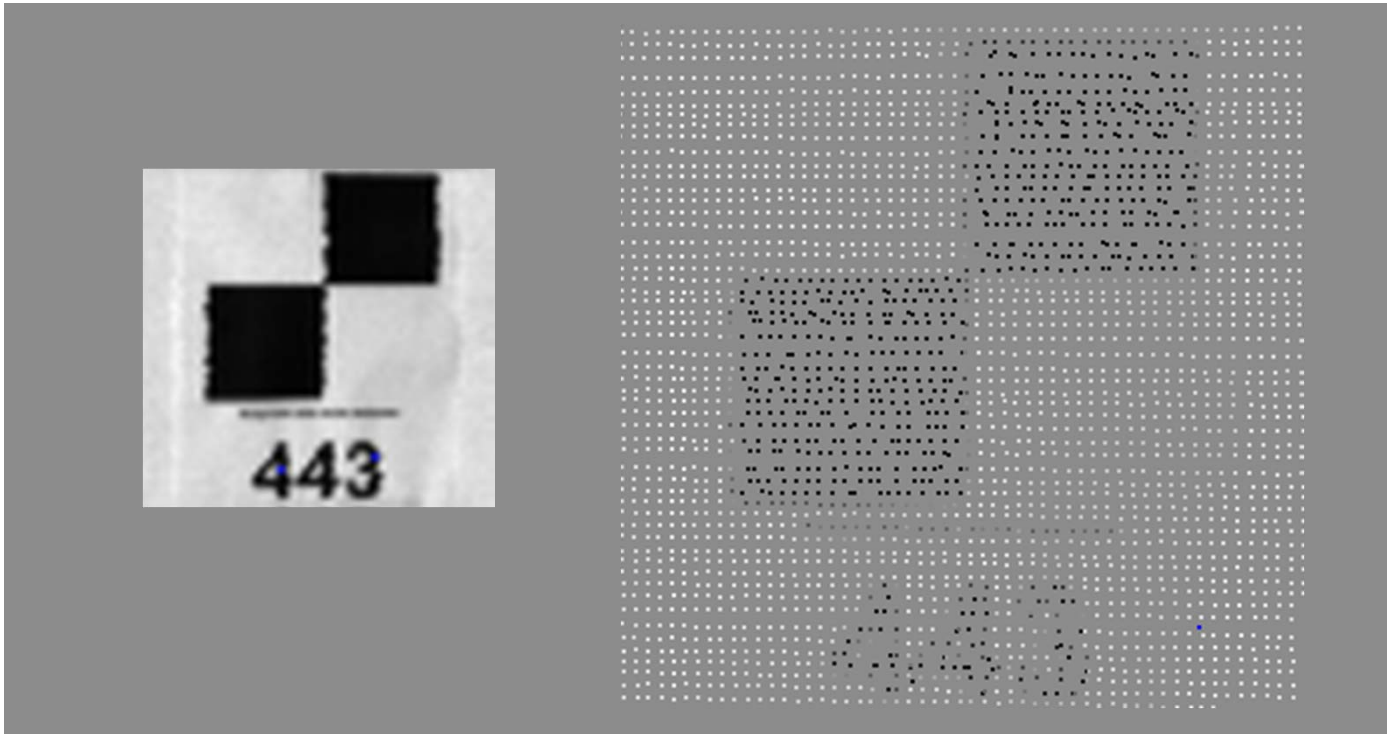
FULL AUTOMATIC REGISTRATION OF LASER SCANNER POINT CLOUDS



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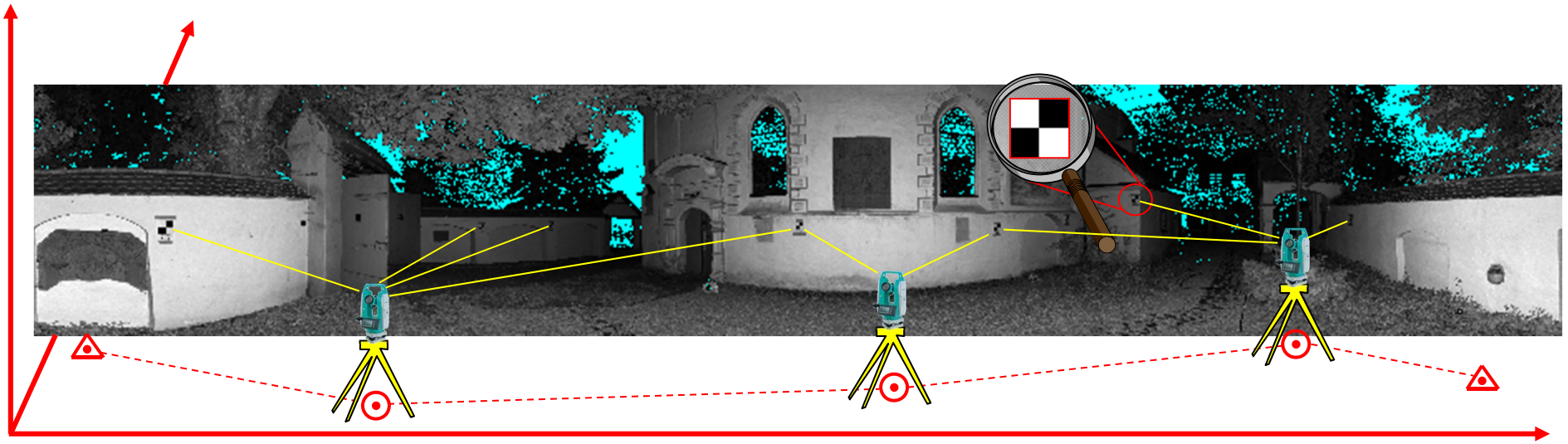
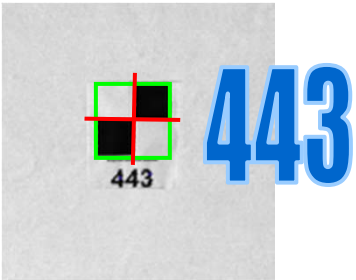
The Goal: is automatic registration of point clouds using template shaped targets.



3D coordinates of the targets are measured with a theodolite in a ground coordinate system, before the scanning process.



The fundamental problems are:

- **Recognition of the targets**
- **Precise localization of the targets**
- **Labeling of the targets**

Processing Steps:

- **Cross-correlation** on intensity images
- **Dimension test** for target candidates
- **Planarity test** for the target candidates
- Consistent labeling by **discrete relaxation**

Separately for each point cloud

- **Absolute orientation** onto ground coordinate system

Simultaneously for all point clouds

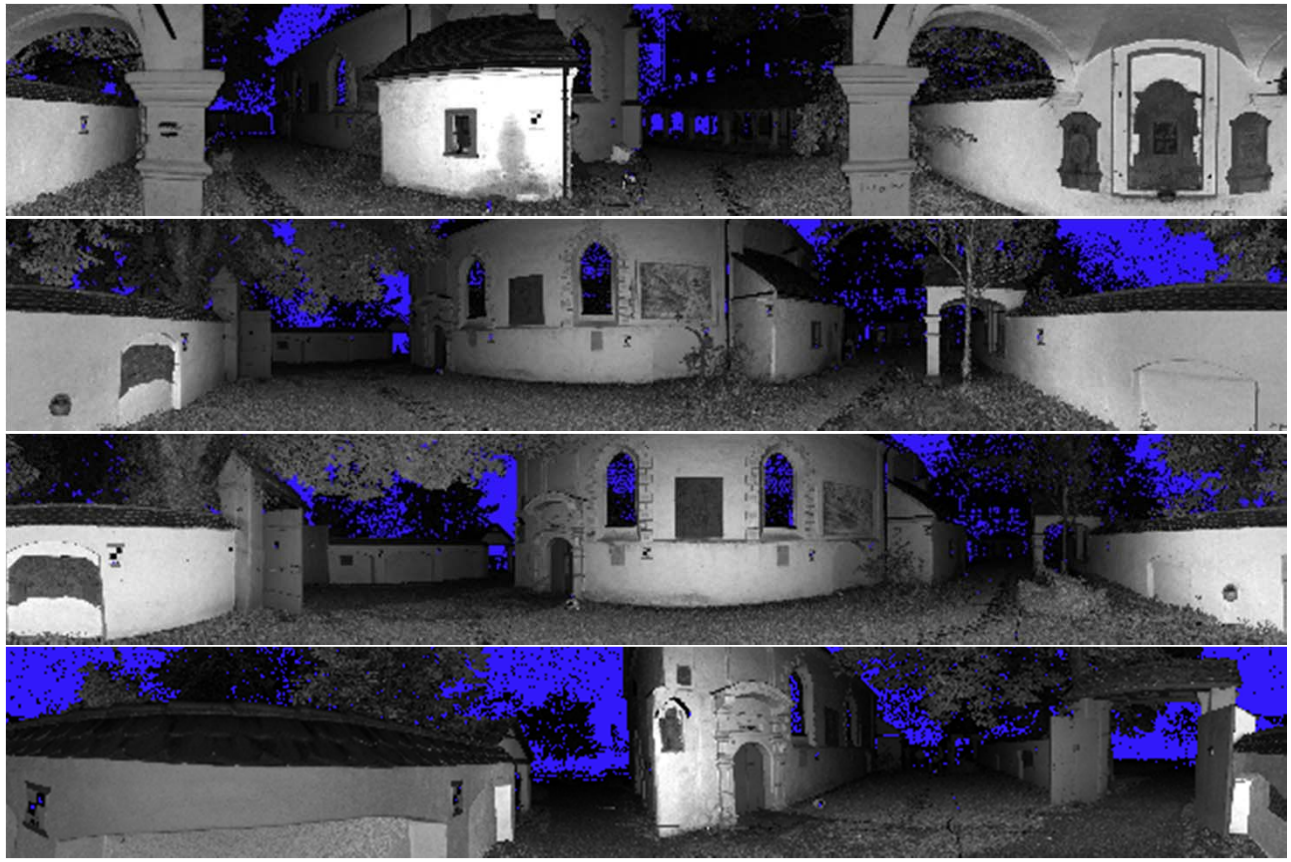
Those information must be supplied:

- **Coordinates** of the targets in ground coordinate system
- **Shape** and **dimension** of the targets
- Angular **scanning resolution**

The Data Set: is provided by Zoller+Froehlich Laser Scanner Company.

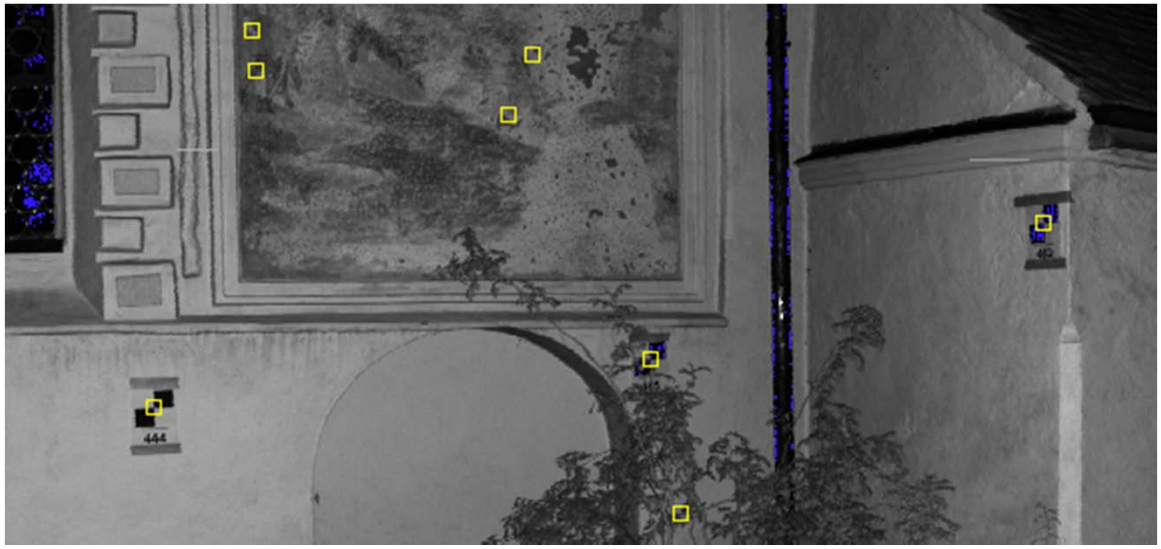
- 4 overlapping point clouds of a part of a chapel, in Wangen, Germany
- acquired Z+F IMAGER 5003 Laser Scanner
- 4000 x 660 points in horizontal/vertical directions respectively
- 16 bits intensity information (converted to 8 bits) for each point

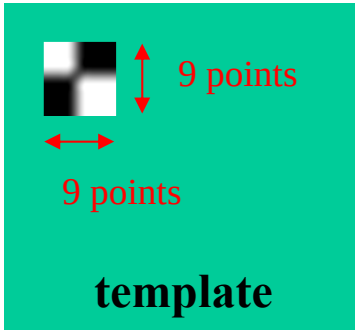
Z+F IMAGER 5003



Cross-correlation on the Intensity Images:

All of the probable **target candidates** are searched in the intensity image (sub-sampled version) using cross-correlation template matching method.

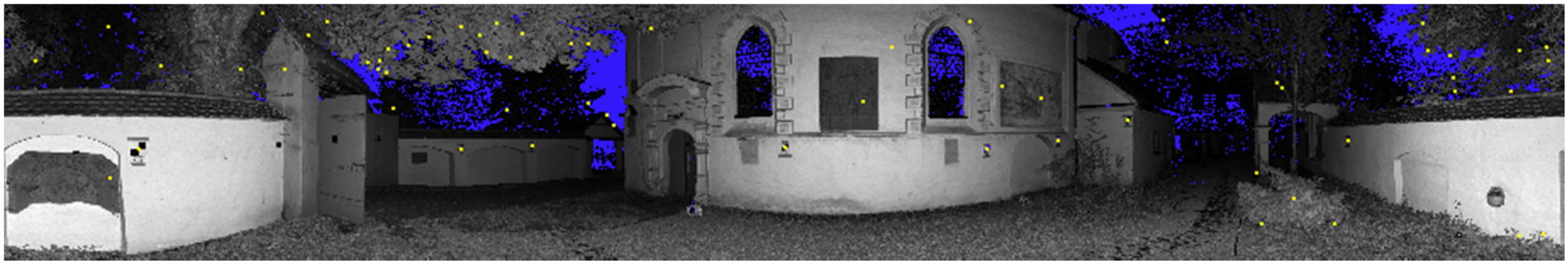




correlation coefficient > **0.7**

The aim of this step is to find as many as possible candidates, in which also contain the correct target points.

Identified target candidates after cross-correlation step:



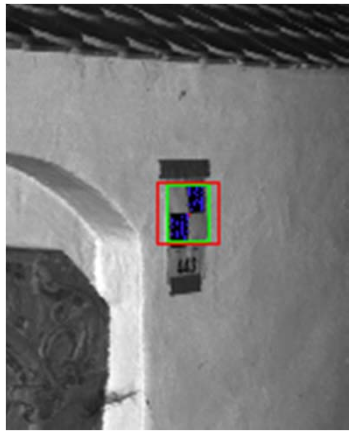
Number of target candidates : **62**

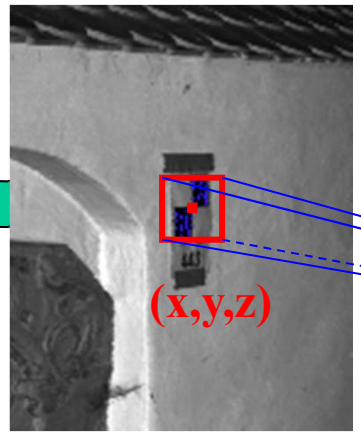
In the following steps, the wrong target candidates will be eliminated step by step using the object space geometrical constraints.

The Dimension Test:

The dimension of each target candidate must be similar to the real dimension of the target both in the ***intensity image space*** and in the ***object space***.

Adaptive Cross-correlation coeff. > **0.75**





Projection of the actual target dimension onto the intensity image

Comparison in the intensity image space tolerance : **25%**

Identified target candidates after dimension test step:

Number of target candidates, passed the Dimension Test : **18**

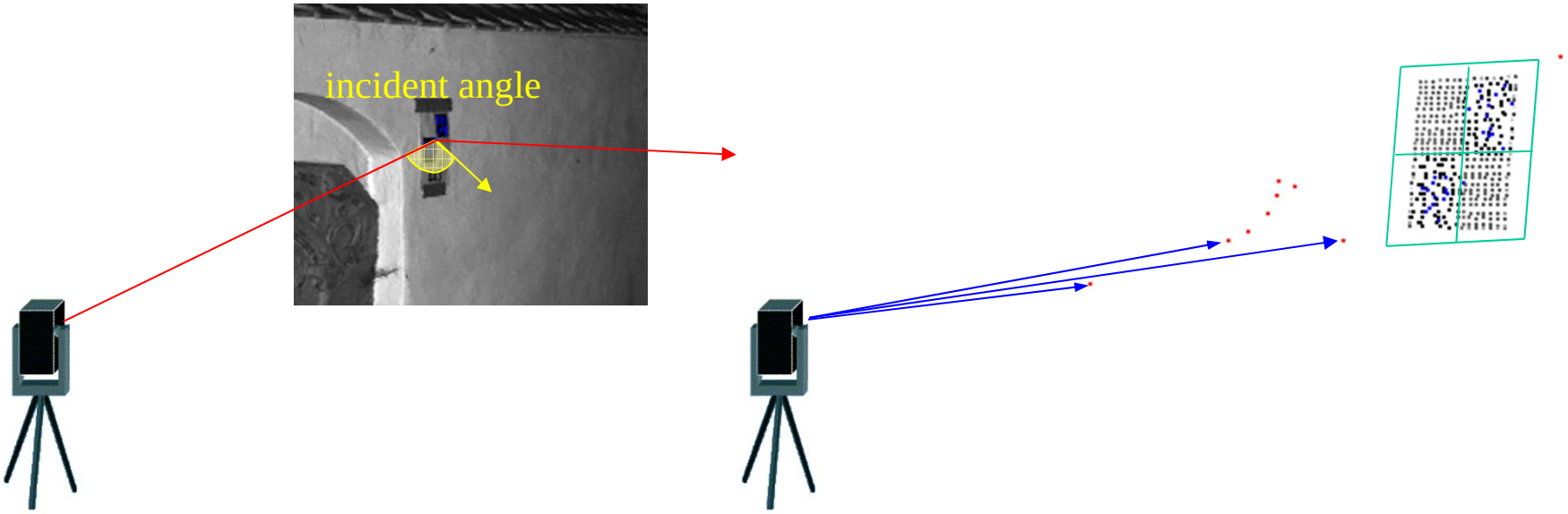
The candidates, do not satisfy the Dimension Test, are rejected from the candidate target list.

The Planarity Test:

Since the used targets are planar, the planarity test is applied to each target candidate, which passes the previous test.

The most important error sources are:

- reflectivity character of the surface
- incident angle between the surface normal and the signal path



$V_i = Ax_i + By_i + Cz_i + D$, P=I , D = constant

Identified target candidates after planarity test step:

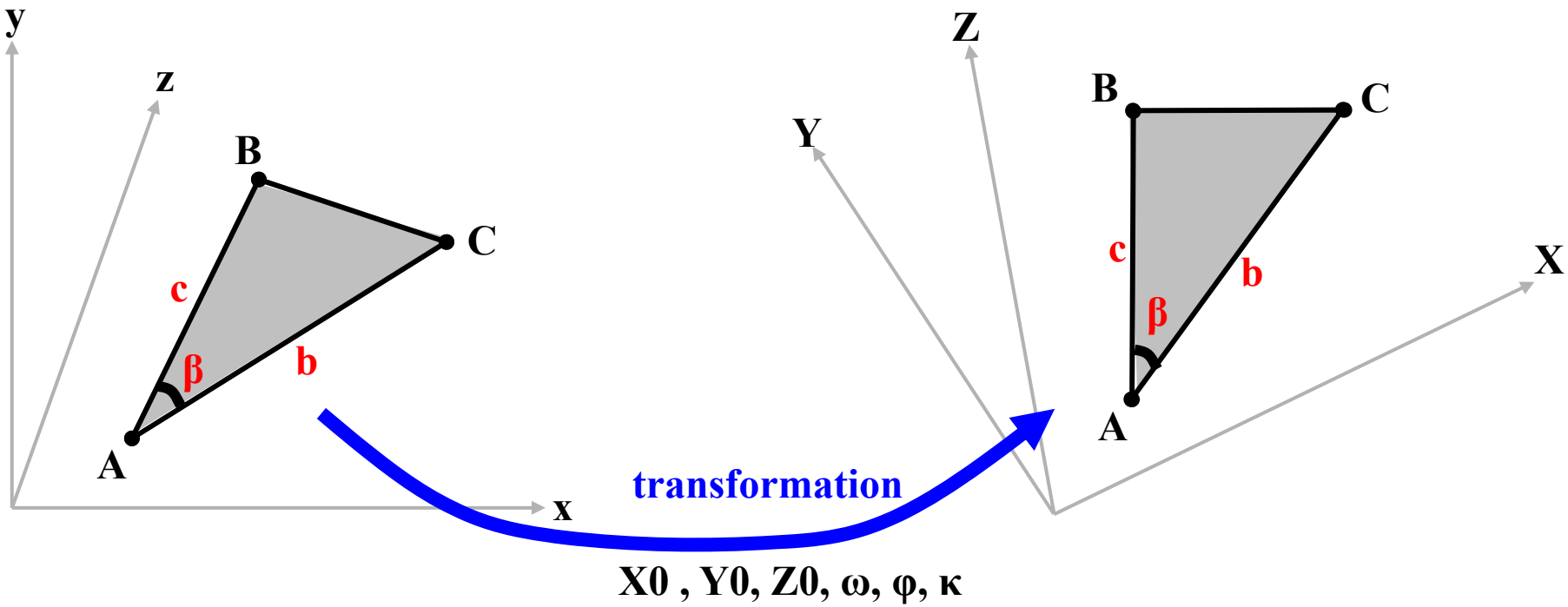
Number of target candidates, passed the Planarity Test : **10**

The candidates, do not satisfy the Planarity Test, are rejected from the candidate targets list.

The candidate targets list may still include 5-7% wrong candidates in many case.

The Consistent Labeling by Discrete Relaxation:

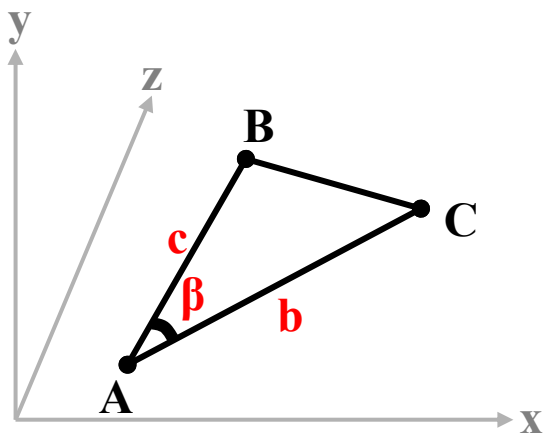
The space angles and distances among a given set of points are translation and rotation invariant parameters.



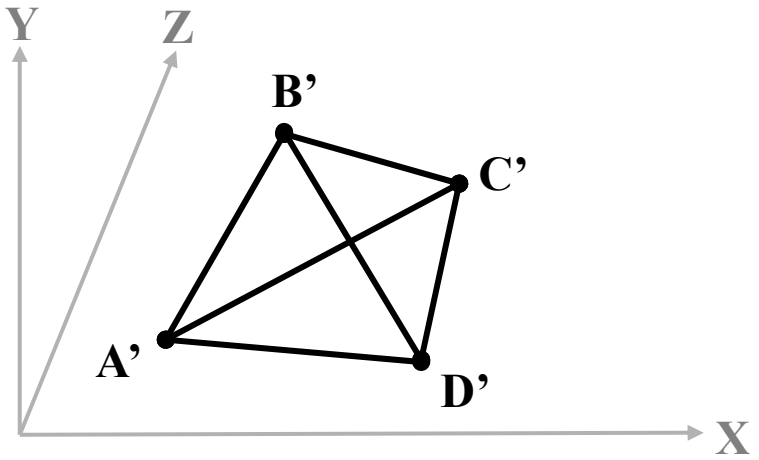
These two certain condition can be used:

- to label the target points
- to eliminate the wrong target candidates completely

All of the possible space angle(**β**) and 2 distances (**b**,**c**) triplets for each point are calculated both in the candidate targets list and in the ground control points list.



Local laser coordinate system



Ground control system

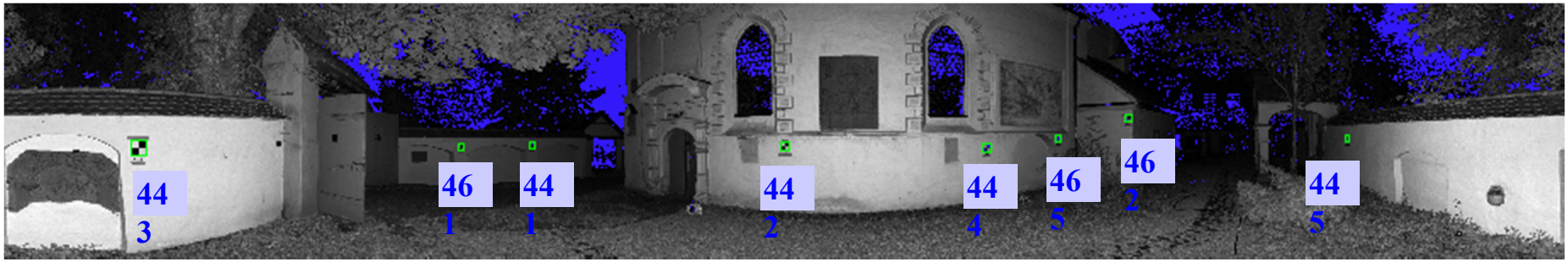
0 compatible 3D Triangle ⇒ **No label**

1 compatible 3D Triangle ⇒ **Label**

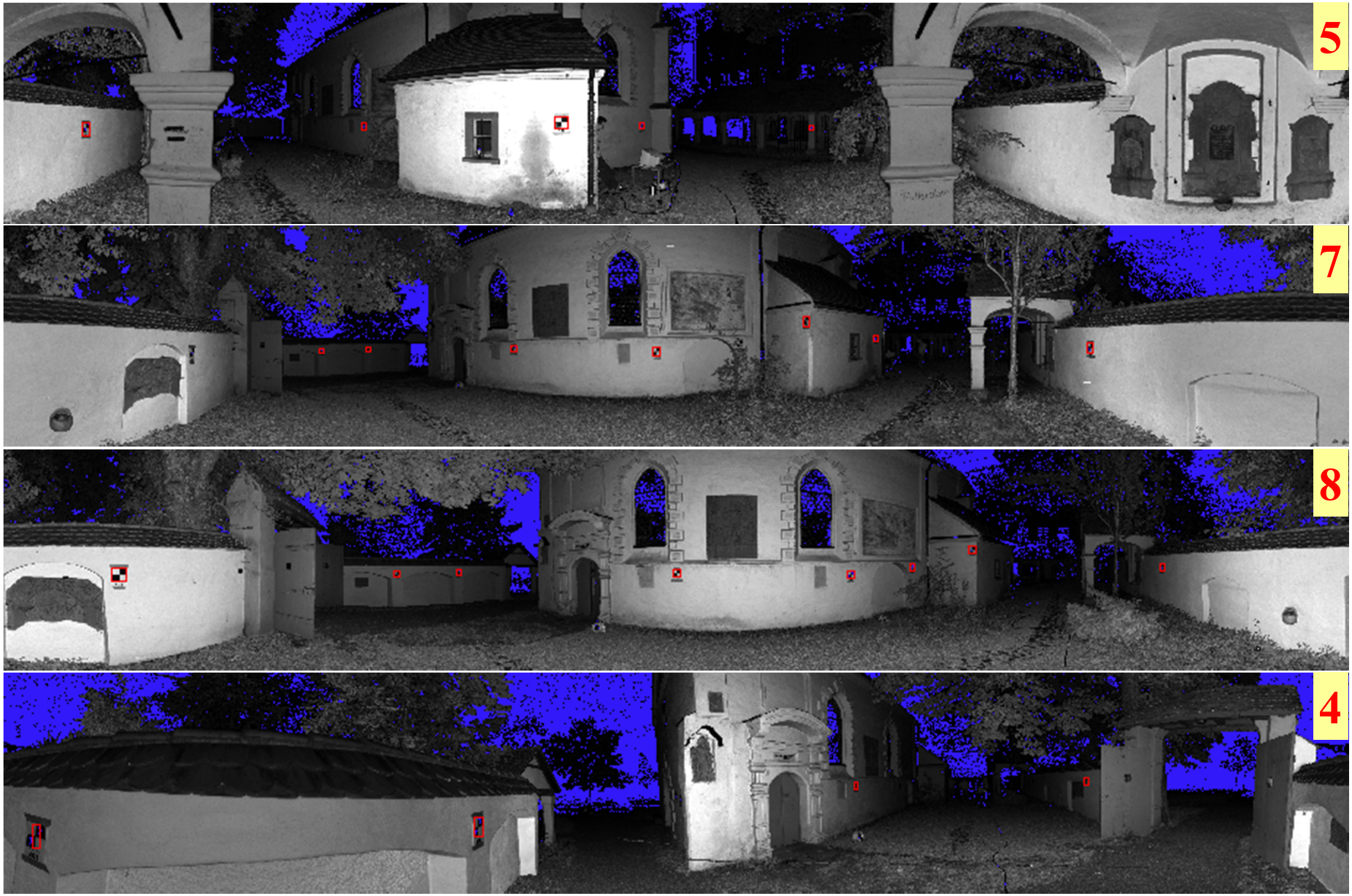
>1 compatible 3D Triangle ⇒ **Ambiguity**

⇒ **Discrete Relaxation**

Identified/labeled targets after consistent labeling step:



The Experimental Results:



Number of points : **11**

Process time for each point cloud : **25-27** seconds { Intel P4 2.53 GHz, 1 GB RAM }

Simultaneous Absolute Orientation:

- **Block Adjustment by Independent Models**

$$v_L = A_1 t + A_2 x - l_L \quad ; \quad P_L$$
$$v_C = \quad I x - l_C \quad ; \quad P_C$$

	σ0 (mm)	**σX** (mm)	**σY** (mm)	**σZ** (mm)
Block Adjustment by Independent Models	**9.2**	5.2	5.2	5.5

- **Generalized Procrustes Analysis**

$$\mathrm{tr}\sum_{i<j}^{M}\left[\left(\mathbf{c}_i A_i \mathbf{T}_i + J\mathbf{t}_i^T\right) - \left(\mathbf{c}_j A_j \mathbf{T}_j + J\mathbf{t}_j^T\right)\right]^T \left[\left(\mathbf{c}_i A_i \mathbf{T}_i + J\mathbf{t}_i^T\right) - \left(\mathbf{c}_j A_j \mathbf{T}_j + J\mathbf{t}_j^T\right)\right] = \min$$

	σ0 (mm)	**SX** (mm)	**SY** (mm)	**SZ** (mm)
Generalized Procrustes Analysis	**--**	1.6	2.4	1.2

Conclusion and Future Work:

- Full automatic registration of laser scanner point clouds
  - ⇒ Does not need operator interaction / identification
  - ⇒ Does not need retro-reflective or other special material based targets
  - ⇒ Exploits radiometric and geometric information supplied by laser scanner
- High internal precision potential of the laser scanner data
- The most important problem is to localize and to eliminate the gross errors
- In the future work, registration without special targets will be focused.

Thank you !