematic measurement errors.

• Frequent and effortless **quality control** of 3D city models,

• **Updating** of 3D city models,

• **Change detection** of 3D city models.



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Thank you for your attention..