First experiences with the integration of a high resolution still video camera on the Riegl LMS-Z420i terrestrial laserscanner

Christian Mulsow, Danilo Schneider
TU Dresden, Germany

Panoramic Photogrammetry Workshop
Dresden, Germany
19-22 February 2004

- Sensors – specifications und characteristics
- Coordinate systems – definition und relations
- Theoretical considerations of accuracy and resolution
- Camera calibration based on laser scanner data
- Practical tests
- Summary and future prospects

Major specifications of LMS-Z420	
Measurement range	up to 800 m (reflectivity 0.8), up to 200 m (reflectivity 0.2)
Ranging accuracy	± 10 mm
Beam parameters	exit diameter 10 mm beam divergence 0.25 mrad
Measuring rate	8000 points/sec average
Scan range	0 to 80 deg vertically 0 to 360 deg horizontally
Scan resolution	0.01 deg

Major specifications of Camera, e.g.,	
Camera model	Nikon D100
Lens model	Nikkor 14 mm / 2.8
Resolution	3008 x 2000 pixels
Field-of-view	80 deg x 58 deg

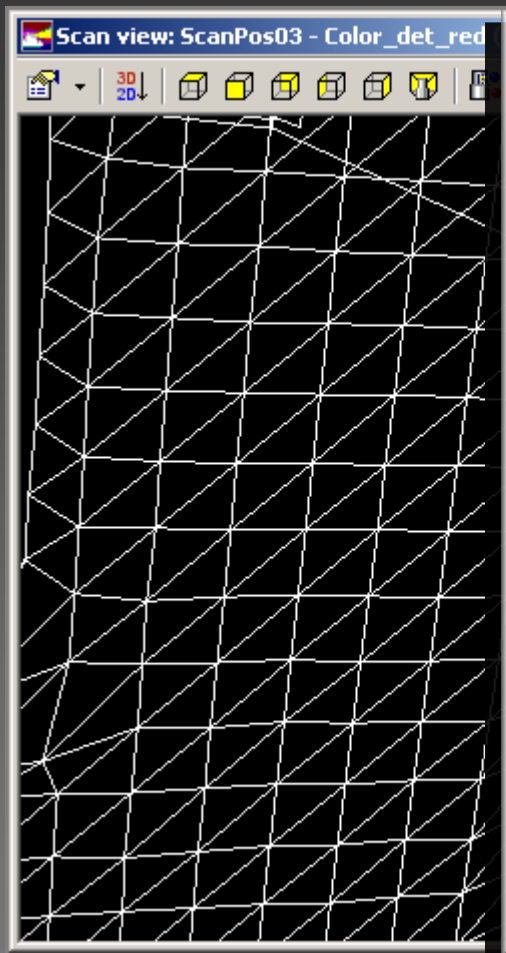
Charakteristik:

- **Laser scanner:**
  - **reliable 3D coordinates (point cloud)**
  - **return signal intensity data (NIR, noise error, restricted usability)**
- **Camera:**
  - **2D RGB information, high interpretability**
  - **high geometric resolution**

complementary attributes -> system elements complements one another

Primary intention of integration:

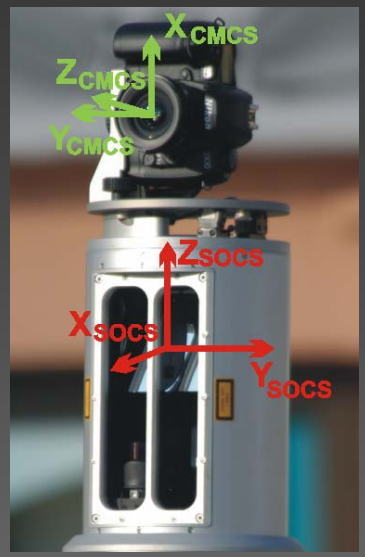
- **Laser scanner: reliable 3D geometry of an object**
- **Camera: texture with high resolution**

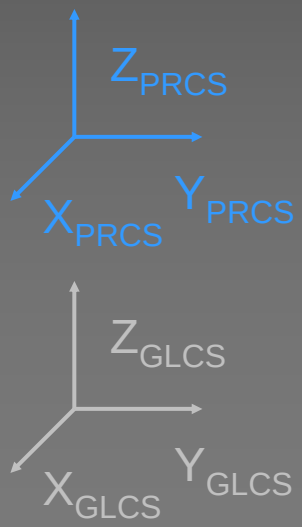


Meshed data

Meshed data with color from vertex color

Meshed data with texture from image





CMCS
CaMera Coordinate System

M_{MOUNT}^{-1} ... Mounting of camera

M_{COP} ... Rotation of scanner top

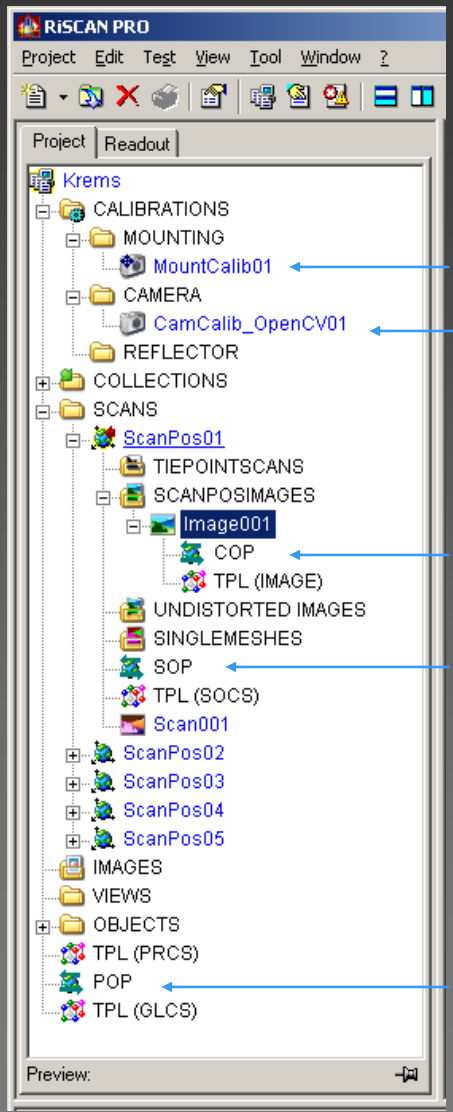
SOCS
Scanners Own Coordinate System

M_{SOP} ... Scanner‘s orientation and position in PRCS

PRCS
PRoject Coordinate System

M_{POP} ... Project coordinate system‘s orientation and position in GLCS

GLCS
GLobal Coordinate System



Coordinate transformation

$$\mathbf{x}_{GLCS} = \mathbf{M}_{POP}\mathbf{M}_{SOP_N}\mathbf{x}_{SOCS_N}$$

$$\mathbf{x}_{GLCS} = \mathbf{M}_{POP}\mathbf{M}_{SOP_N}\mathbf{M}_{COP_{N,M}}\mathbf{M}^{-1}_{mount}\mathbf{x}_{CMCS_{N,M}}$$

Camera model

$$x_i = \frac{x_{CMCS}}{z_{CMCS}}, y_i = \frac{y_{CMCS}}{z_{CMCS}}, r^2 = x_i^2 + y_i^2$$

$$u = x_i f_x + c_x, v = y_i f_y + c_y$$

$$u_d = u + x_i f_x \left(k_1 r^2 + k_2 r^4 + k_3 r^6\right) + 2 f_x x_i y_i p_1 + p_2 f_x \left(r^2 + 2x_i^2\right)$$

$$v_d = v + y_i f_y \left(k_1 r^2 + k_2 r^4 + k_3 r^6\right) + 2 f_y x_i y_i p_2 + p_1 f_y \left(r^2 + 2y_i^2\right)$$

Accuracy und Reliability (Characteristics):

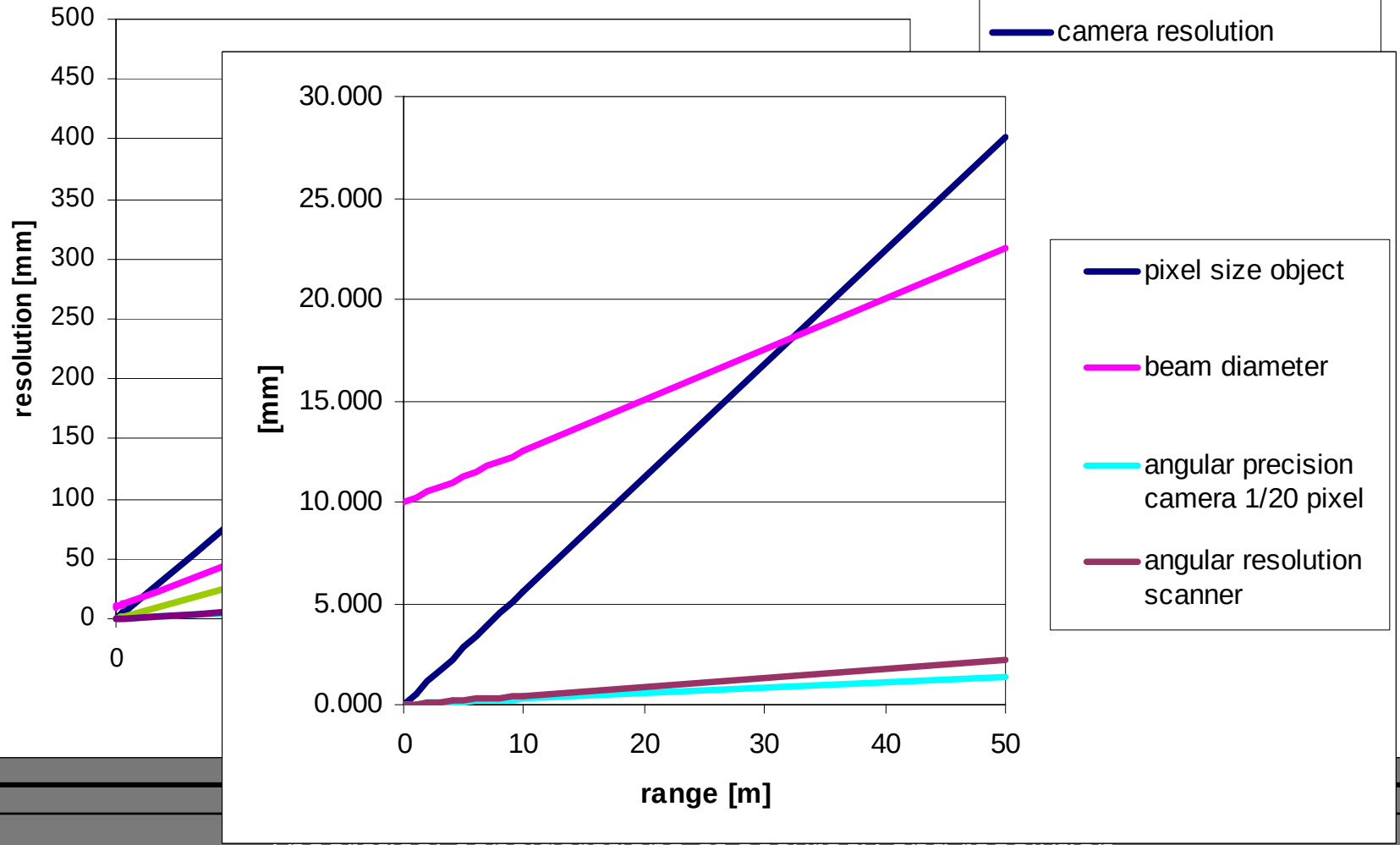
- **Camera:**
  - planimetric precision up to 1/20 Pixel (sub pixel operators)
  - 3D information (depth) only ascertainable from more then one image (stereoscopic analysis of multiple images with high complexity, requirement of approximated values for the unknowns, limited reliability , coordinate in camera direction normal less accurate then the plane coordinates)
- **Laser scanner:**
  - Accuracy of the information in depth direction depend on rangefinder (acc. ca. 10mm, not a function of distance)
  - Information's about the directions (horizontal & vertical) from mechanical systems (limited accuracy, liability to system faults)

complementary attributes

Primary intention of integration: : optimisation of accuracy

- ***First experiments...***

Considerations of accuracy and resolution



Integrated camera calibration routines (RiscanPro)

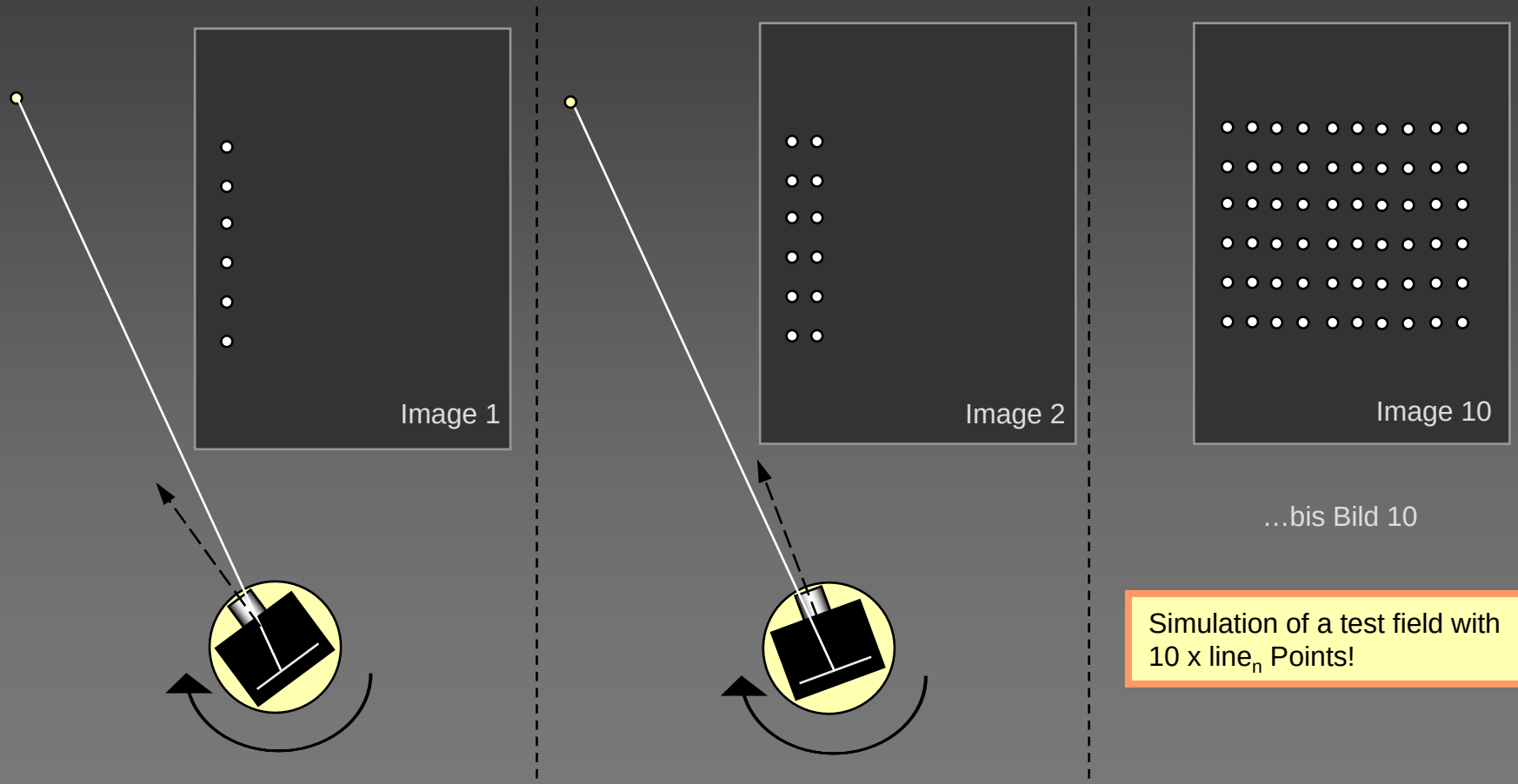
- **Field of 3-D points**
  - based on scanner determined 3-D coordinates of a field of retro targets
  - measurement of retro targets in images through center of gravity operator
  - computation of camera parameters via resection

- **Calibration based on a single vertical Line of Retro targets**
  - based on scanner determined 3-D coordinates of a vertical top)
  - measurement of retro targets in images through center of gravity line of retro targets
  - image sequence from different directions (rotation of scanner's operator
  - simulation of an field of n 3-D Points through duplication (transformations based on the angles from the rotation of the scanners top)

    n = Number of points in line x Number of images

  - computation of camera parameters via resection

- Calibration based on a single vertical Line of Retro targets



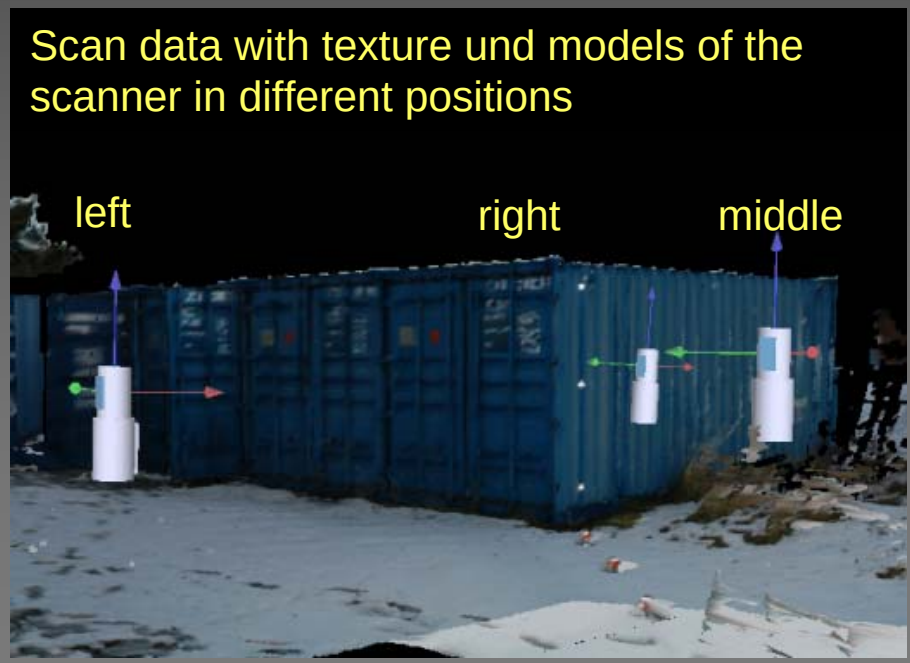
Results of camera calibration

- determination of 3-D coordinates of retro targets
- image acquisition
- measurement of retro targets in images through center of gravity
- resection
  - observations: Bildkoordinaten
  - 3-D coordinates of retro targets (fixed)
- prospect: sigma-0 of resection (with Brown Parameters) ca. 0.05 Pixel
  result: sigma-0 = 0.3 Pixel
- Distance precision is of sub-ordinate importance, relevant precision in lateral direction
- discrepance between prospect and results indicates that the angular precision of the laser scanner is less accurate than the camera
- potentials for an integrated System calibration ...

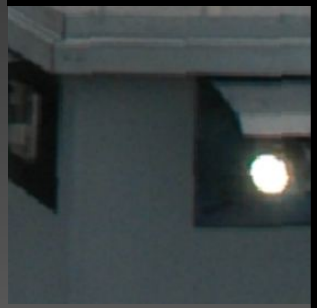
Measuring system

Measurement setup: 3 Scanner Positionen			
	X [m]	Y [m]	Z [m]
Scanner middle position	-0.001	0.007	2.017
Scanner right position	-2.183	-2.210	1.891
Scanner left position	2.238	-2.300	1.853

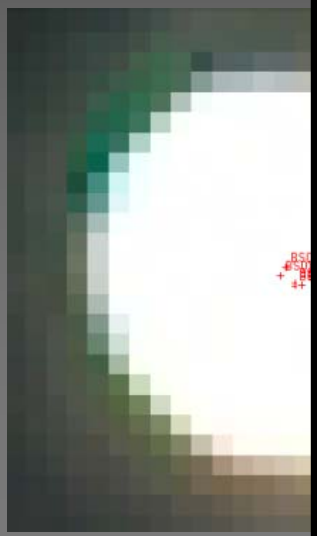
Scan data with texture und models of the scanner in different positions



Reflector 50 mı

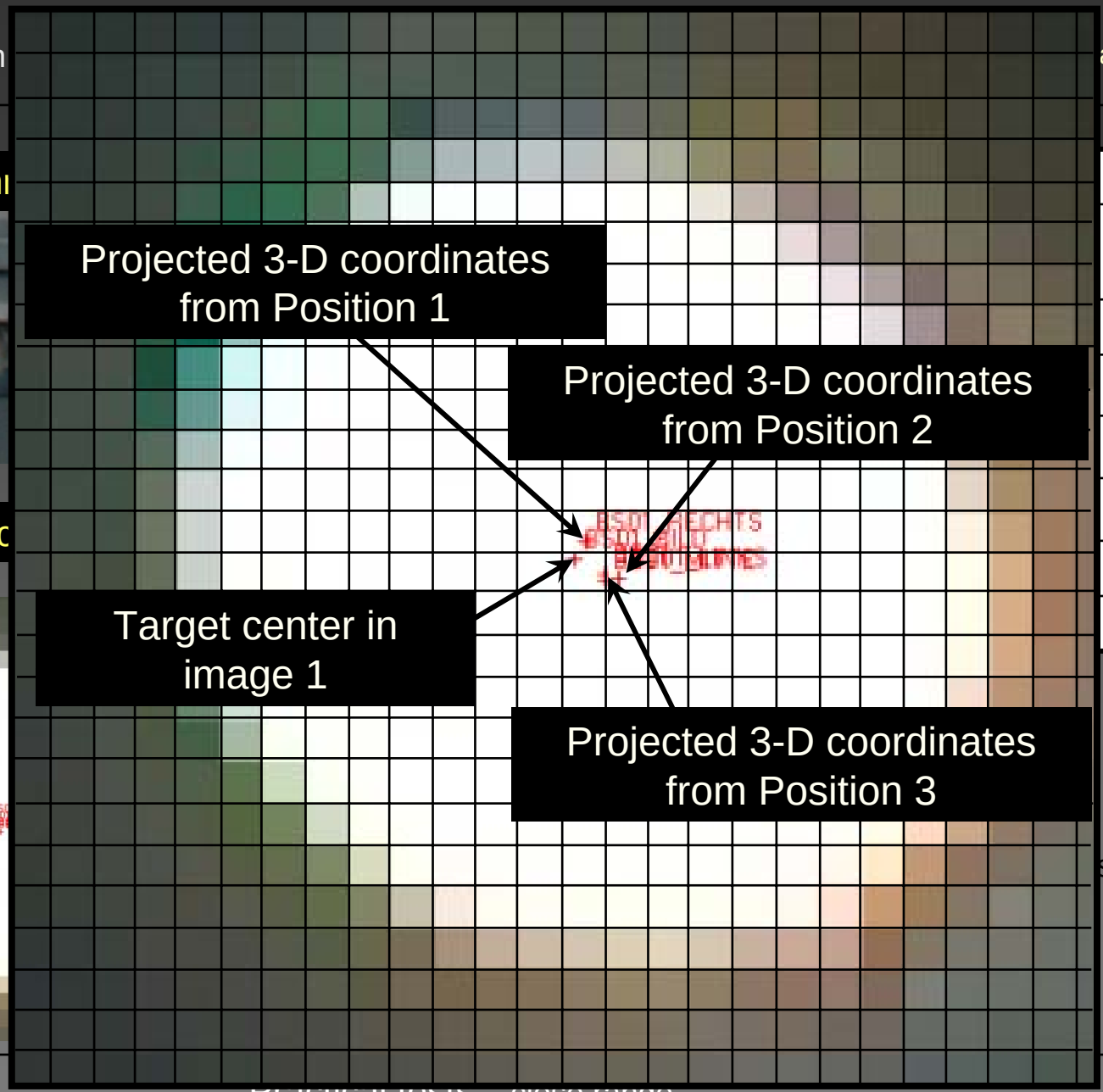


Zoom-In Reflec

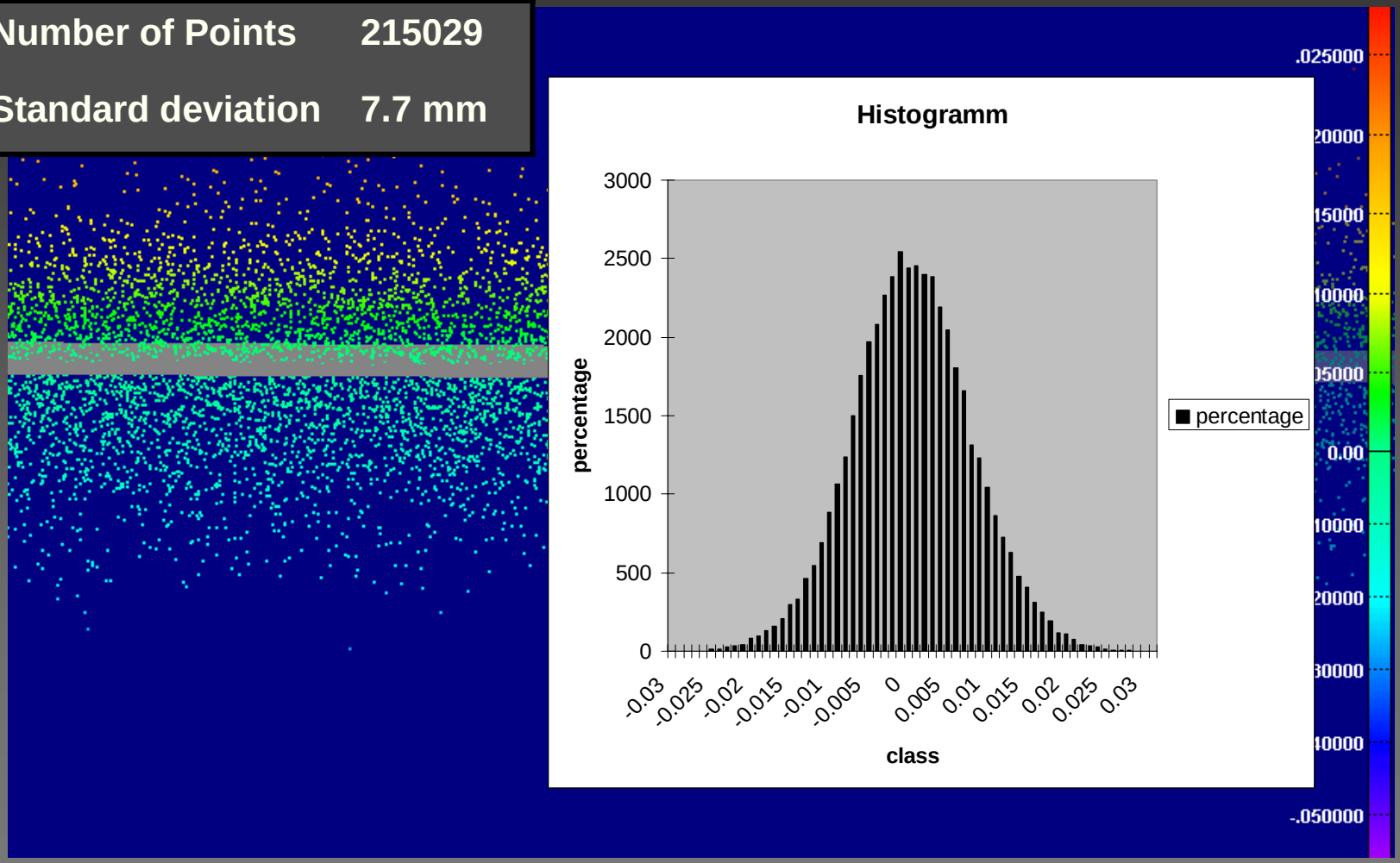


Z [m]
0.883
0.882
0.885
0.882
0.883

s 1.5 pixel



Number of Points	**215029**
Standard deviation	**7.7 mm**



Future prospects **:**

- Development of an integrated system calibration
- Integration of a rotating line camera (similar characteristics in movement and transformation like the Laser scanner)
- Integrated analysis of laser scanner- and image data