

Stereo acquisition with a filter wheel multispectral camera on a goniometric measuring setup

Julie Klein^a, Simon Larsson^a, Vjaceslav Brunnmeier^a,
Rico Nestler^b, Karl-Heinz Franke^c, Bernhard Hill^d, Dorit Merhof^a

^a Institute of Imaging and Computer Vision, RWTH Aachen University

^b Computer Graphics Group, Ilmenau University of Technology

^c Zentrum für Bild- und Signalverarbeitung e.V. Ilmenau (ZBS)

^d Research Group Color and Image Processing, RWTH Aachen University

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Introduction

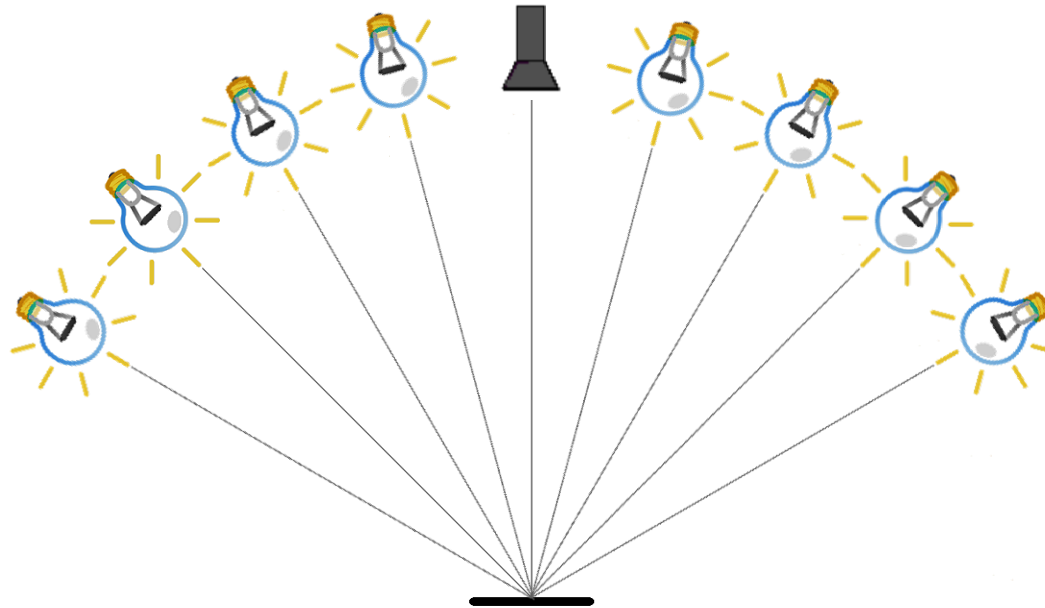
- Motivation
- Experimental setup
- Stereo systems
- Calibration of stereo system
- Extraction of depth information
- Results
- Conclusions

Motivation

Goniometric measurement

Measurement of a material with

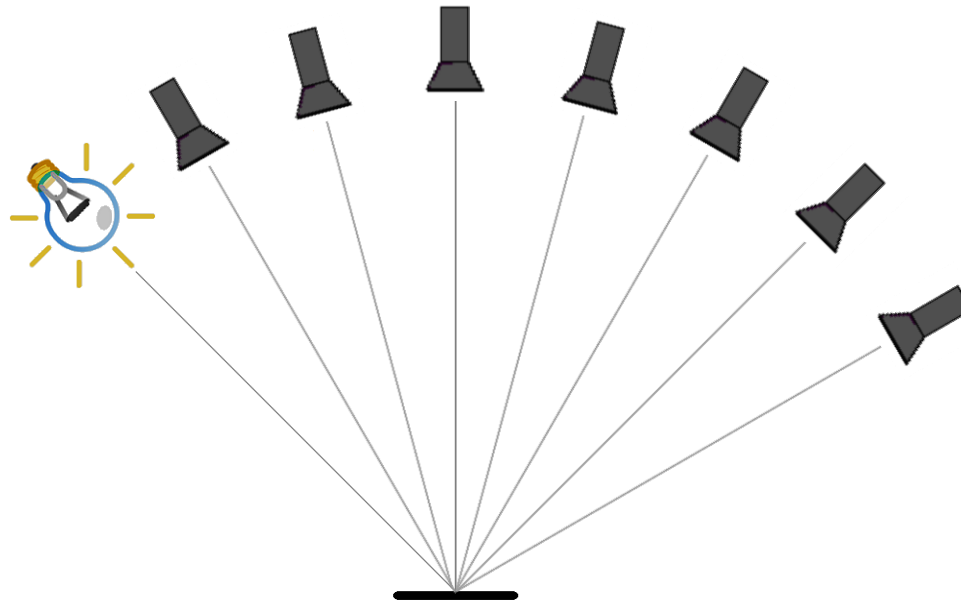
- different illumination directions



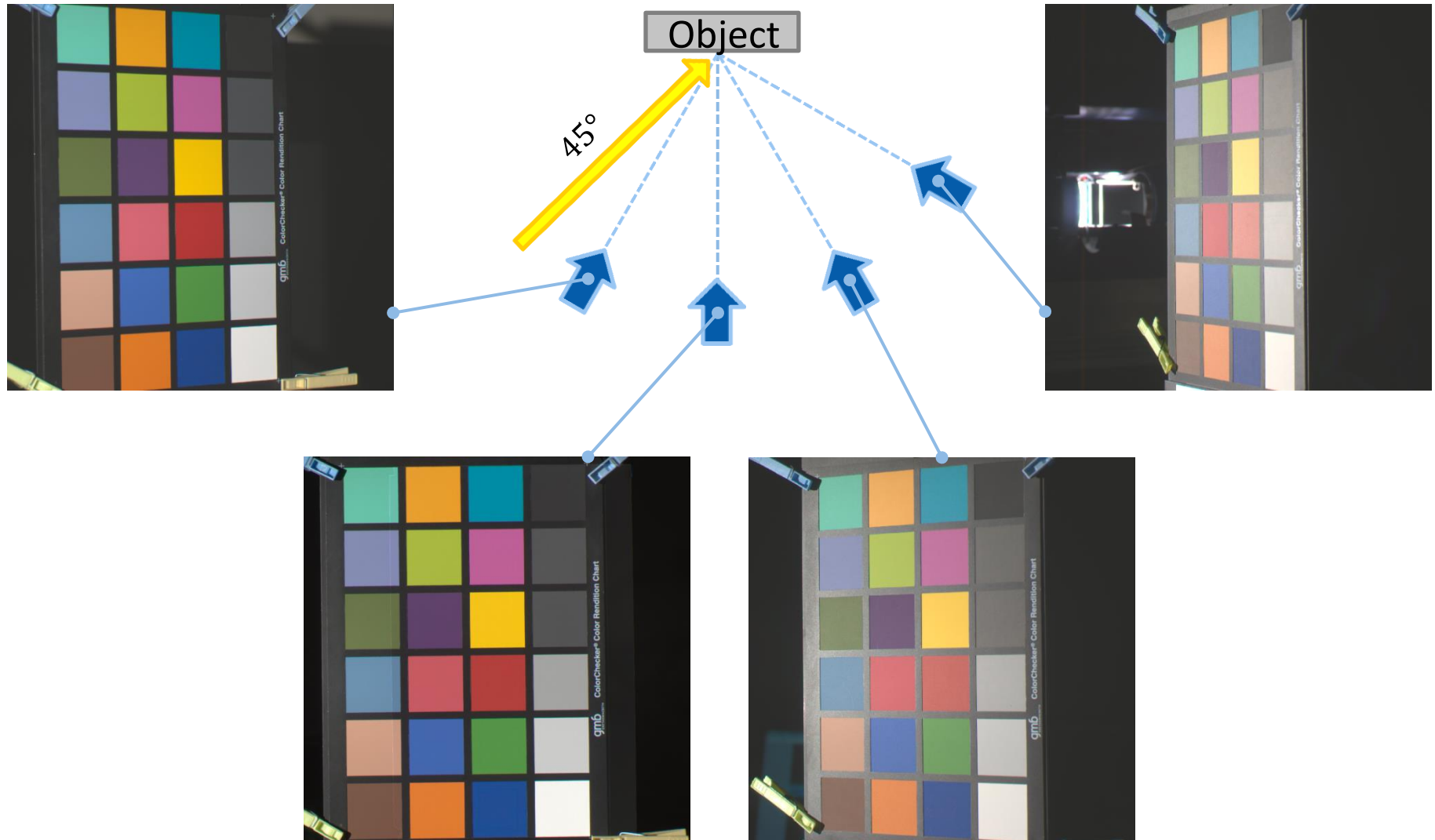
Goniometric measurement

Measurement of a material with

- different illumination directions
- different viewing directions

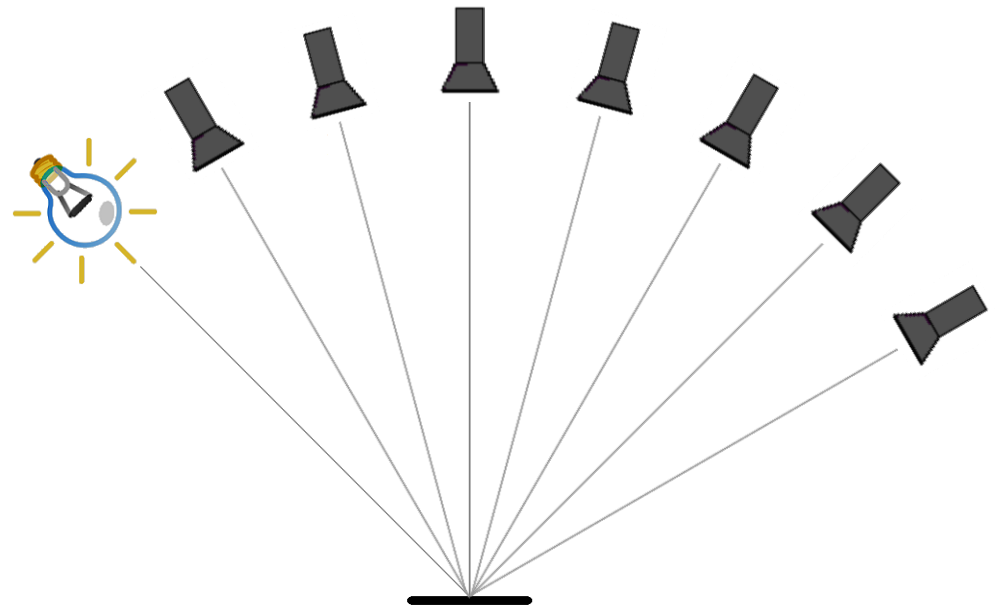


Example of acquisition



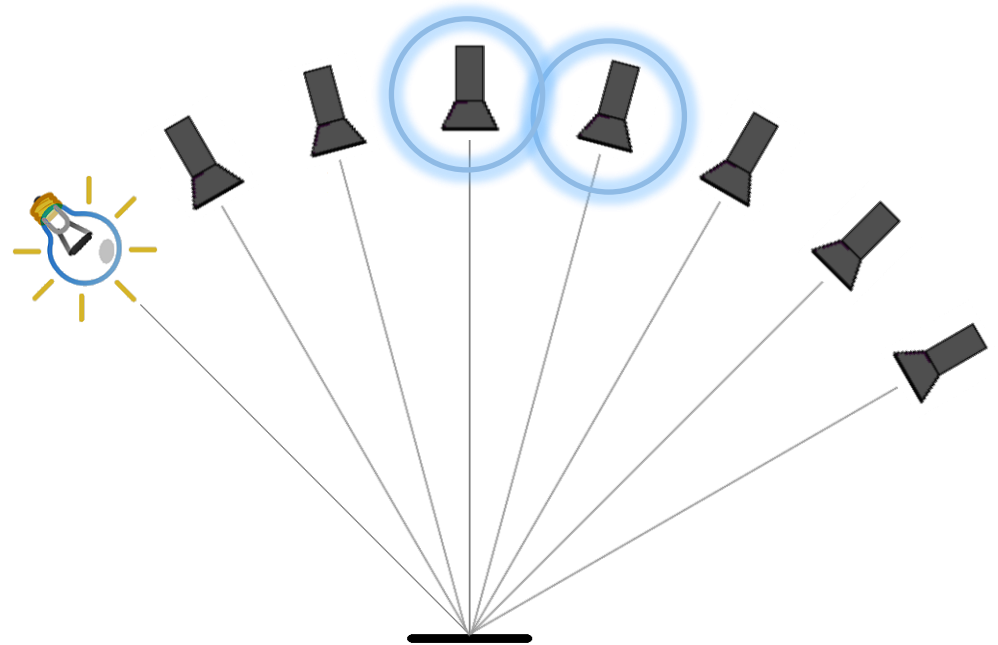
Camera positions

- Numerous positions available
→ stereo systems for depth information?



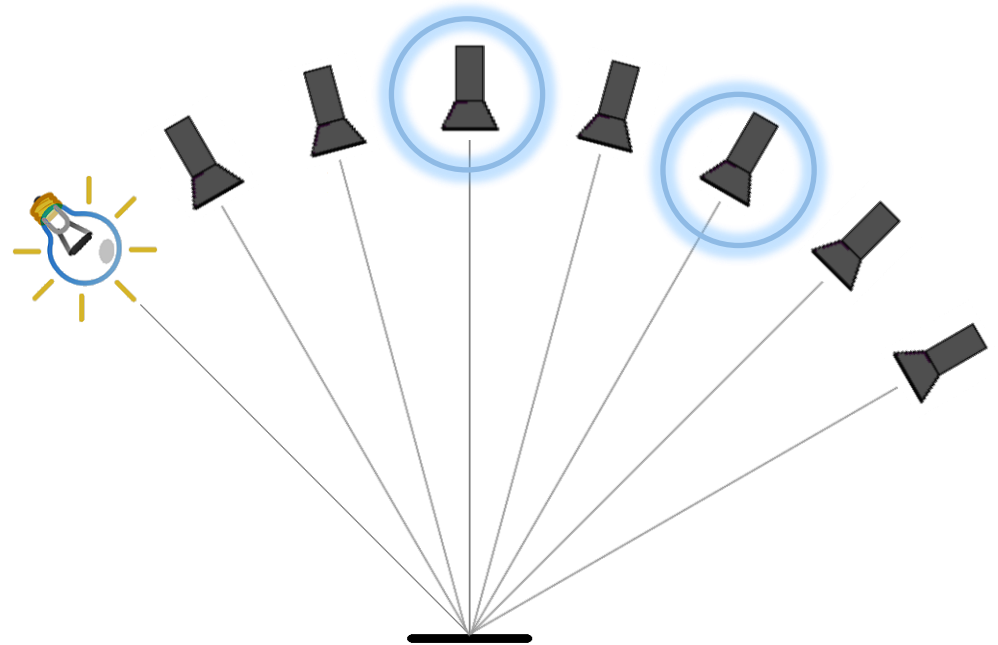
Camera positions

- Numerous positions available
→ stereo systems for depth information?
- Simulation
 - Angle between both cameras?



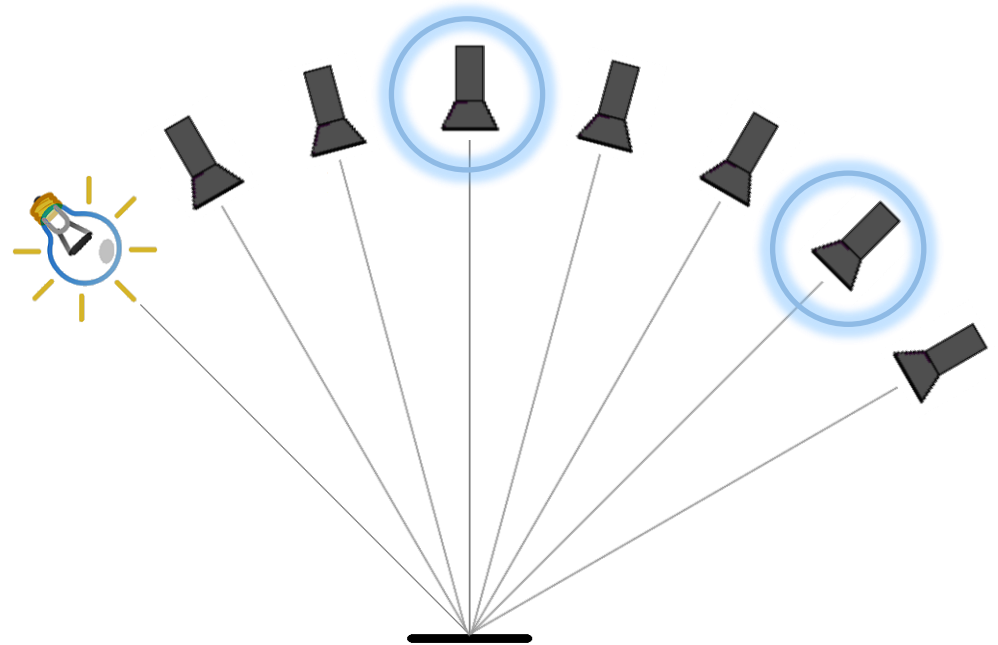
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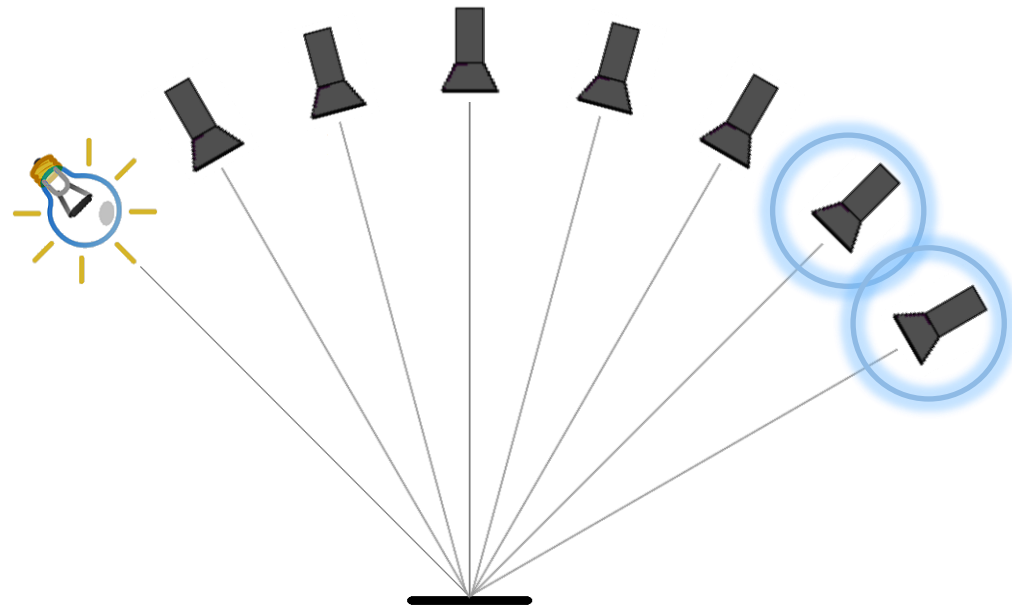
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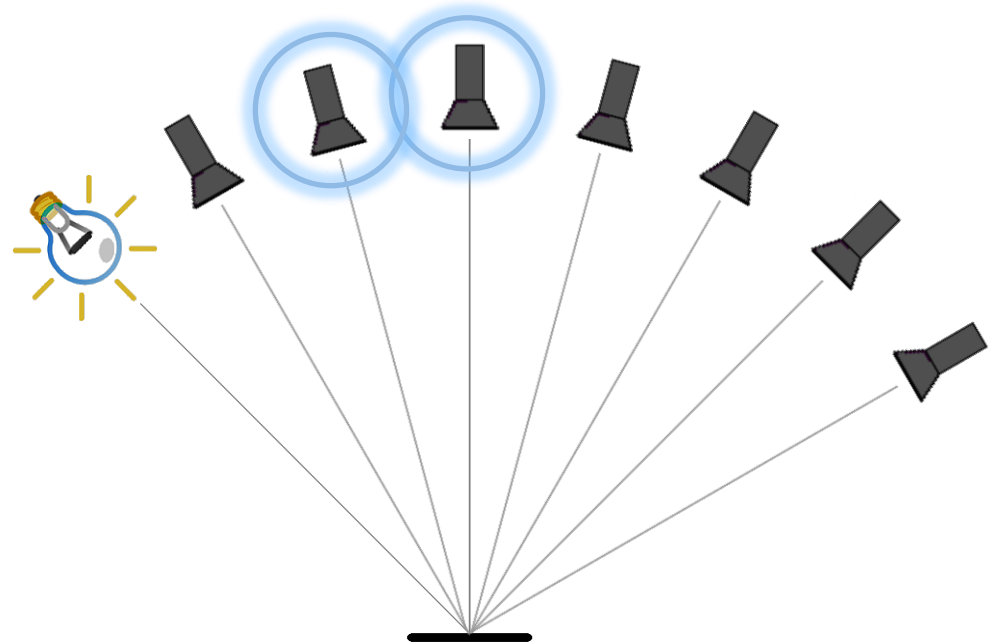
Camera positions

- Numerous positions available
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 - Angle between both cameras?
 - Position of stereo system?



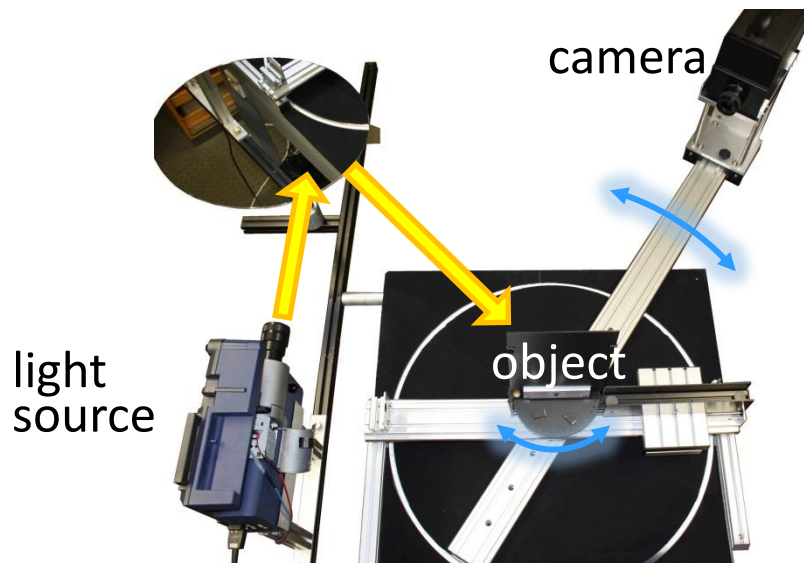
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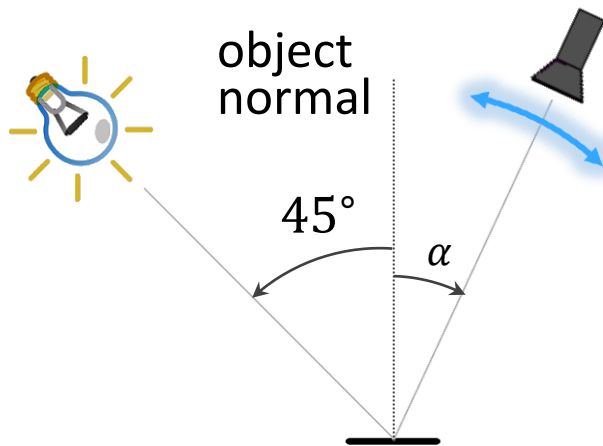


Experimental setup

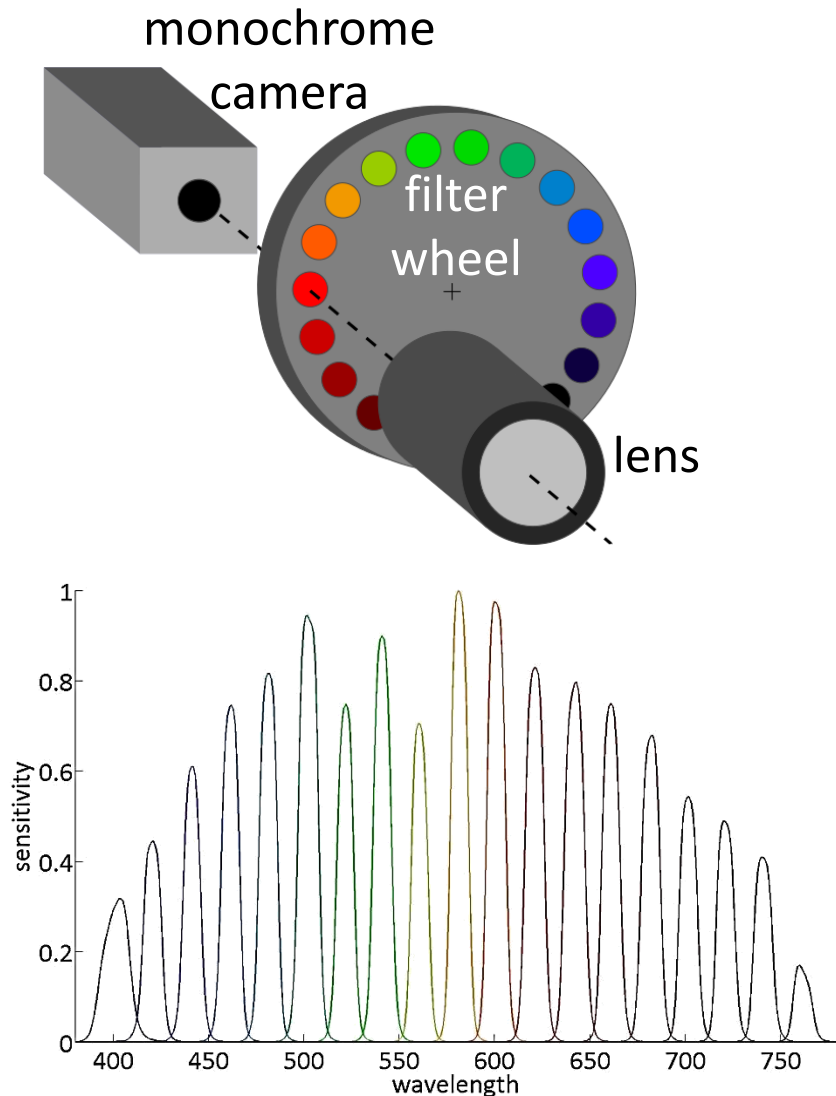
Measuring setup



- Object and camera can be rotated
- Light source is fixed
- ➔ In-plane measurement
 - different acquisition angles α
 - here: illumination angle 45°
- Multispectral camera for accurate color information



Multispectral camera

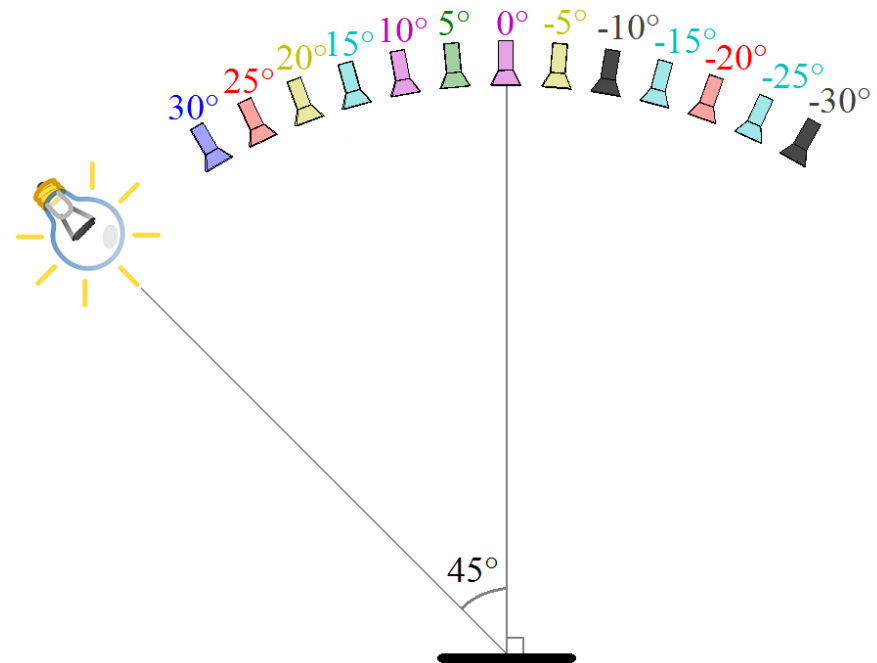


- Monochrome camera
SciCam SC4022,
2072x2136 pixels
- Lens
- Between them: filter
wheel with 19 filters
 - central wavelengths
from 400 to 760nm
 - steps of 20nm
 - bandwidths of 10nm

Stereo systems

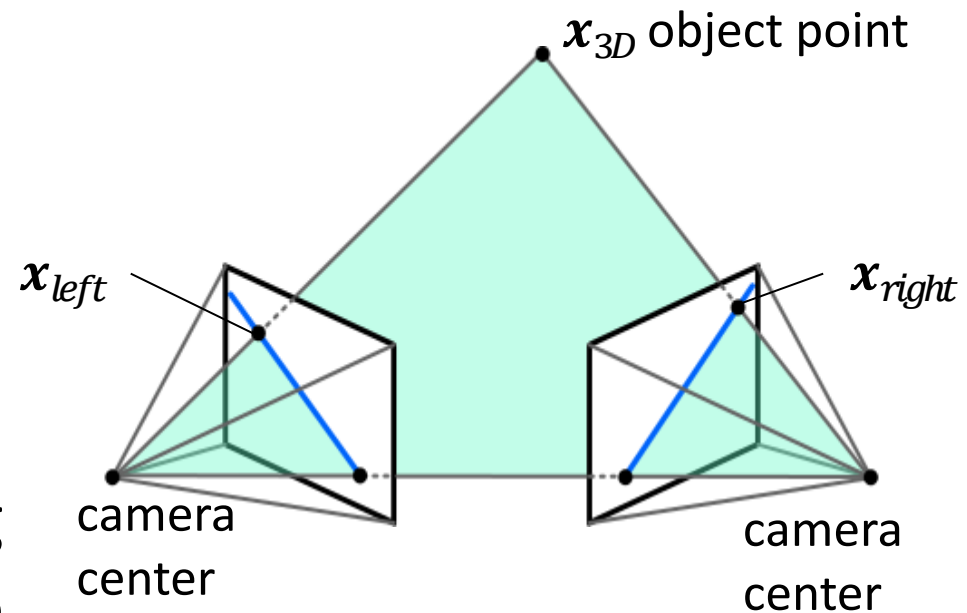
Considered systems

- Illumination at $+45^\circ$
- Acquisition angle α between $+30^\circ$ and -30° in steps of 5°
- Stereo systems with angles of 5° , 10° , 15° , 20° , 25° and 30° between both cameras



Stereo imaging

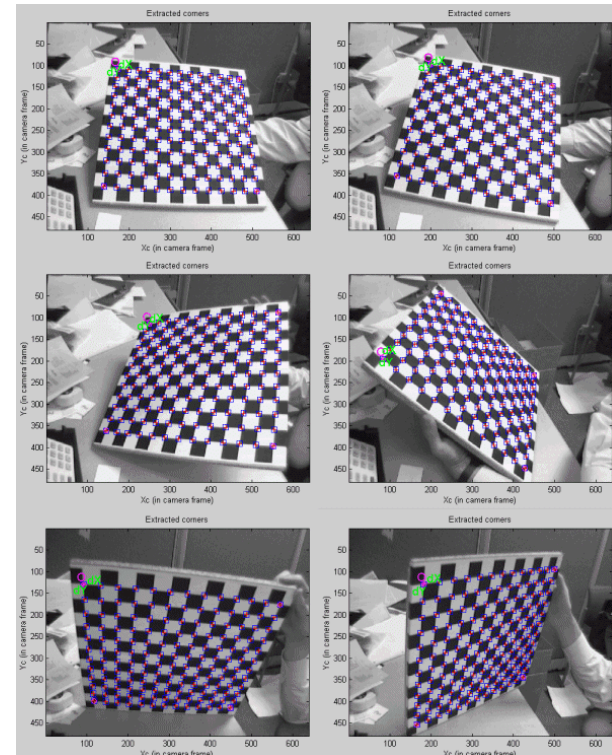
- Corresponding image points \mathbf{x}_{left} and \mathbf{x}_{right}
- Intrinsic parameters: focal length, pixel size, ...
- Extrinsic parameters: rotation and translation
- Calculation of underlying object point \mathbf{x}_{3D} possible



Calibration

Camera calibration

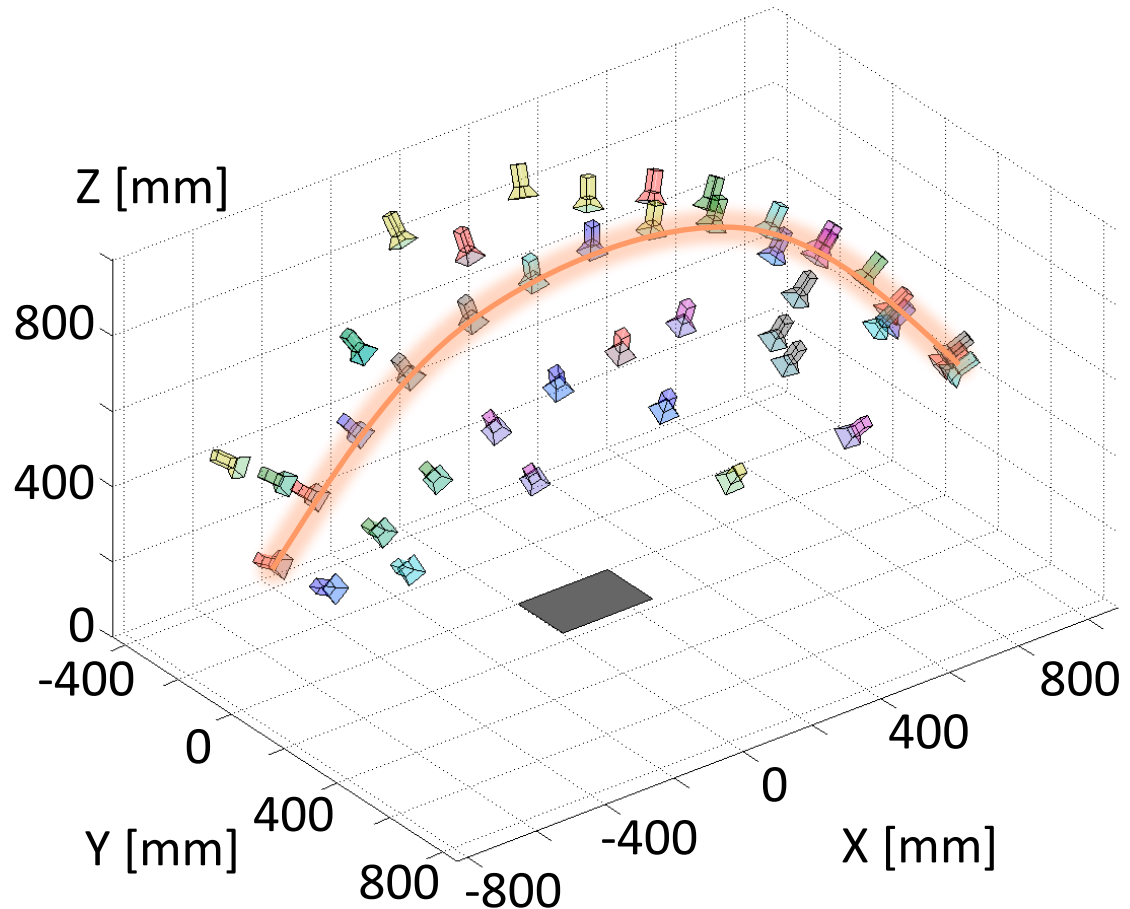
- Method from Bouguet:
 - checkerboard pattern imaged from different viewing positions
 - corners detected in all images
 - correspondences give camera parameters



http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/example.html

Positions for calibration

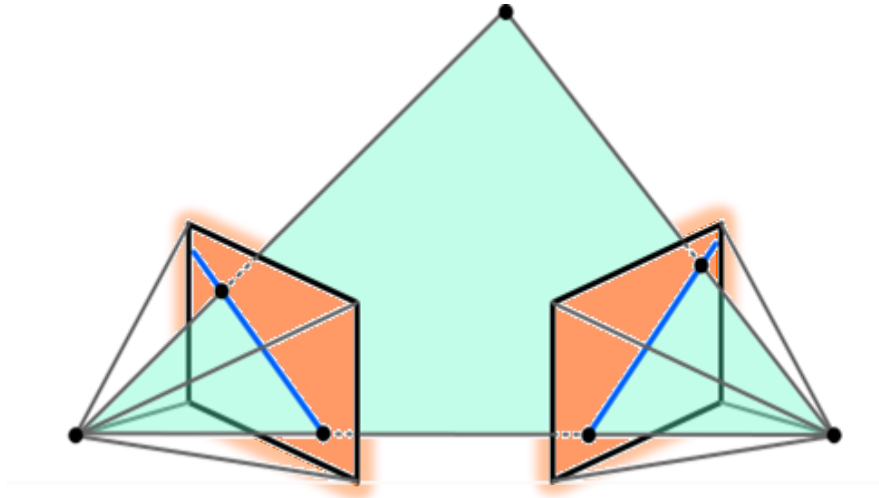
- 46 camera positions
 - 13 in-plane (in orange)
 - 33 out-of-plane, by tilting the calibration pattern



Extraction of depth

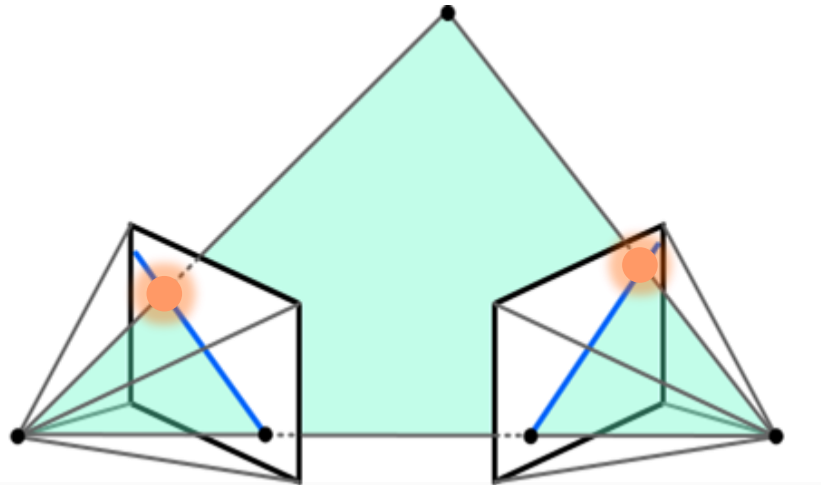
Reconstruction algorithm

- Input: stereo images, color channels considered separately



Reconstruction algorithm

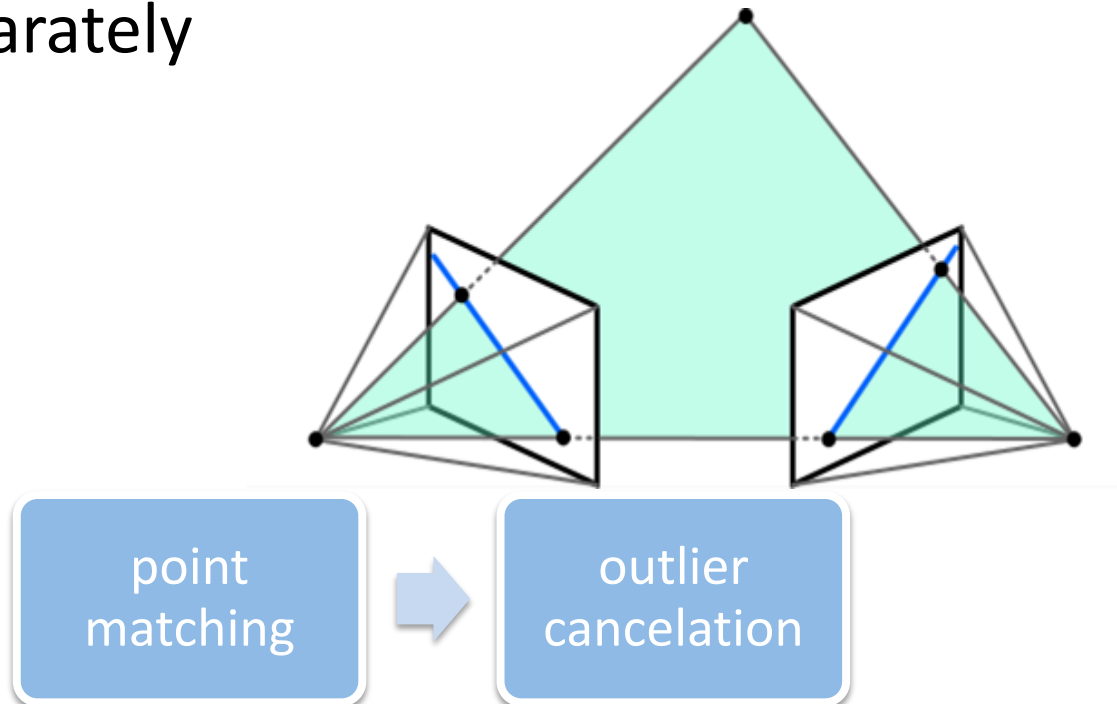
- Input: stereo images, color channels considered separately



point
matching

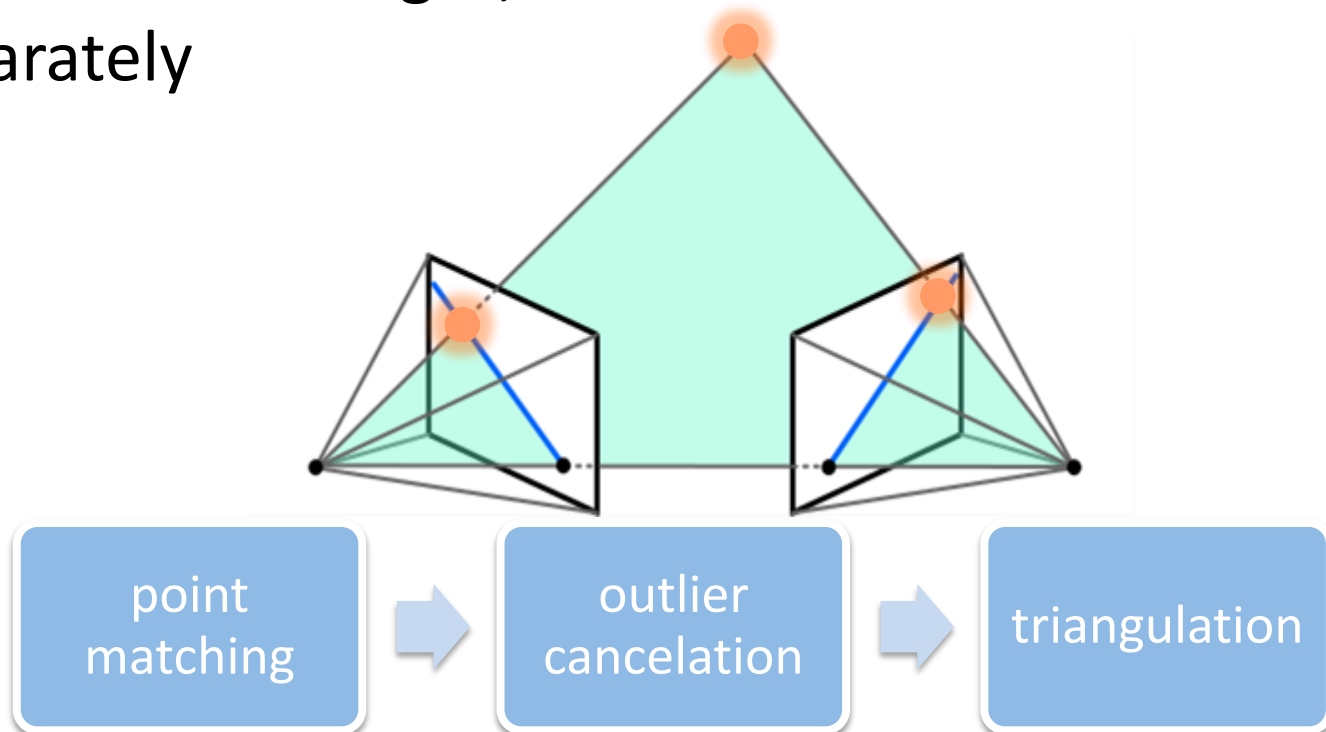
Reconstruction algorithm

- Input: stereo images, color channels considered separately



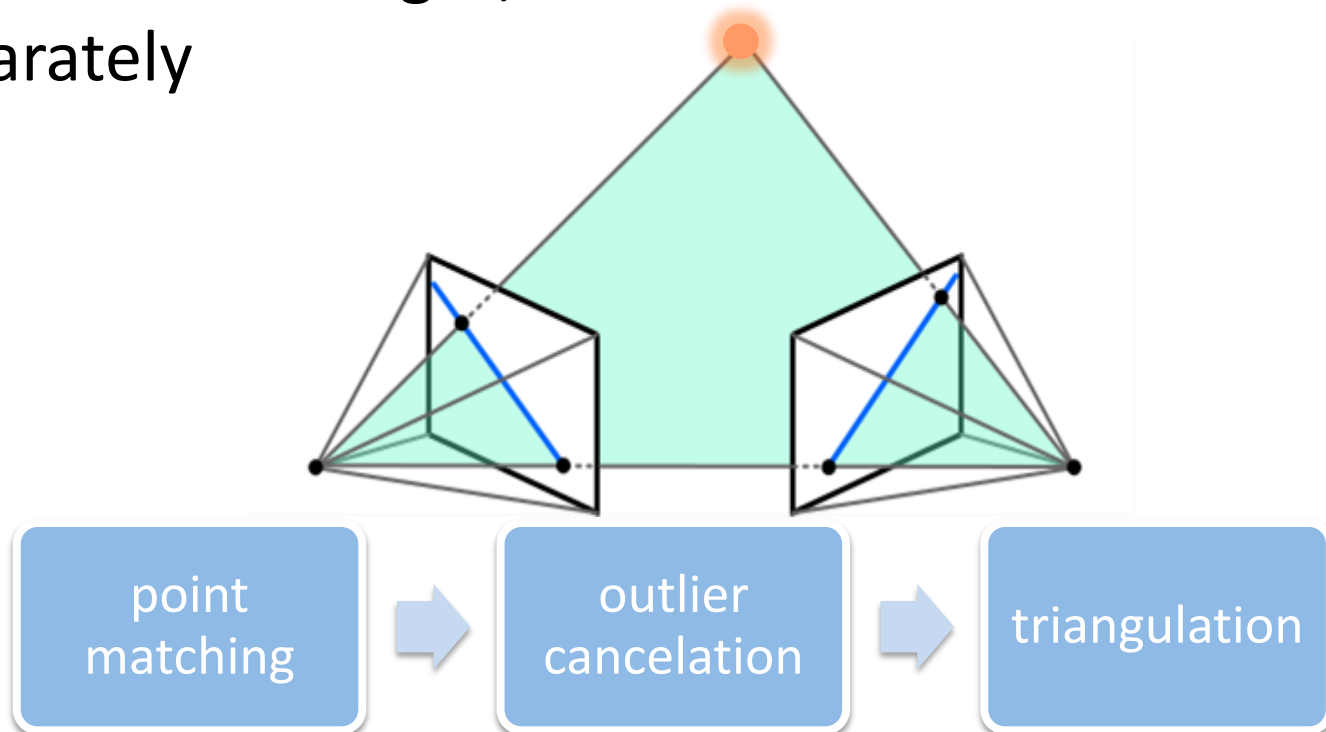
Reconstruction algorithm

- Input: stereo images, color channels considered separately



Reconstruction algorithm

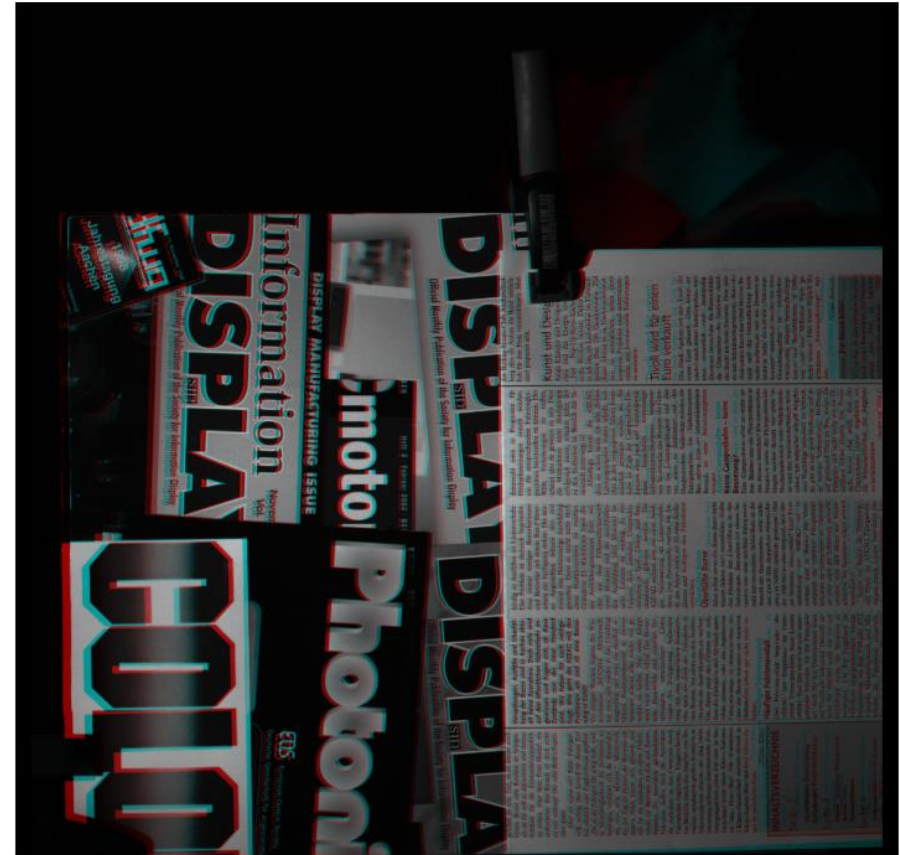
- Input: stereo images, color channels considered separately



- Output: 3D positions of feature points
- Data for all color channels merged

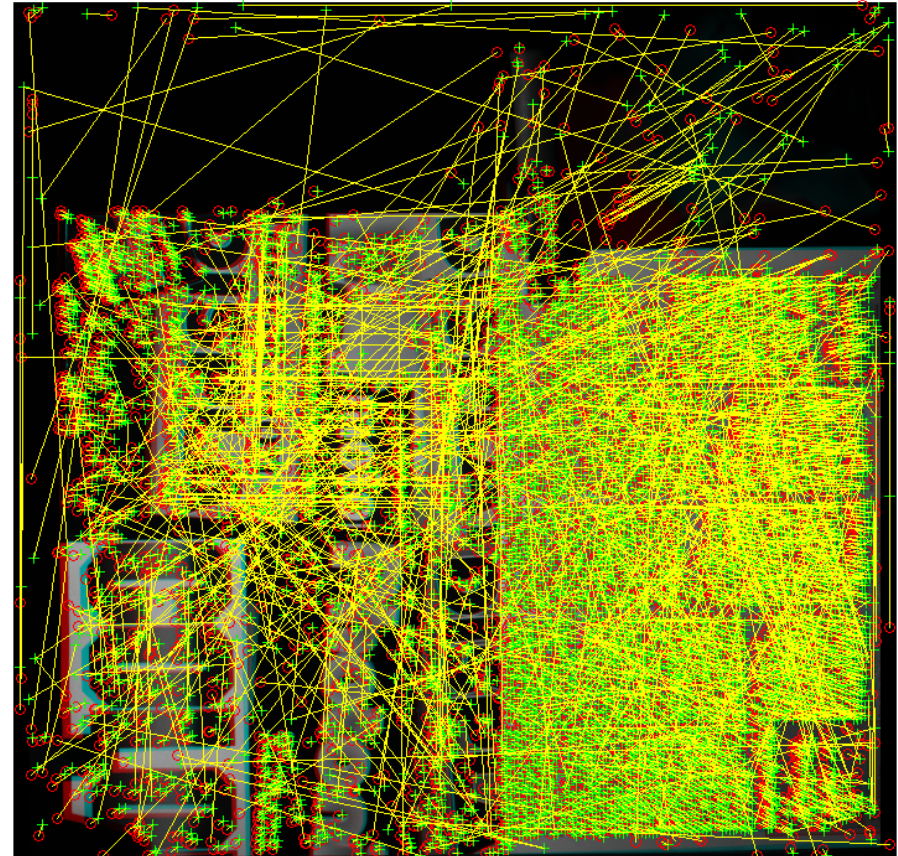
Point matching

- Method based on feature points:
fast computation



Point matching

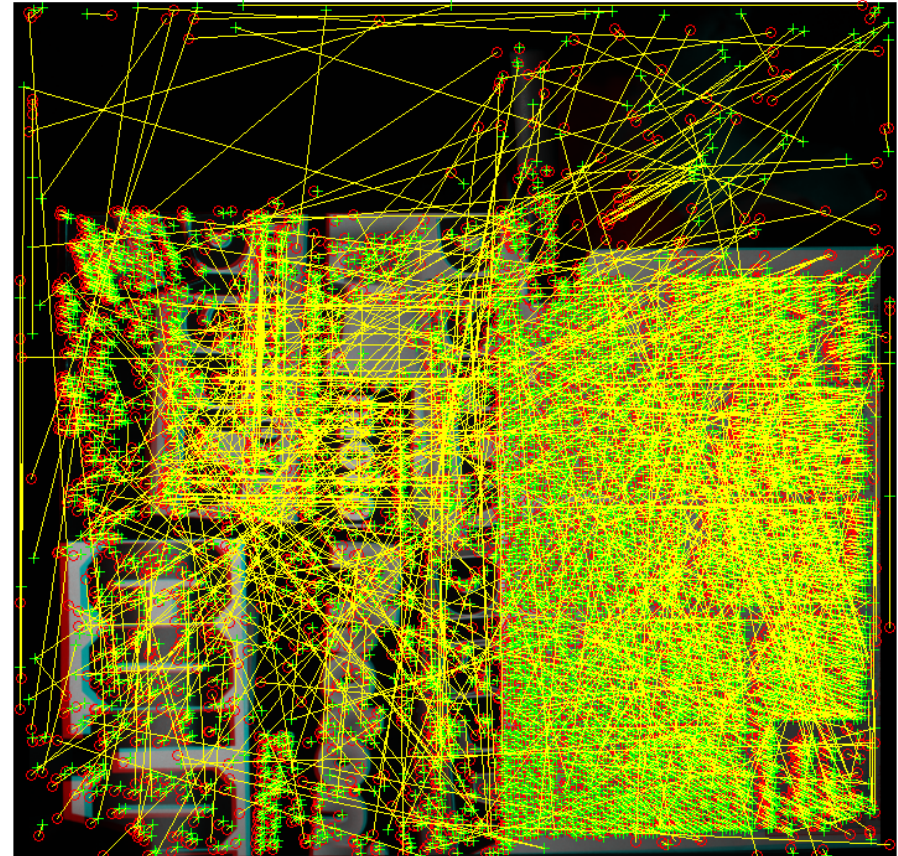
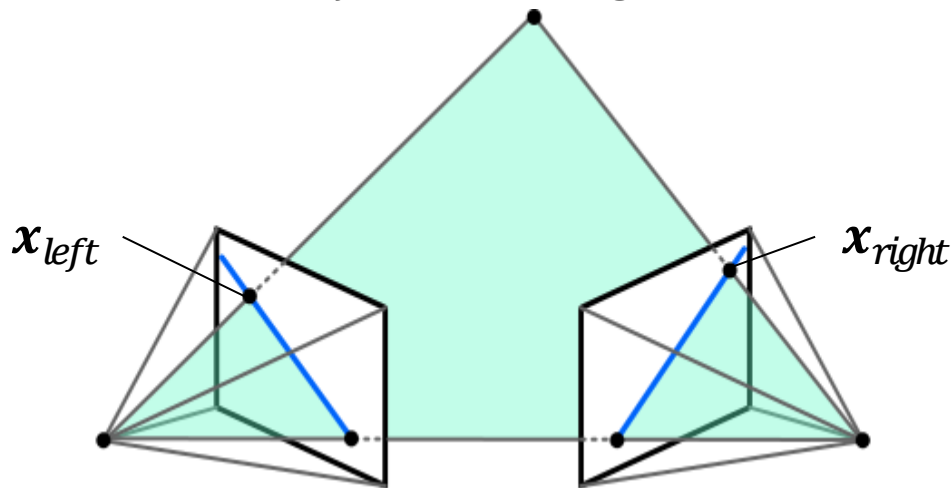
- Method based on feature points:
fast computation
- Scale Invariant Feature Transformation (SIFT)
 - Invariant to image scale and rotation
 - Robust



Outlier cancelation

- Epipolar constraint given stereo geometry

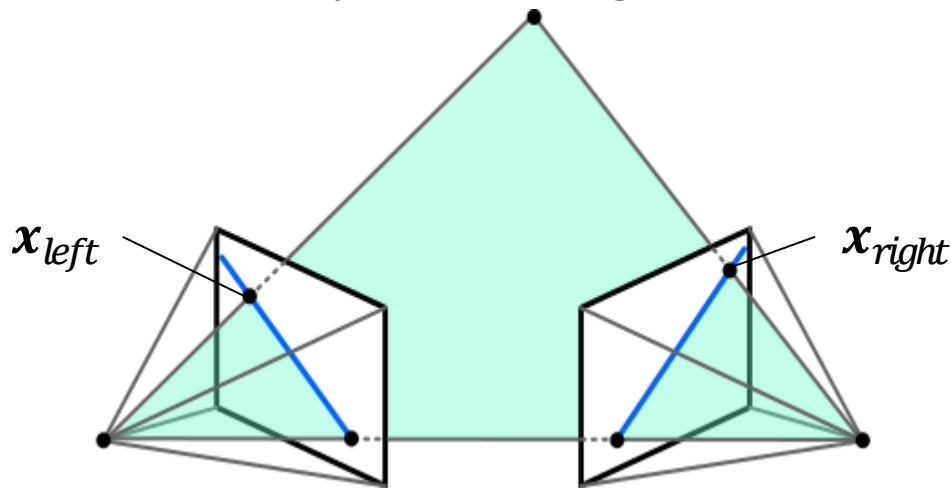
$$\mathbf{x}_{\text{left}}^T \cdot \mathbf{F} \cdot \mathbf{x}_{\text{right}} = 0$$



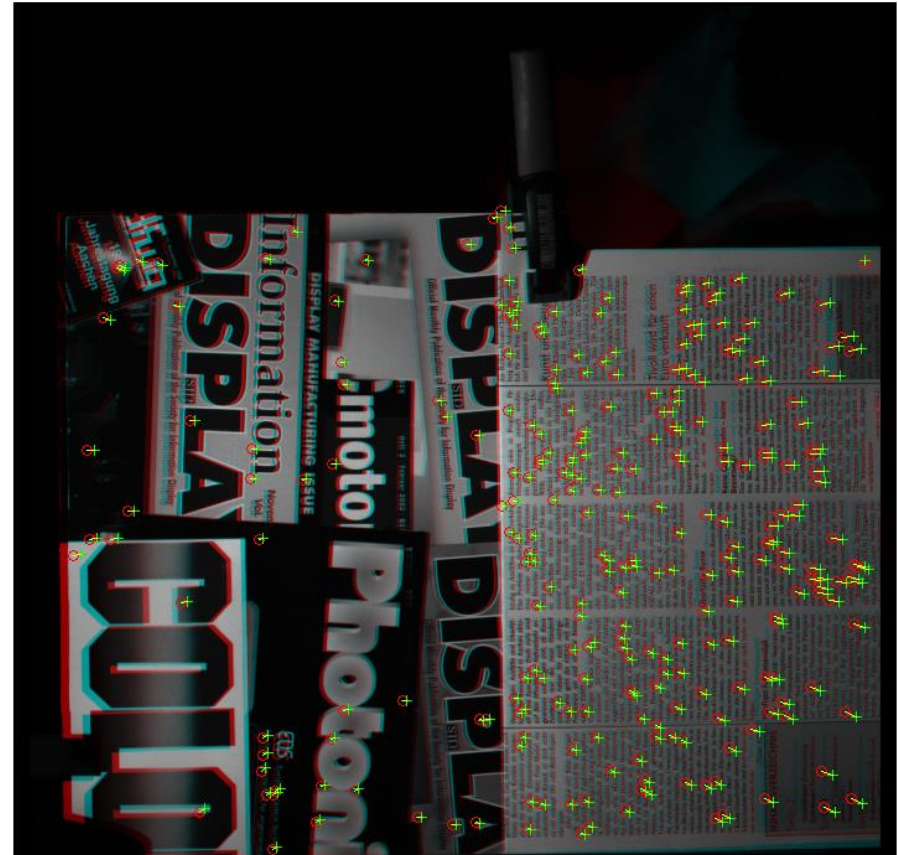
Outlier cancelation

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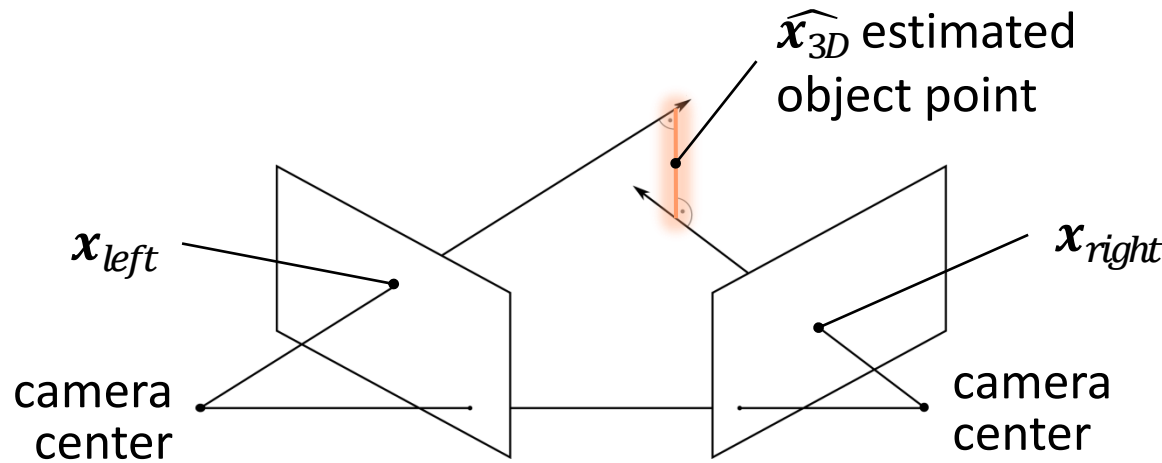


- Point pairs that do not verify the constraint are canceled



Triangulation

- Calculation of 3D position of underlying object point \mathbf{x}_{3D} for detected image points \mathbf{x}_{left} and \mathbf{x}_{right}
- Noise etc. \rightarrow rays of \mathbf{x}_{left} and \mathbf{x}_{right} do not cross
- Possible estimation of $\hat{\mathbf{x}}_{3D}$: middle of the perpendicular distance of the rays



Results

Measured objects



Cover of a box

- Rec. points should lie on a plane



Half sphere

- Radius should be 75mm

Advantages of multispectral imaging

- Textures of object surface have different spectral characteristics

Channel 3



Channel 6



Channel 9



Channel 11



Channel 16



Advantages of multispectral imaging

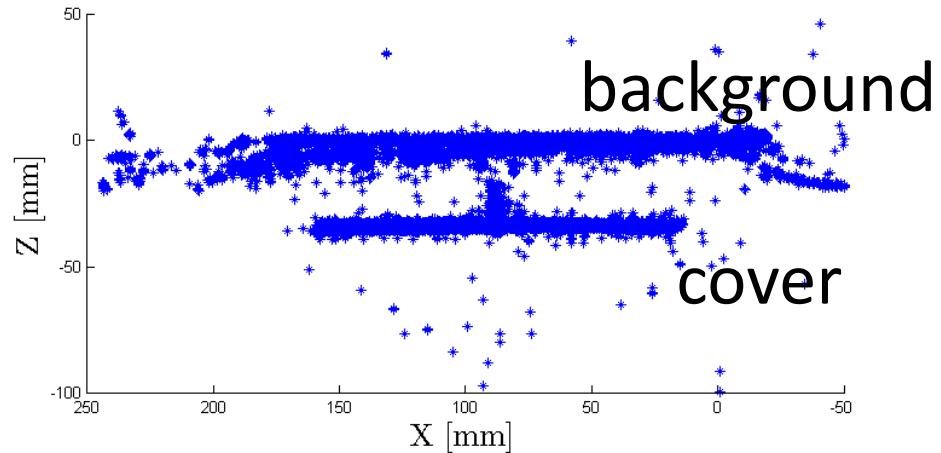
- Different feature points detected in each of the 19 color channels
- Box cover with feature points from 19 color channels superposed
- Channels

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	



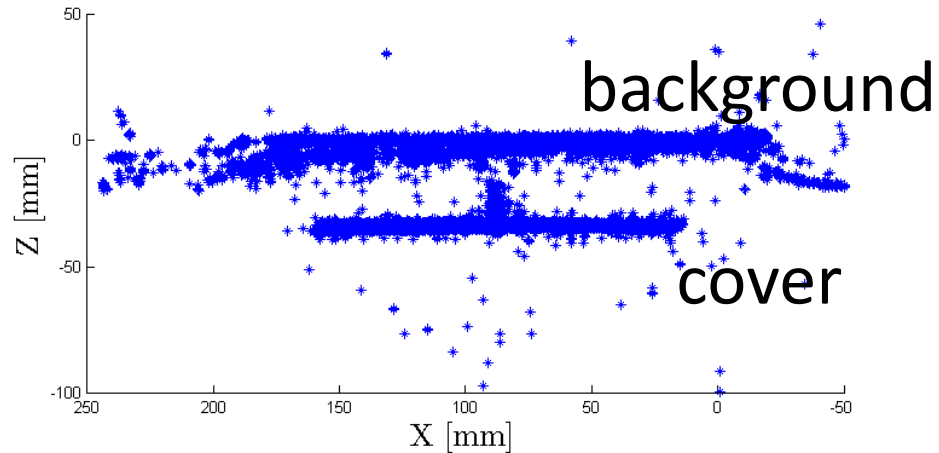
Evaluation for box cover

- Reconstructed object points for cover box and background



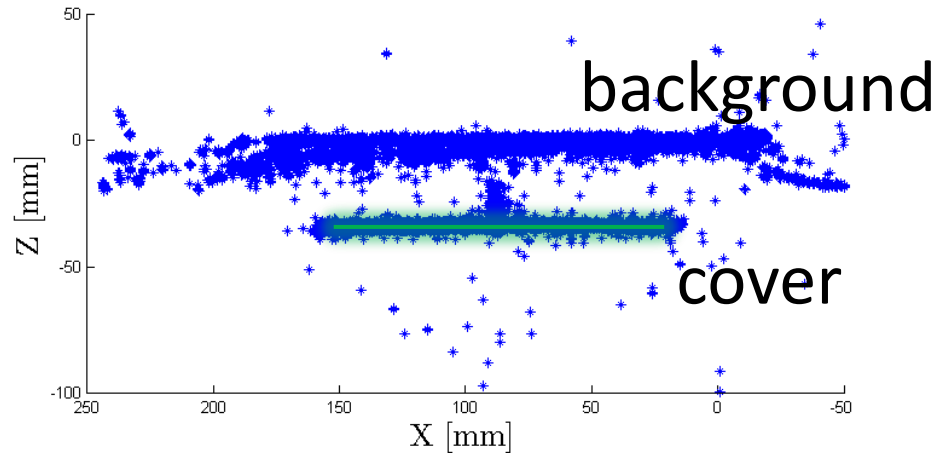
Evaluation for box cover

- Reconstructed object points for cover box and background
- Only points of cover box selected



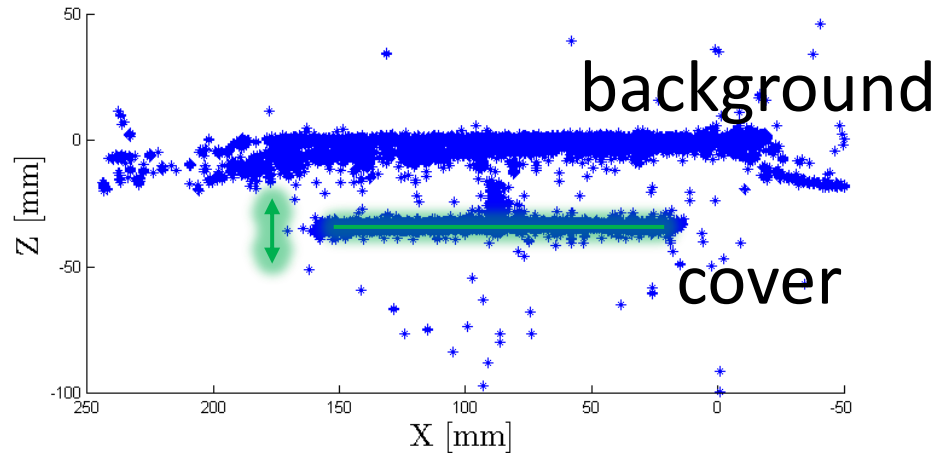
Evaluation for box cover

- Reconstructed object points for cover box and background
- Only points of cover box selected
- Plane fitted on this data

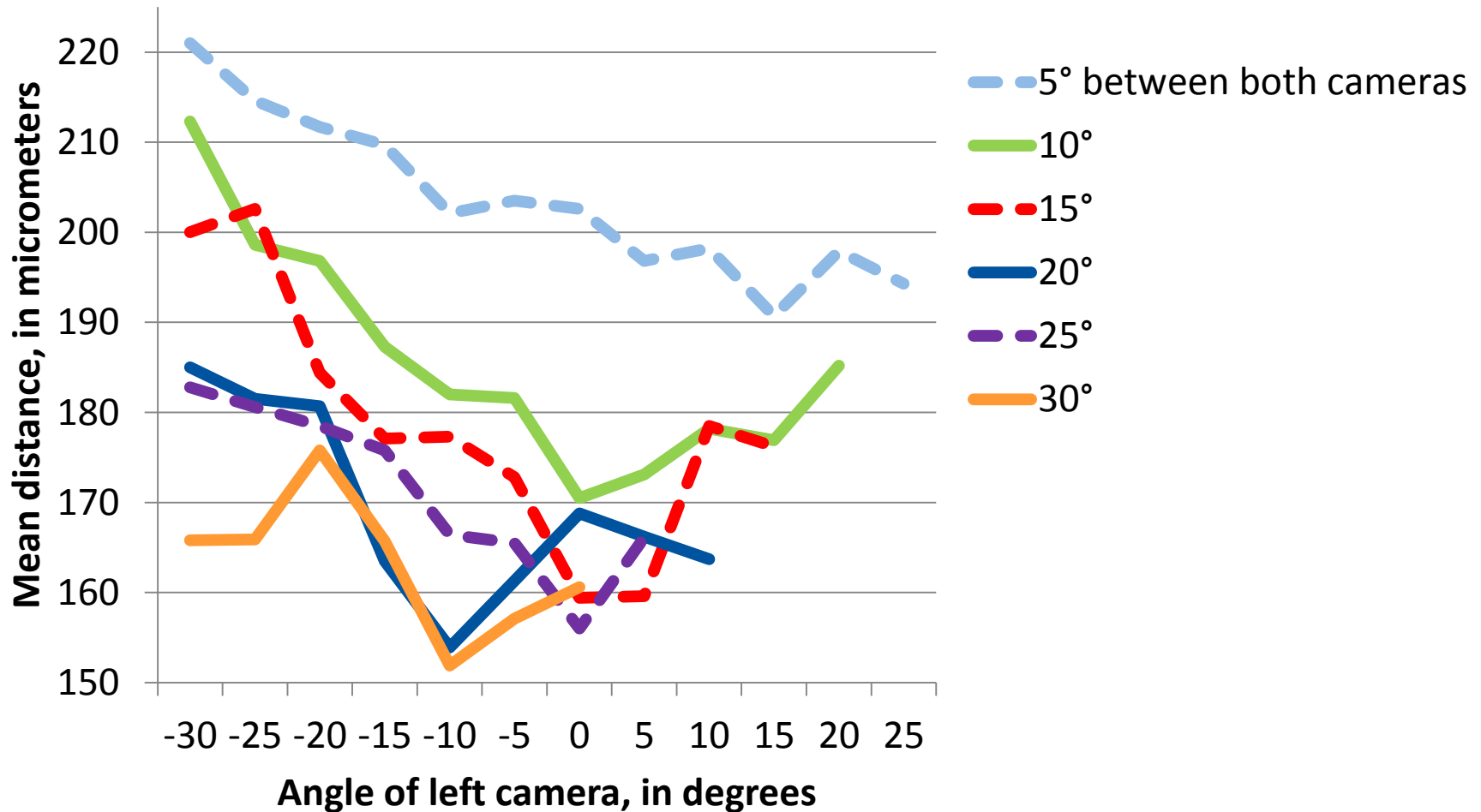


Evaluation for box cover

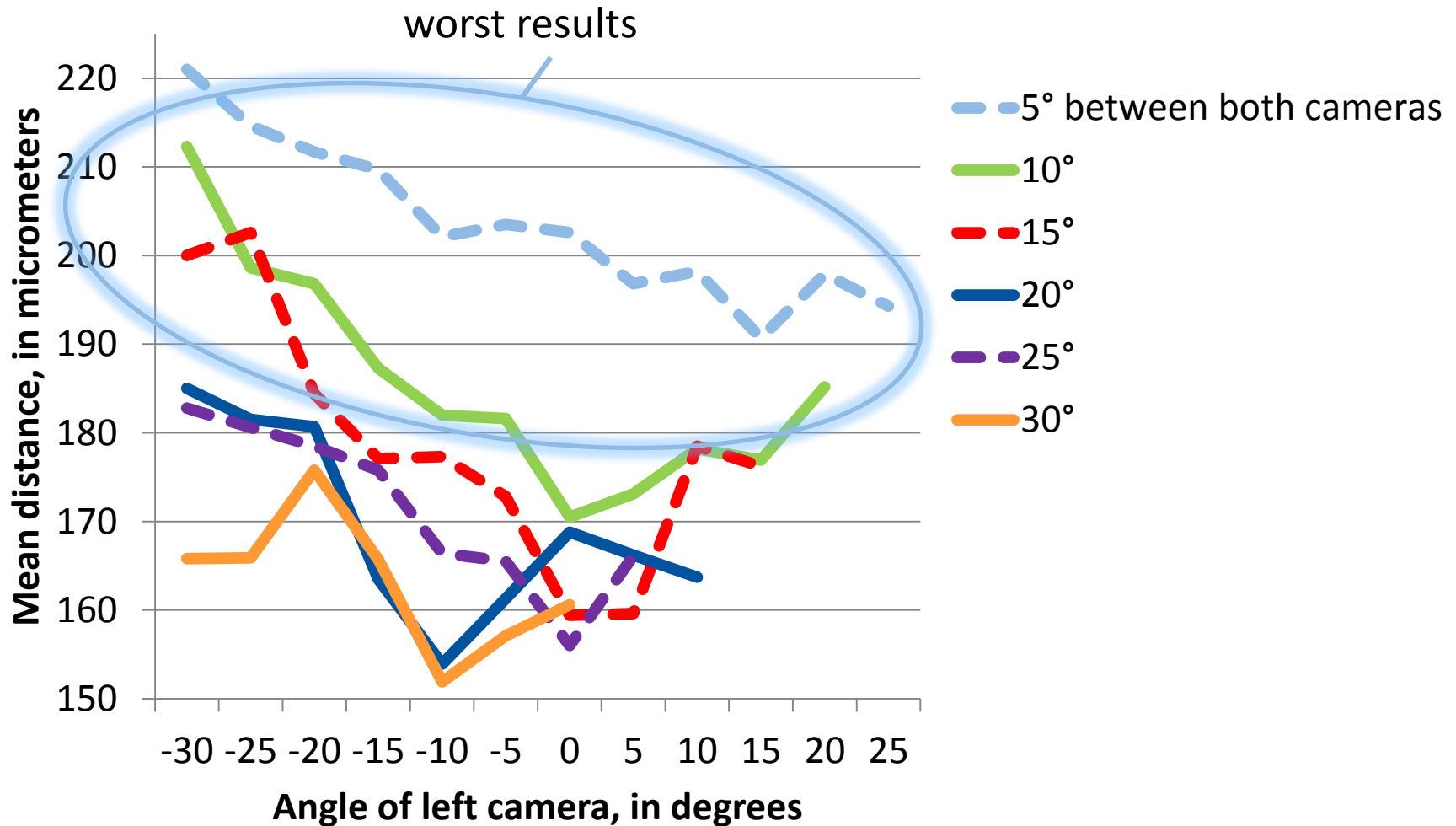
- Reconstructed object points for cover box and background
- Only points of cover box selected
- Plane fitted on this data
- Deviations from this plane for the points of the box cover
- Desired value: 0mm



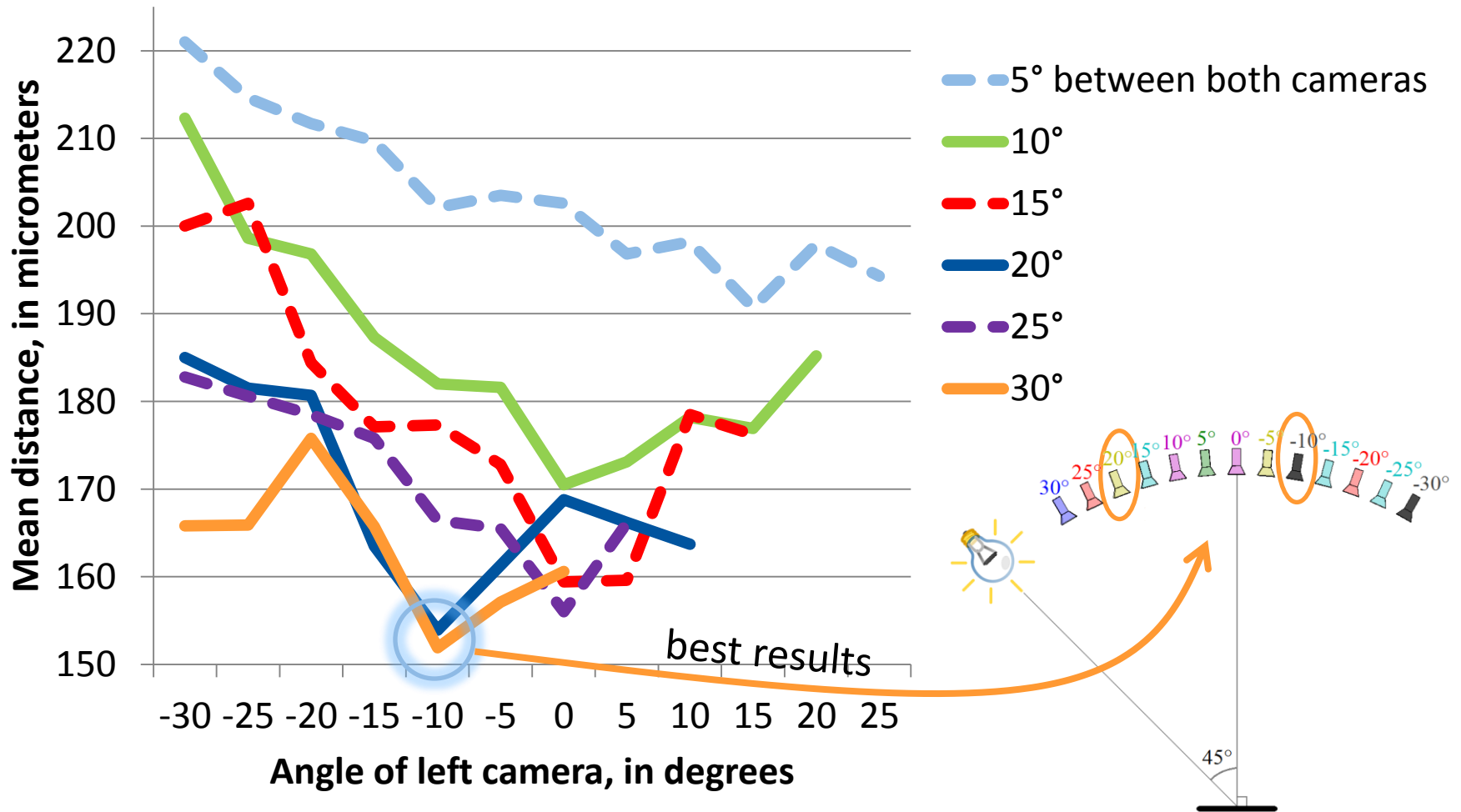
Deviations from plane



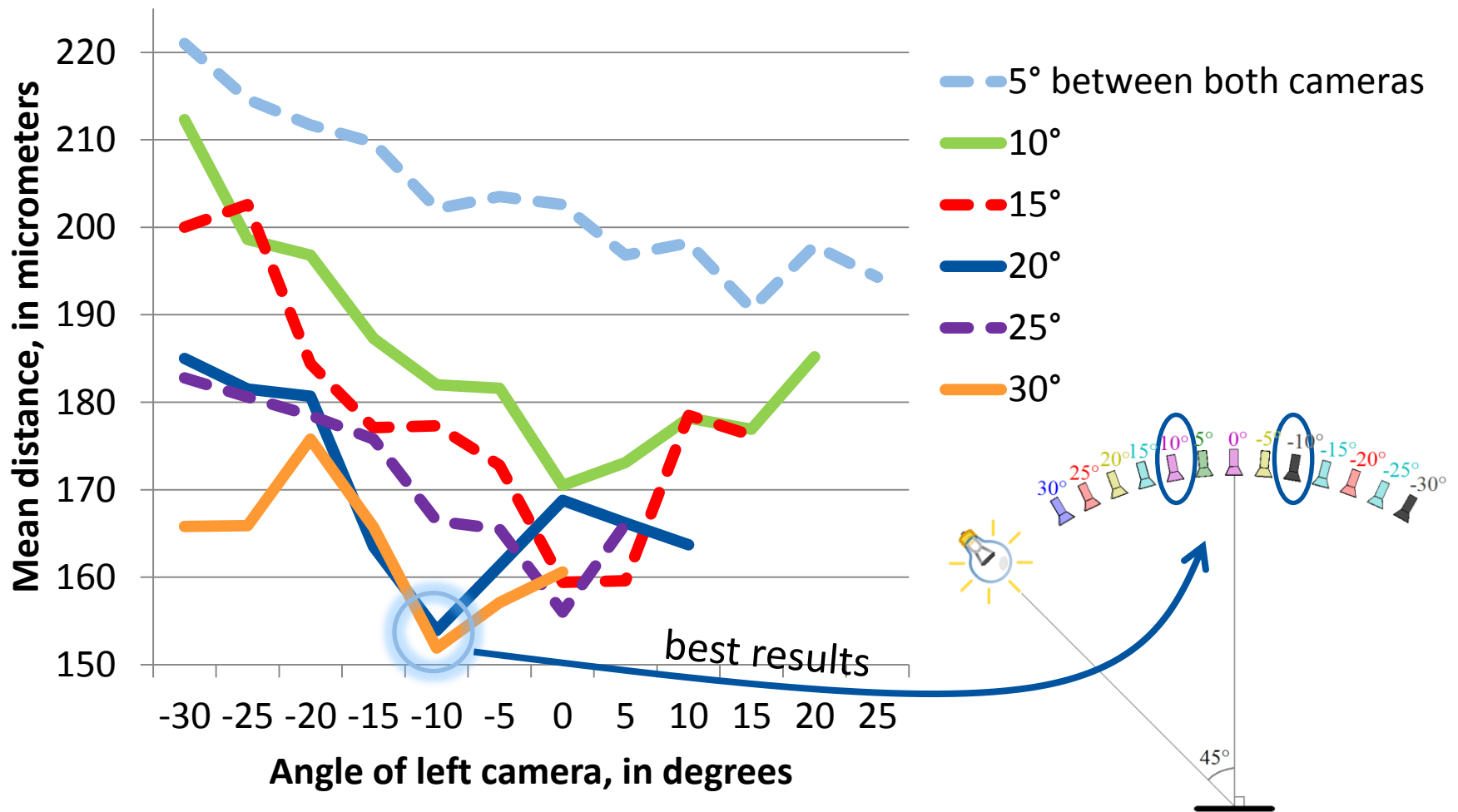
Deviations from plane



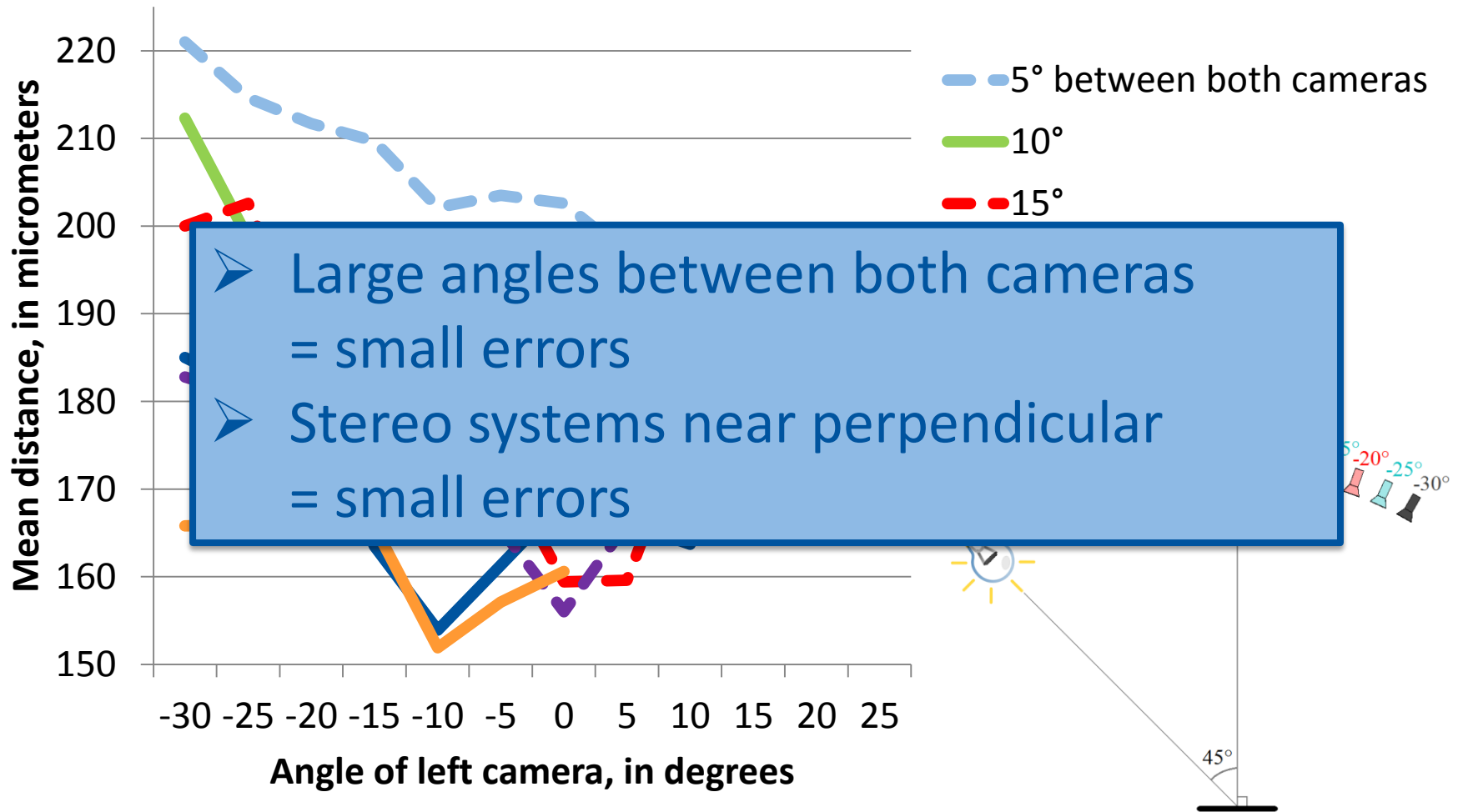
Deviations from plane



Deviations from plane

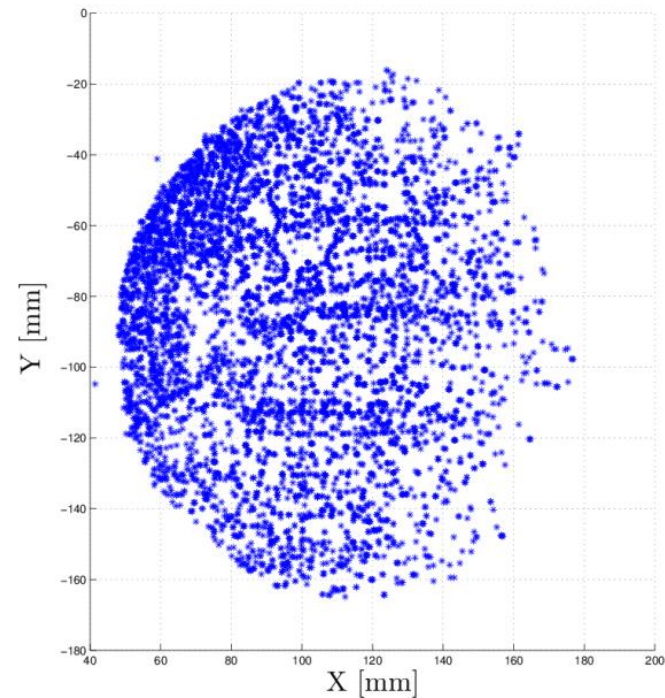


Deviations from plane



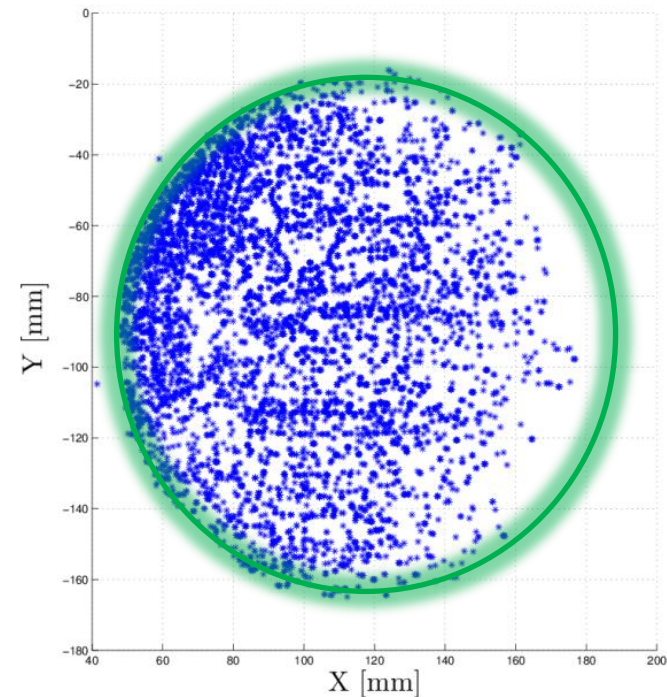
Evaluation for half sphere

- Reconstructed object points



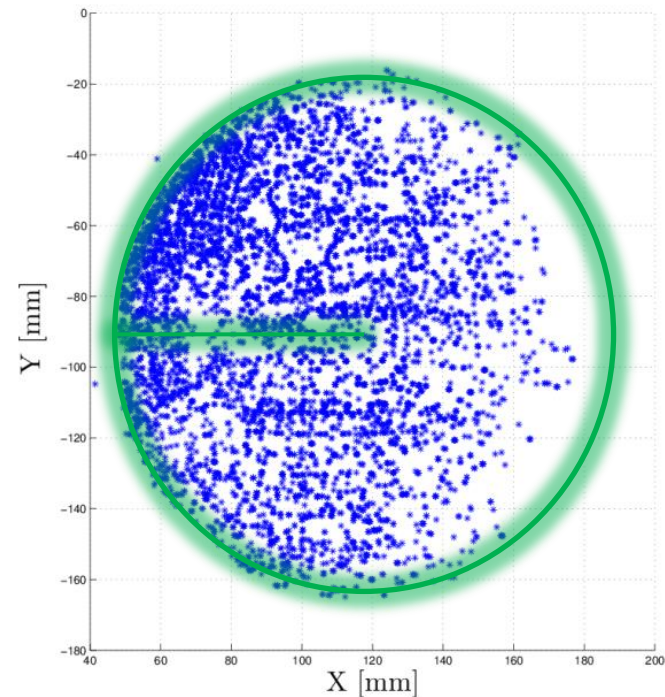
Evaluation for half sphere

- Reconstructed object points
- Sphere fitted on this data

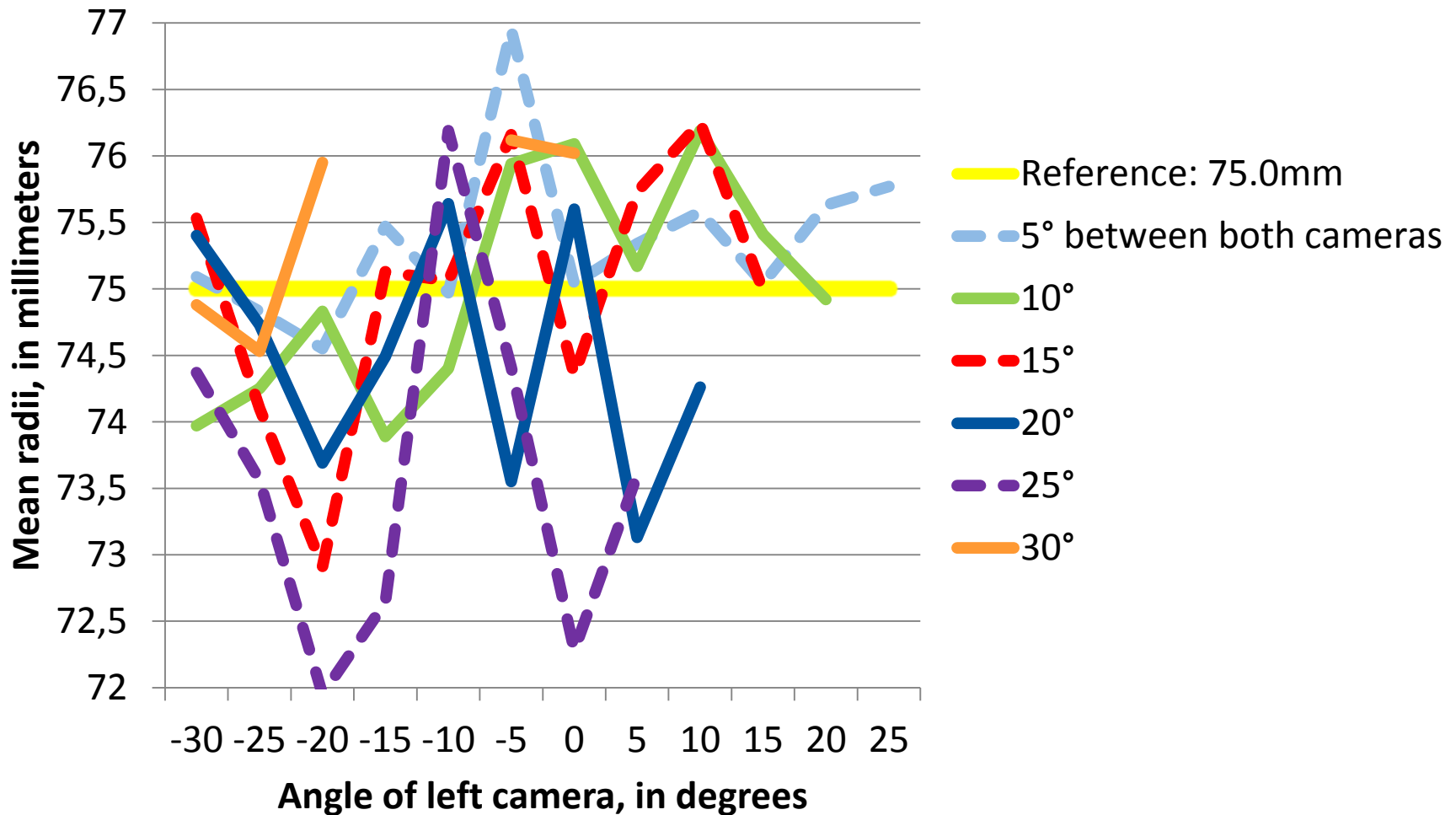


Evaluation for half sphere

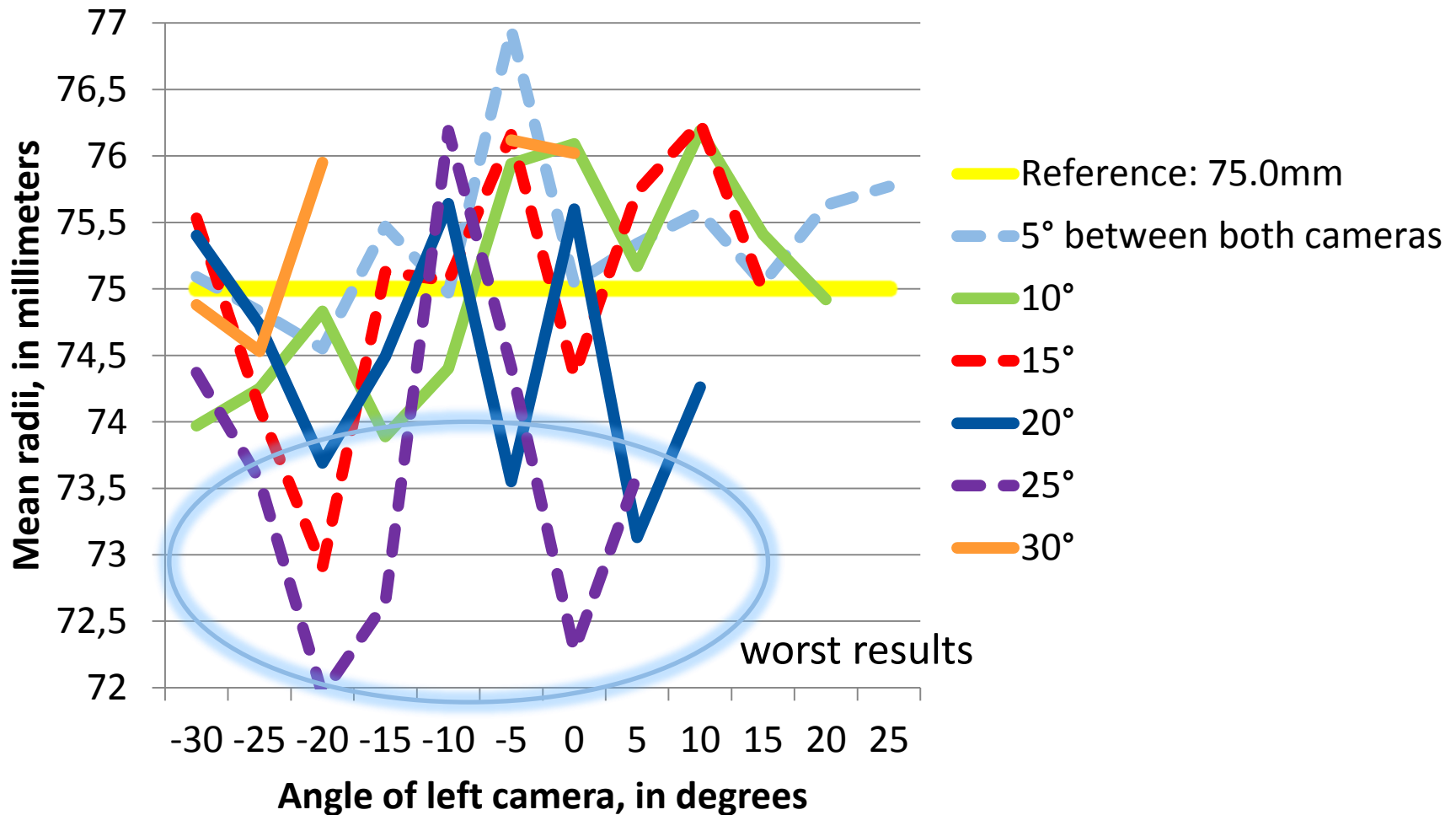
- Reconstructed object points
- Sphere fitted on this data
- Radius of the sphere calculated
- Reference value: 75.0mm



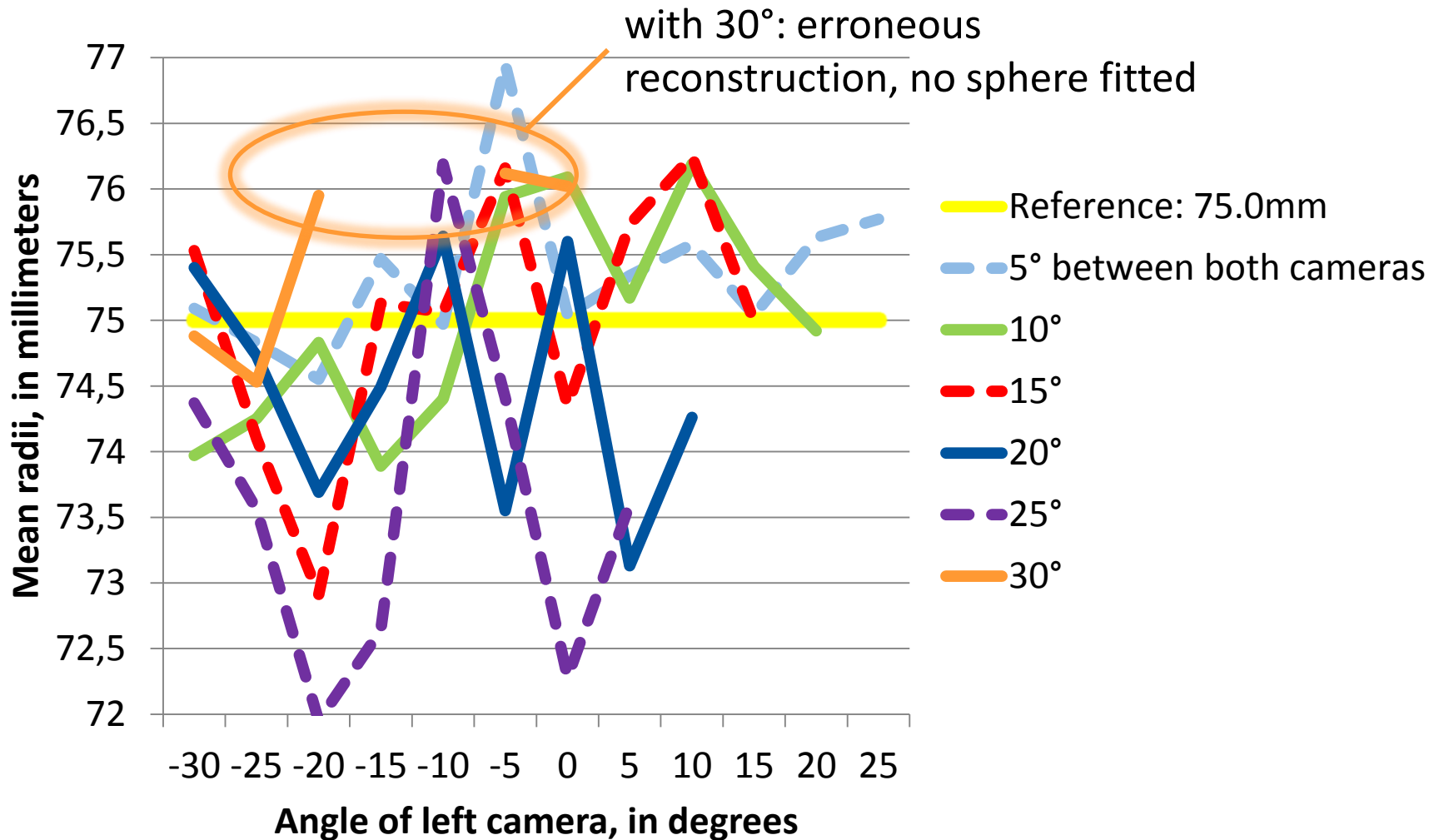
Radius of fitted half sphere



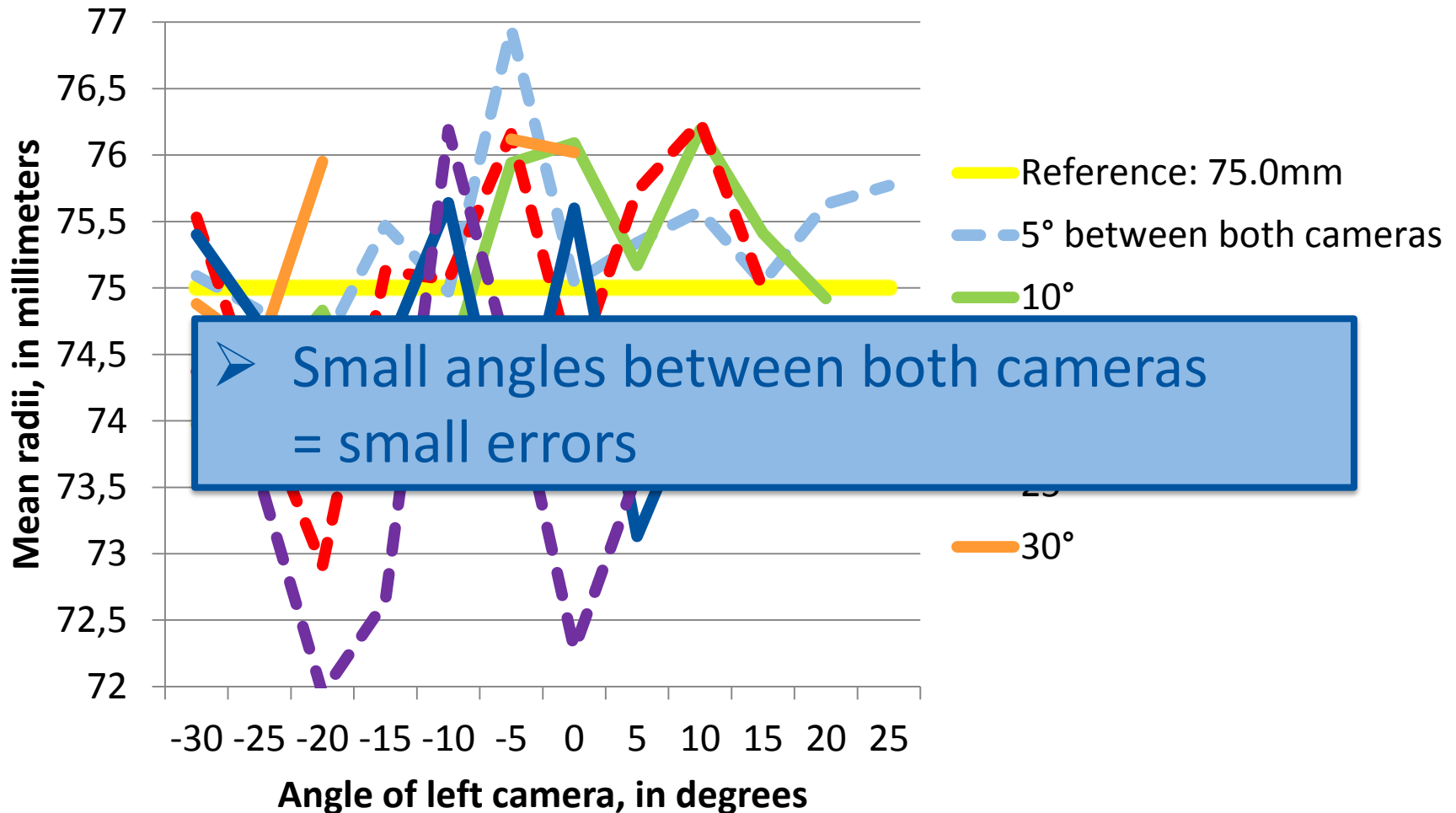
Radius of fitted half sphere



Radius of fitted half sphere



Radius of fitted half sphere



Conclusions

Conclusions

- 19-channel camera on a goniometric setup for angle-dependence of the reflectance functions of materials
- Different purpose here: extract 3D information simultaneously
- First test with stereo systems: simulation of several angles and several positions
- Complementary results with 19 color channels
- Best accuracy of reconstructed 3D points
 - with angle 20° between both cameras
 - for stereo system perpendicular to the surface

**Thank you
for your attention**