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BA Final:
Pose-aware rendering of
live ultrasound data
for mixed medical AR

26/01/18

Slide 1



Structure

- Motivation
- Goal
- State-of-the-Art
- Setup
- Framework
- Results



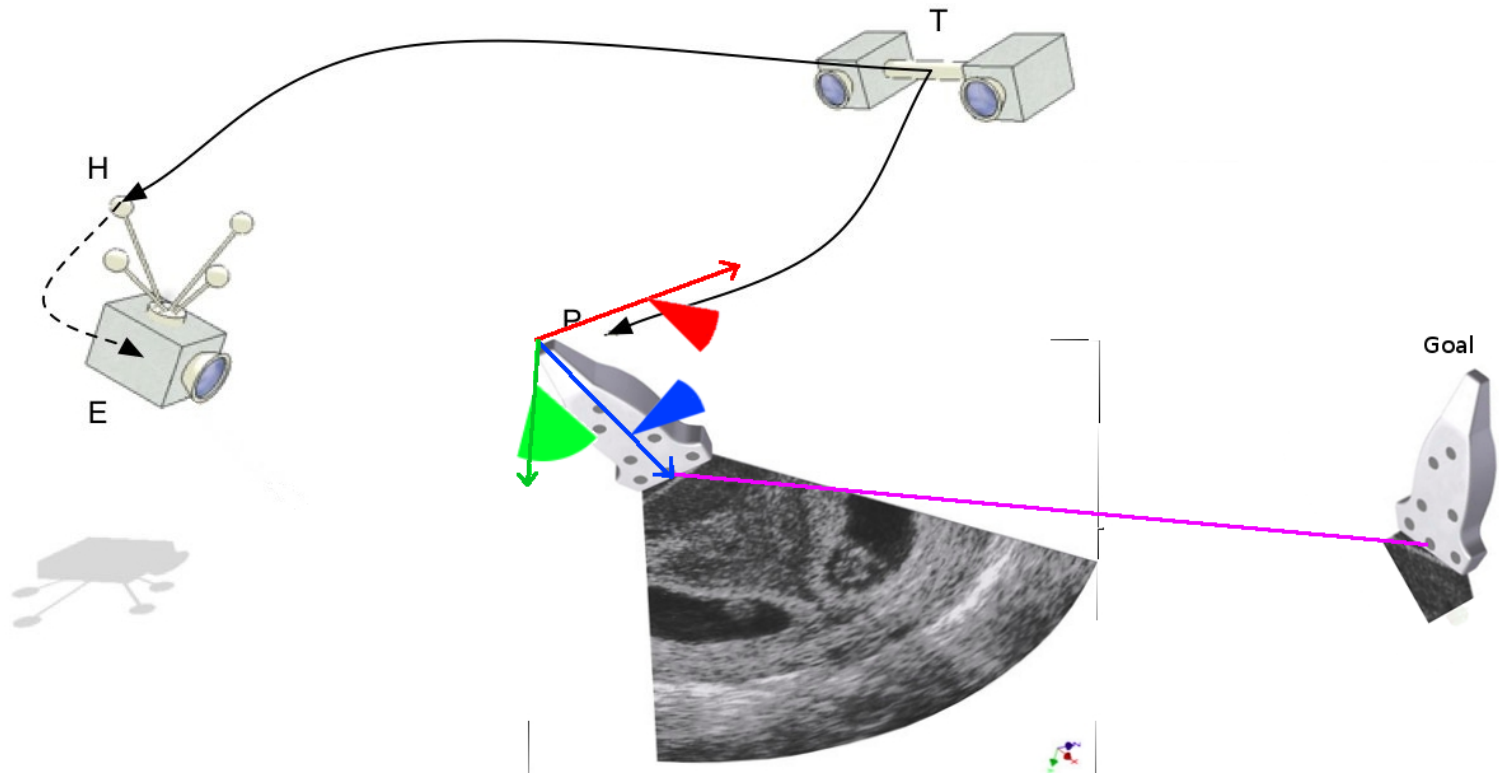
Motivation

- Teaching
- Find past poses
- Possibly as HMD
- Exchangeable display



Goal

- Augmenting tracked live ultrasound data on a tracked Android device (Tablet, Smartphone, Google Cardboard)
- Live-Guidance to find past measures

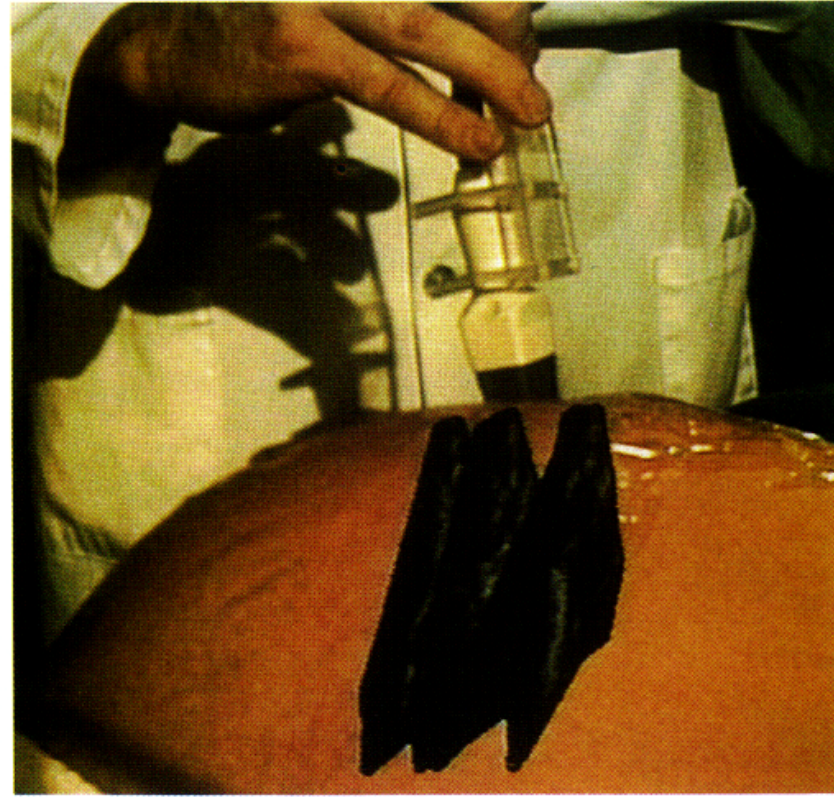


CAMP at TUM and Framos. <http://campar.in.tum.de/Chair/HandEyeCalibration> 05/09/17 and <https://www.framos.com/us/solutions/medical/optical-tracking-system/> 05/09/17



First live ultrasound with AR

- live ultrasound data (1-2 fps) augmented on a HMD in 1992
- Polhemus EM Tracker

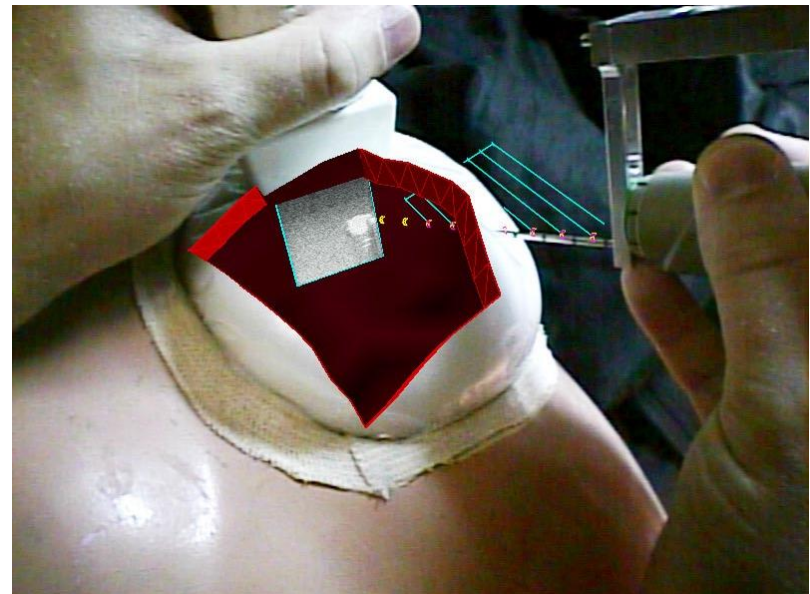


Bajura et al. 1992 "Merging virtual objects with the real world: Seeing ultrasound imagery within the patient"
SIGGRAPH 1992



AR-driven Needle Application

- Modified Sony Glasstron LDI-D100 HMD
- Image-guided technologies FlashPoint™ 5000 optoelectronic tracker

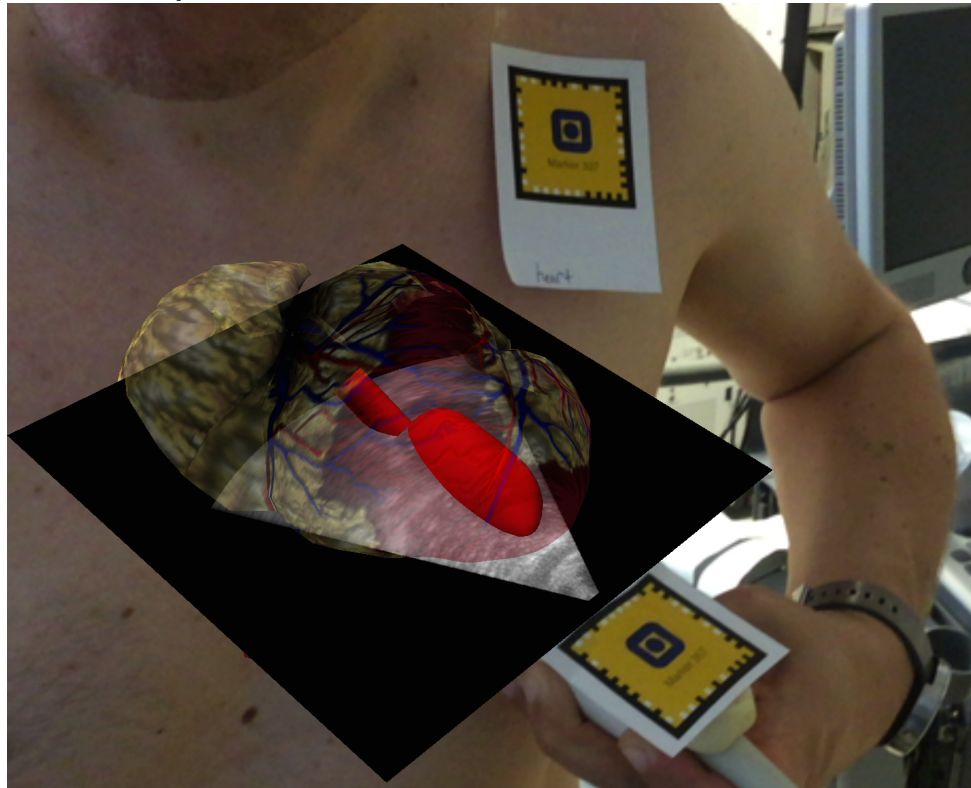


Rosenthal M. et al. 2001 "Augmented Reality Guidance for Needle Biopsies: A Randomized, Controlled Trial in Phantoms"
- MICCAI 2001



Mobile 3D

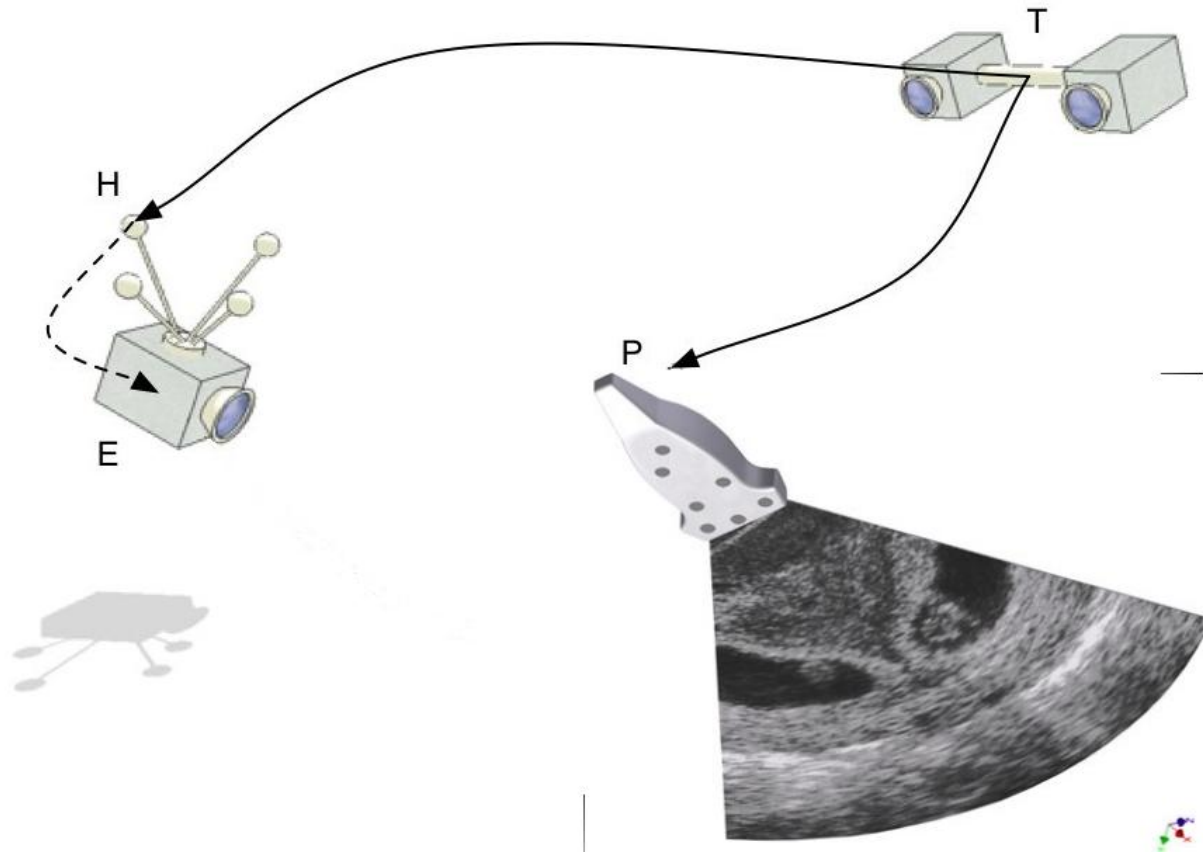
- Teaching system for the use of ultrasound device
- Mobile live AR on iOS and Android
- Marker based tracking (Vuforia)
- Deforming heart



Palmer, C. L. et al. 2015 "Mobile 3D augmented-reality system for ultrasound applications" IUS 2015



Setup



CAMP at TUM and Framos. <http://campar.in.tum.de/Chair/HandEyeCalibration> 05/09/17 and <https://www.framos.com/us/solutions/medical/optical-tracking-system/> 05/09/17

Setup

- Android device (Smartphone, Tablet)
 - with Api-level ≥ 21 (5.0 / Lollipop)
- Android Smartphone: Samsung Galaxy J5 (2016)
 - Android 6.0 (API Level 23 / Marshmallow)
 - 5,2'' Display
 - Resolution 1280*720 (HD)
 - 2 GB RAM
 - CMOS 13.0MP (aperture F1.9)
 - Video recording with Resolution 1280*720 @30fps
 - 1.2GHz Quadcore



<http://www.samsung.com/ph/smartphones/galaxy-j5-2016-j510gn/SM-J510GZDUXTC/>
21/01/18



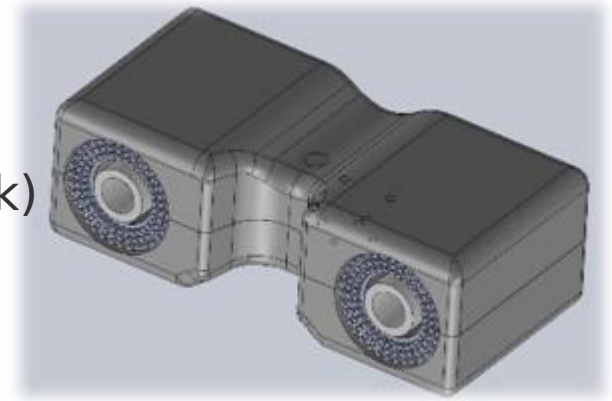
Setup

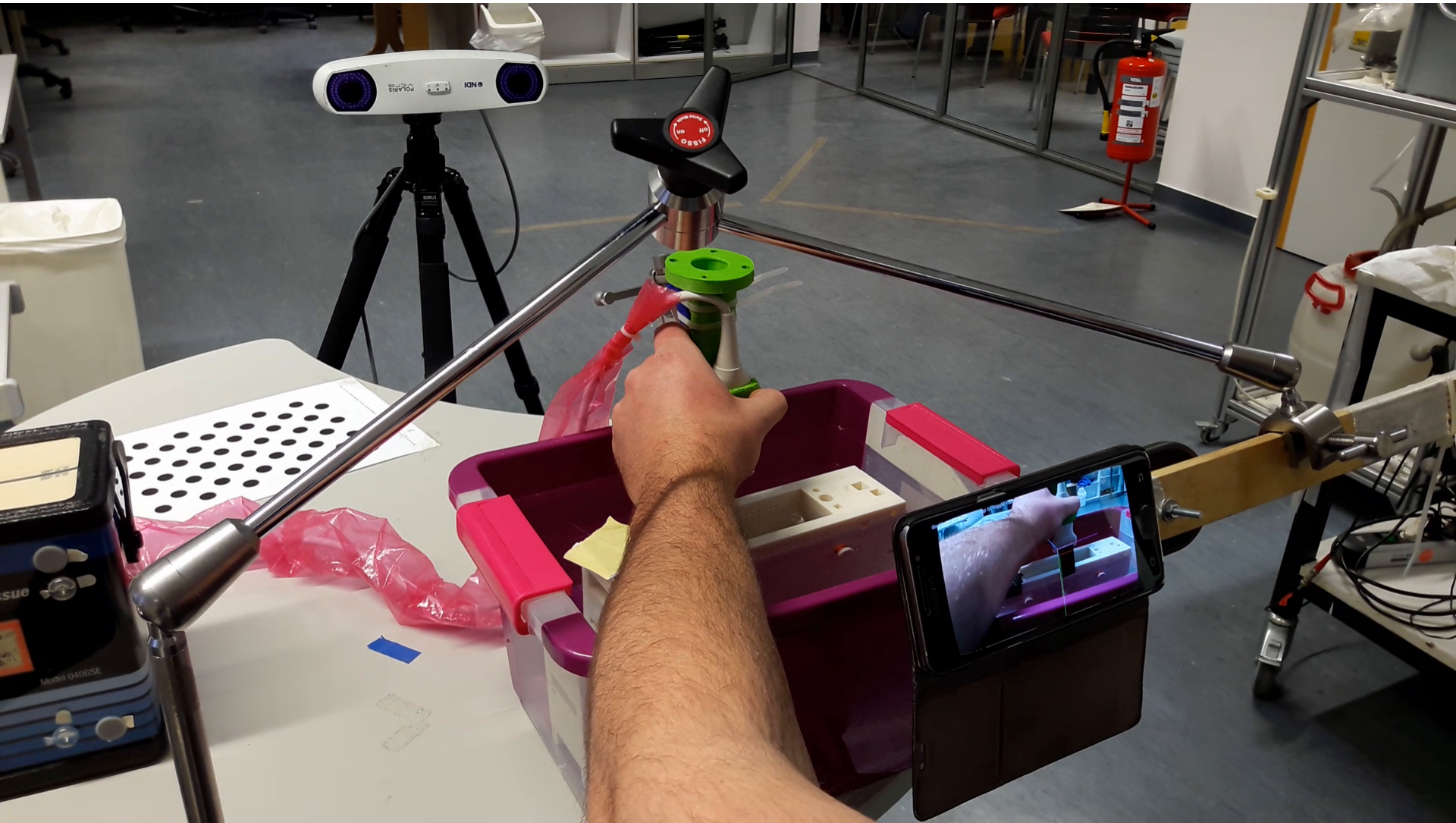
- Android Device
- Ultrasound Probe (calibrated to NDI-Marker)



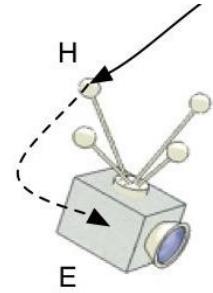
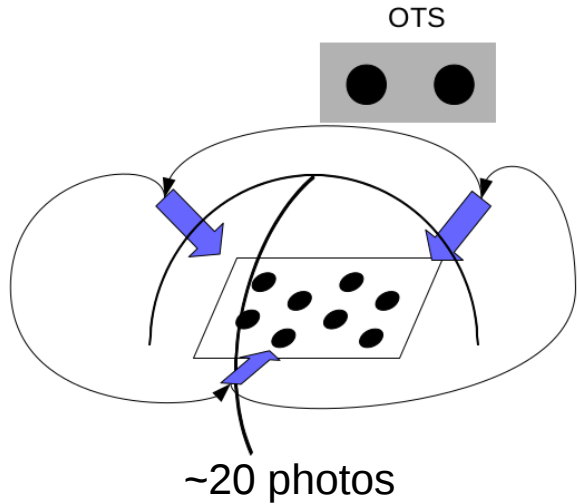
Setup

- Android Device
- Ultrasound Probe
- Switch/Hub for local network (OpenIGTLink)
- NDI Polaris Vicra



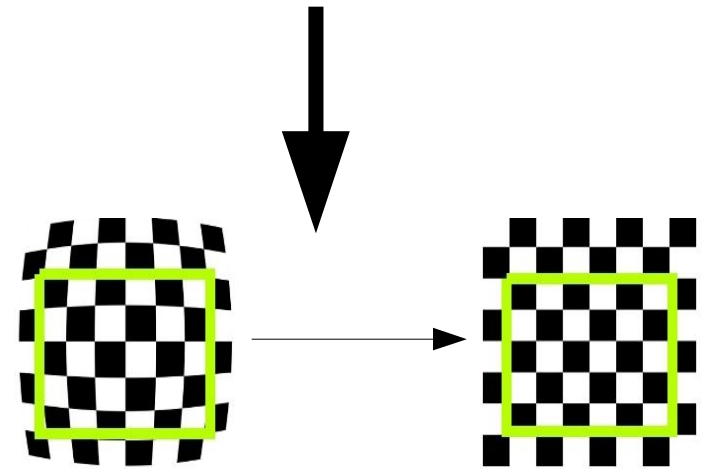


Framework

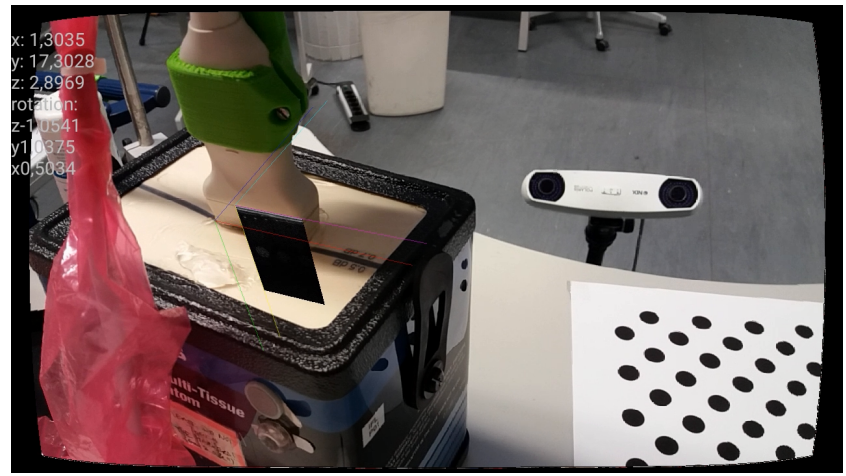


[http://campar.in.tum.de/..](http://campar.in.tum.de/)
05/09/17

hand-eye calibration



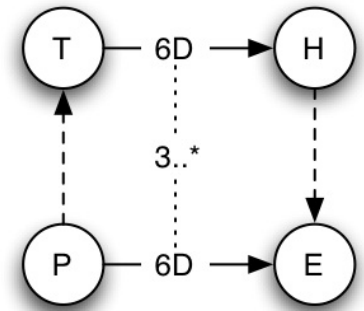
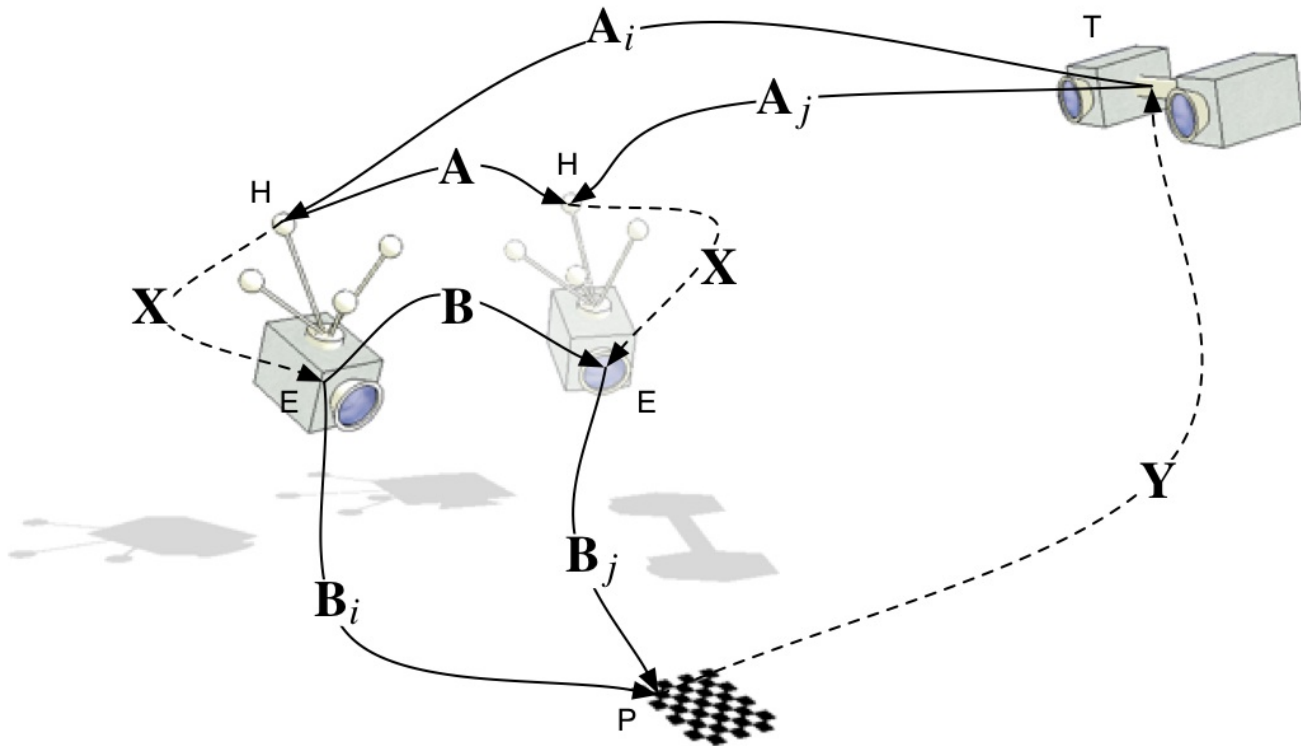
undistort



<https://docs.opencv.org/2.4/modules/calib3d/> 05/09/17

Hand-Eye Calibration

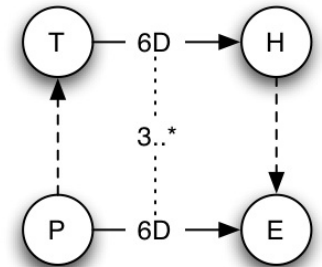
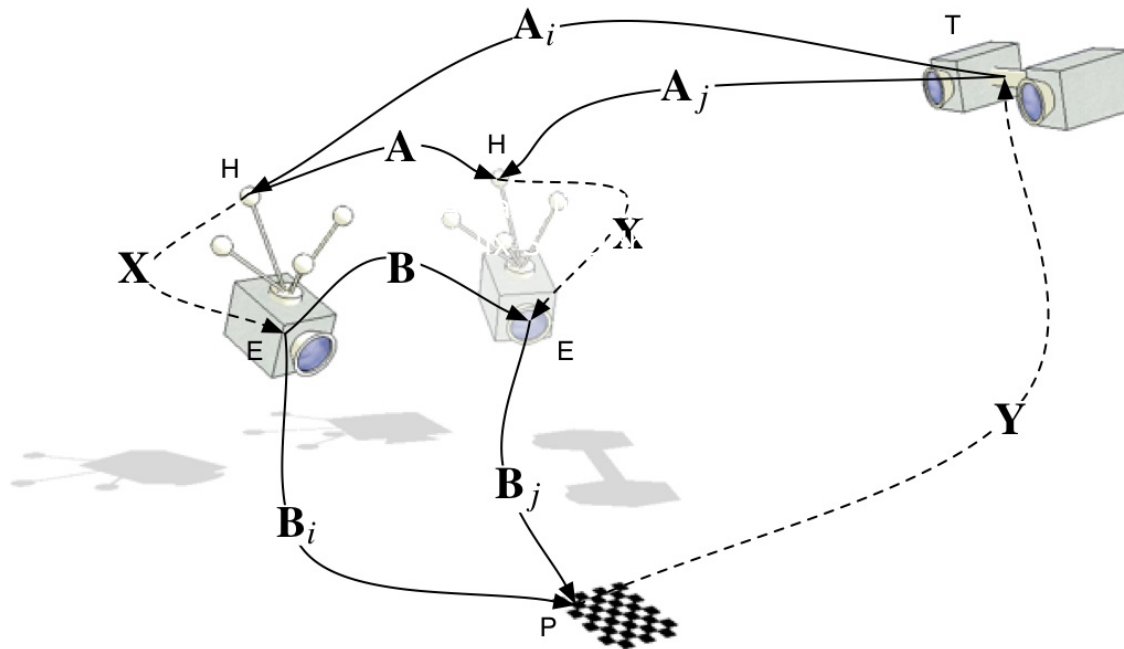
- if Y is unknown



<http://campar.in.tum.de/Chair/HandEyeCalibration> 05/09/17

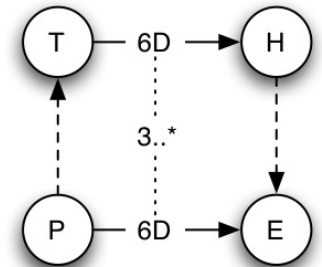
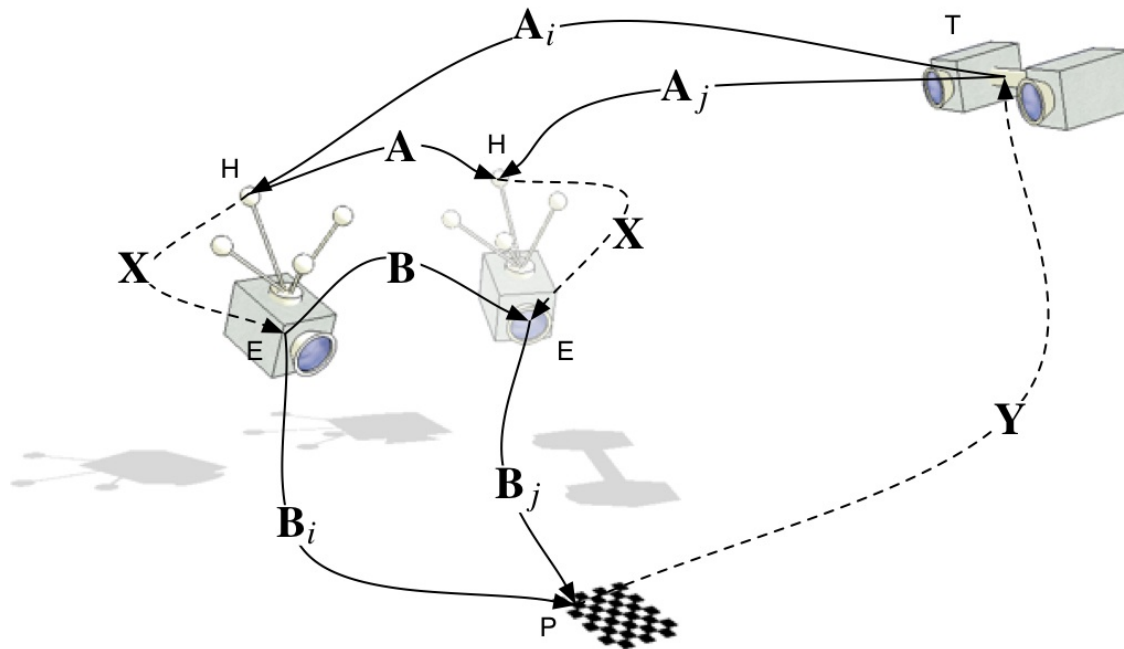
Hand-Eye Calibration

- Capture n (~ 20) pictures and poses at the same time (“stations”)
- OpenCV: calibrate [Zhang 2000]
 - intrinsic parameters
 - n extrinsic transforms B_i



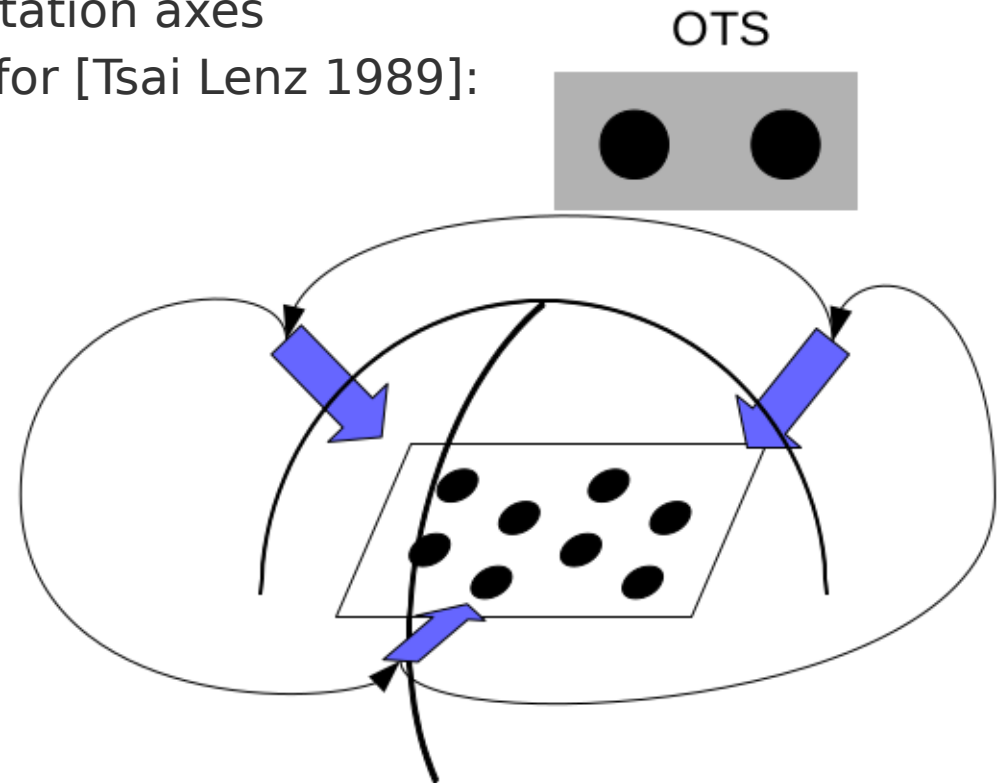
Hand-Eye Calibration

- [Tsai Lenz 1989] linear least-squares solution to find
 - first rotation
 - then translation of X



Hand-Eye Calibration

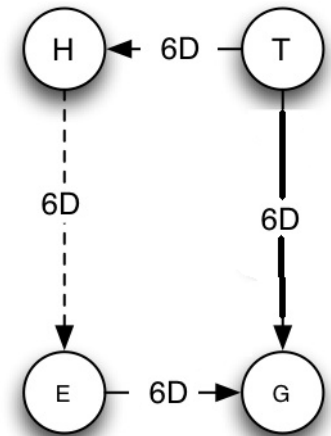
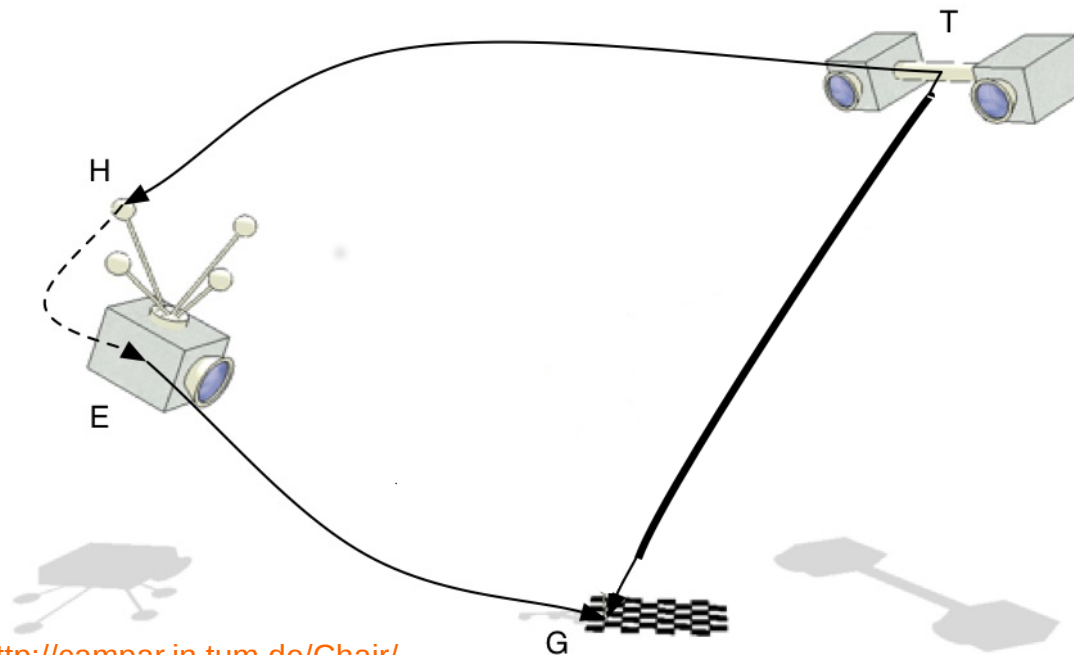
- For better results
 - large rotations between stations
 - Large angle between rotation axes
- → Take stations in this order for [Tsai Lenz 1989]:



Tsai, R.Y., Lenz, R.K.: „A new technique for fully autonomous and efficient 3D robotics hand/eye calibration“ TRA 1989

Hand-Eye Calibration

- Capture n (~ 20) pictures and poses at the same time (“stations”)
- OpenCV: calibrate pictures [Zhang 2000]
 - intrinsic parameters
 - n extrinsic transforms $\begin{matrix} E \\ G \end{matrix}^T \rightarrow n$ same $\begin{matrix} E \\ H \end{matrix}^T \rightarrow$ average



[http://campar.in.tum.de/Chair/
HandEyeCalibration](http://campar.in.tum.de/Chair/HandEyeCalibration)
05/09/17

Zhang "A flexible new technique for camera calibration" TPAMI 2000

Transformation Averaging

- The i -th transformation ${}^E T_i$ consists of
 - rotation ${}^E R_i$ and translation vector ${}^E P_{HORG_i}$

$${}^E T_i \cdot {}^H P = {}^E R_i \cdot {}^H P + {}^E P_{HORG_i}$$

- Average of Rotation
- Average Translation

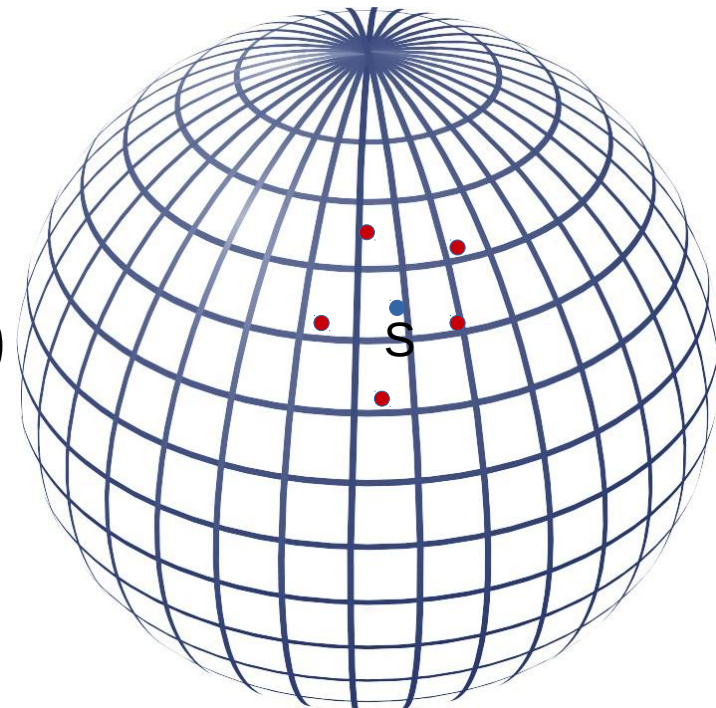


Transformation Averaging

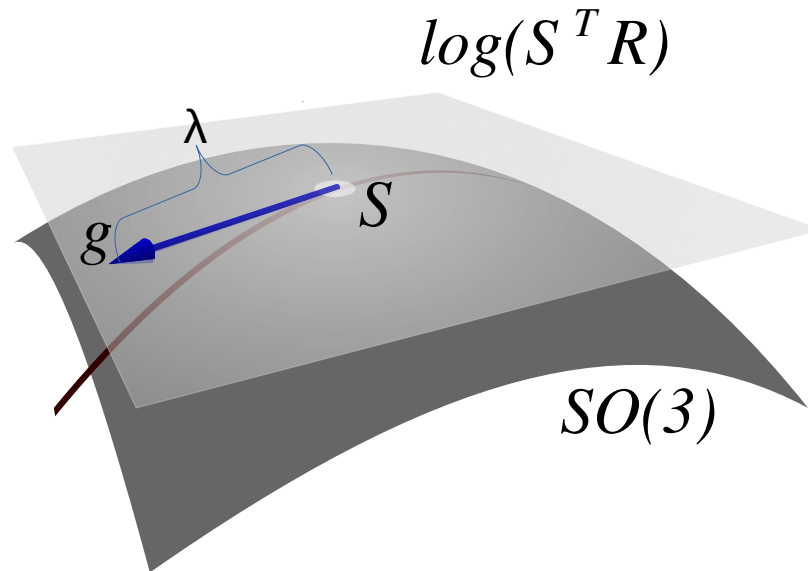
- Average over all n rotations:

$$S = \operatorname{argmin}_{R \in SO(3)} \sum_{i=1}^n d \left(\begin{matrix} E \\ H \end{matrix} R_i, R \right)$$

- Using Weiszfeld algorithm [Hartley 2011]:
 - Initiate S^0 with any L2-mean, repeat:



wikipedia.org/wiki/Sphere
25/01/18



Richard I. Hartley et al. "L1 rotation averaging using the Weiszfeld algorithm" CVPR 2011

<https://commons.wikimedia.org/wiki/File:Tangentialvektor.svg> 15/01/18



Transformation Averaging

$$\frac{E}{H} T_i \cdot H P = \frac{E}{H} R_i \cdot H P + E P_{HORG_i}$$

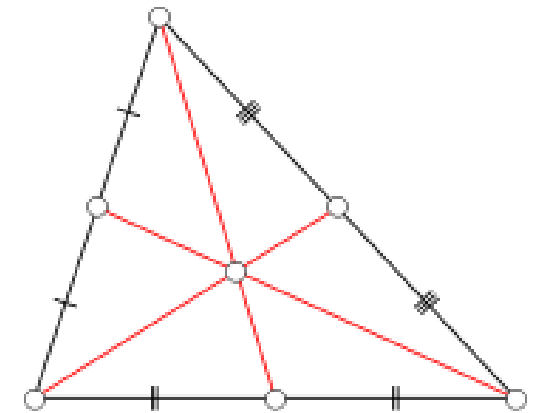
- Average of translation:

- Describe translations relative to coordinate system E':

$$E' P_{HORG_i} = S \cdot \frac{E}{H} R_i^T \cdot E P_{HORG_i}$$

- Average with arithmetic mean:

$$E' P_{HORG} = \sum_i \frac{E' P_{HORG_i}}{n}$$



- Average transformation

$$\frac{E'}{H} T = \begin{pmatrix} S & E' P_{HORG} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

<https://en.wikipedia.org/wiki/Centroid> 21/01/18



Rendering

- Distortion correction of received images from Camera
 - Known undistortion [BouguetMCT MATLAB calibration tool] + [Zhang2000]:

$$r_u = r_d * \left(1 + k_1 * r_d^2 + k_2 * r_d^4 + k_3 * r_d^6 \right)$$

- Undistort once (bilinearly interpolated)
- positions as color → lookup table

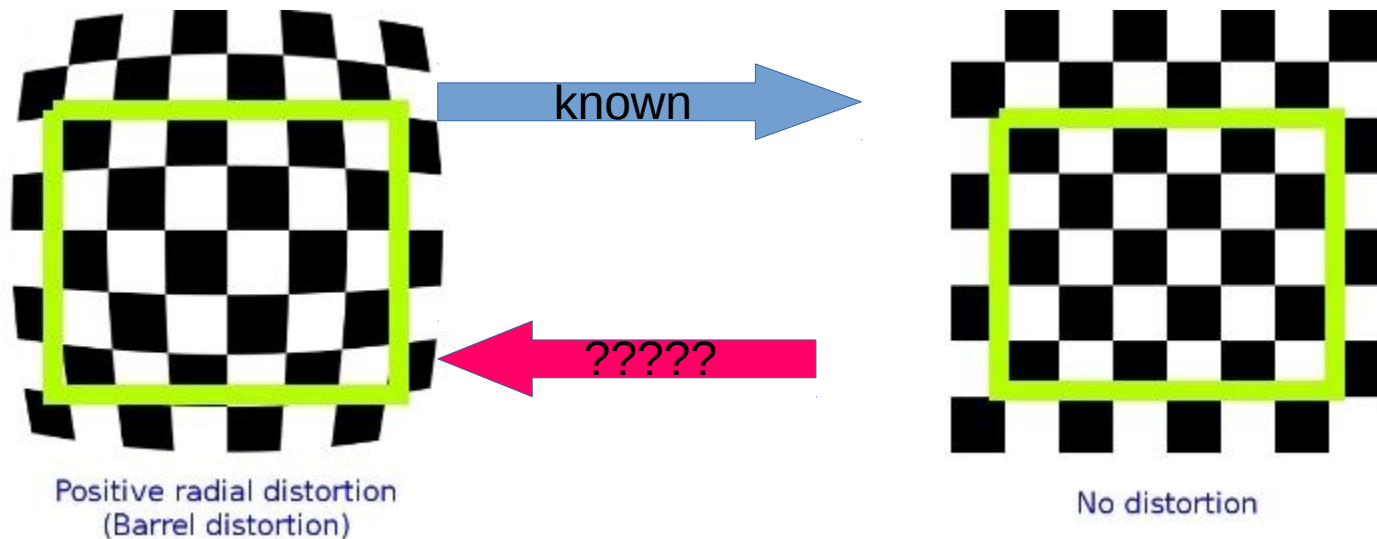
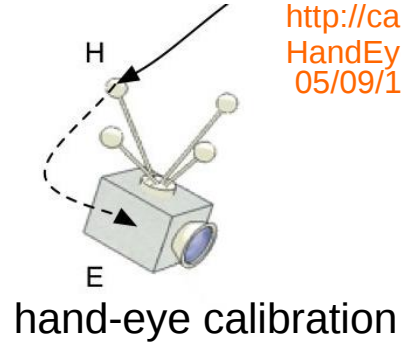
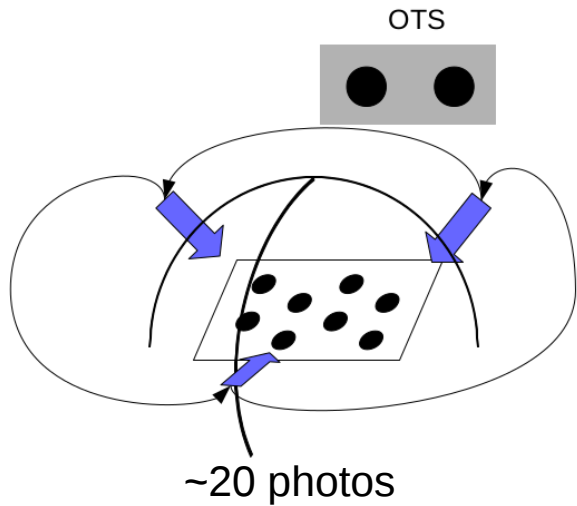


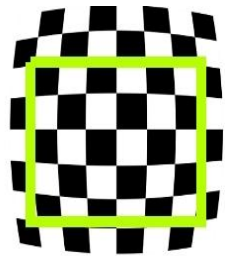
Image: docs.opencv.org/./camera_calibration_and_3d_reconstruction.html 05/09/17



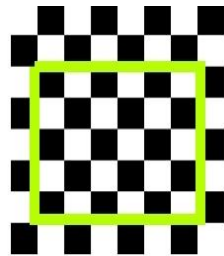
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<http://campar.in.tum.de/Chair/HandEyeCalibration>
05/09/17



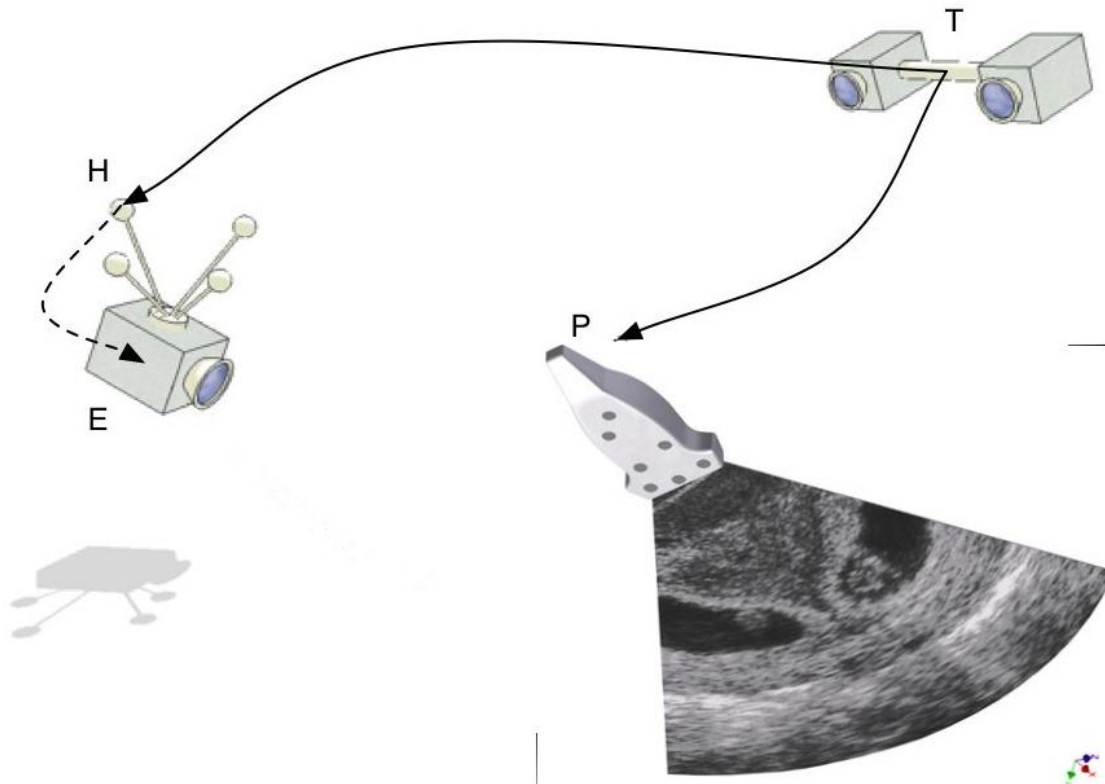
undistort



[docs.opencv.org/.../camera_calibration_and_3d_reconstruction.html](https://docs.opencv.org/4.x/doc/tutorials/calib3d/camera_calibration_and_3d_reconstruction.html)

Rendering

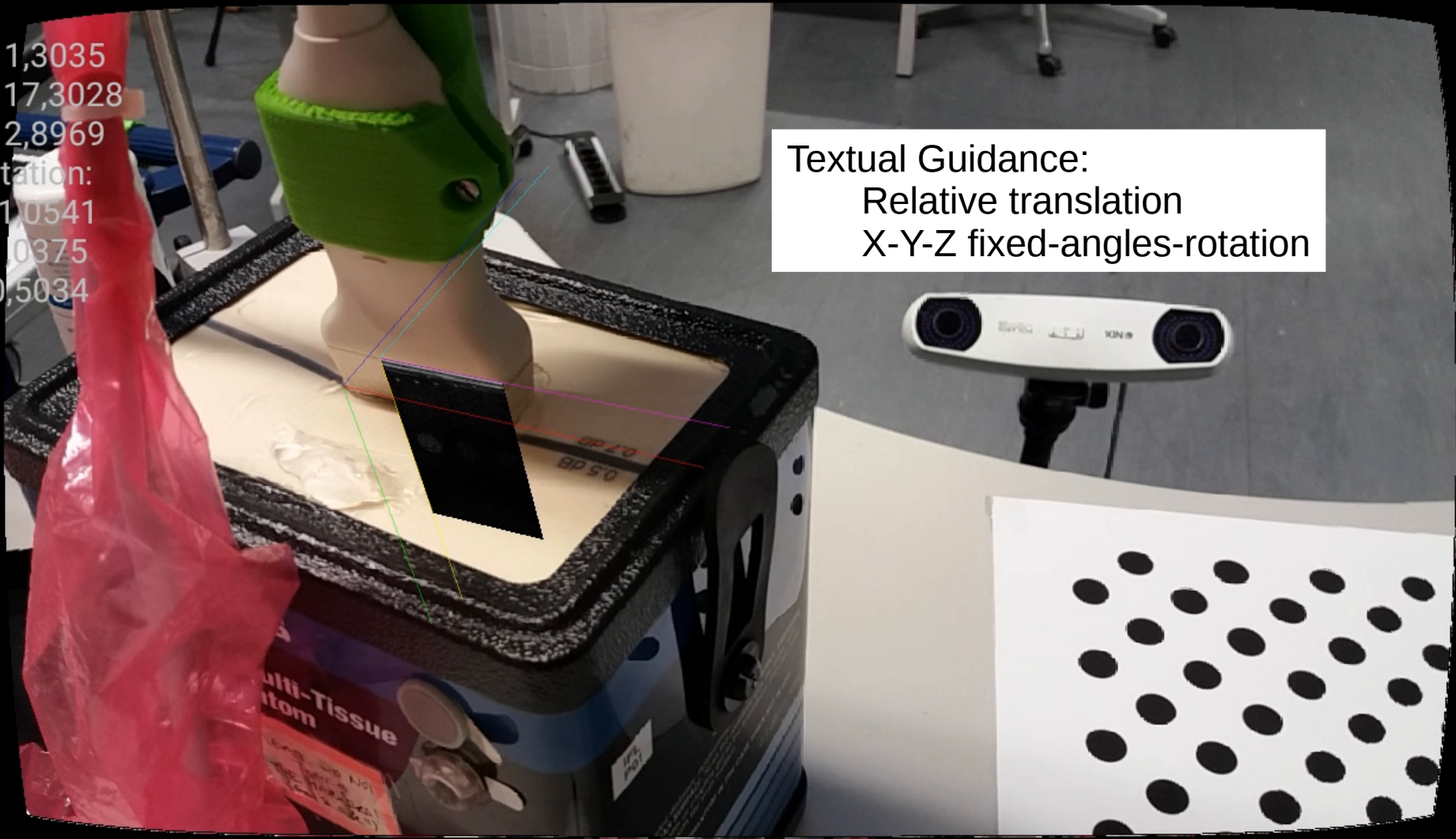
- Transform Ultrasound Image to Camera view
- perspective projection



Guidance

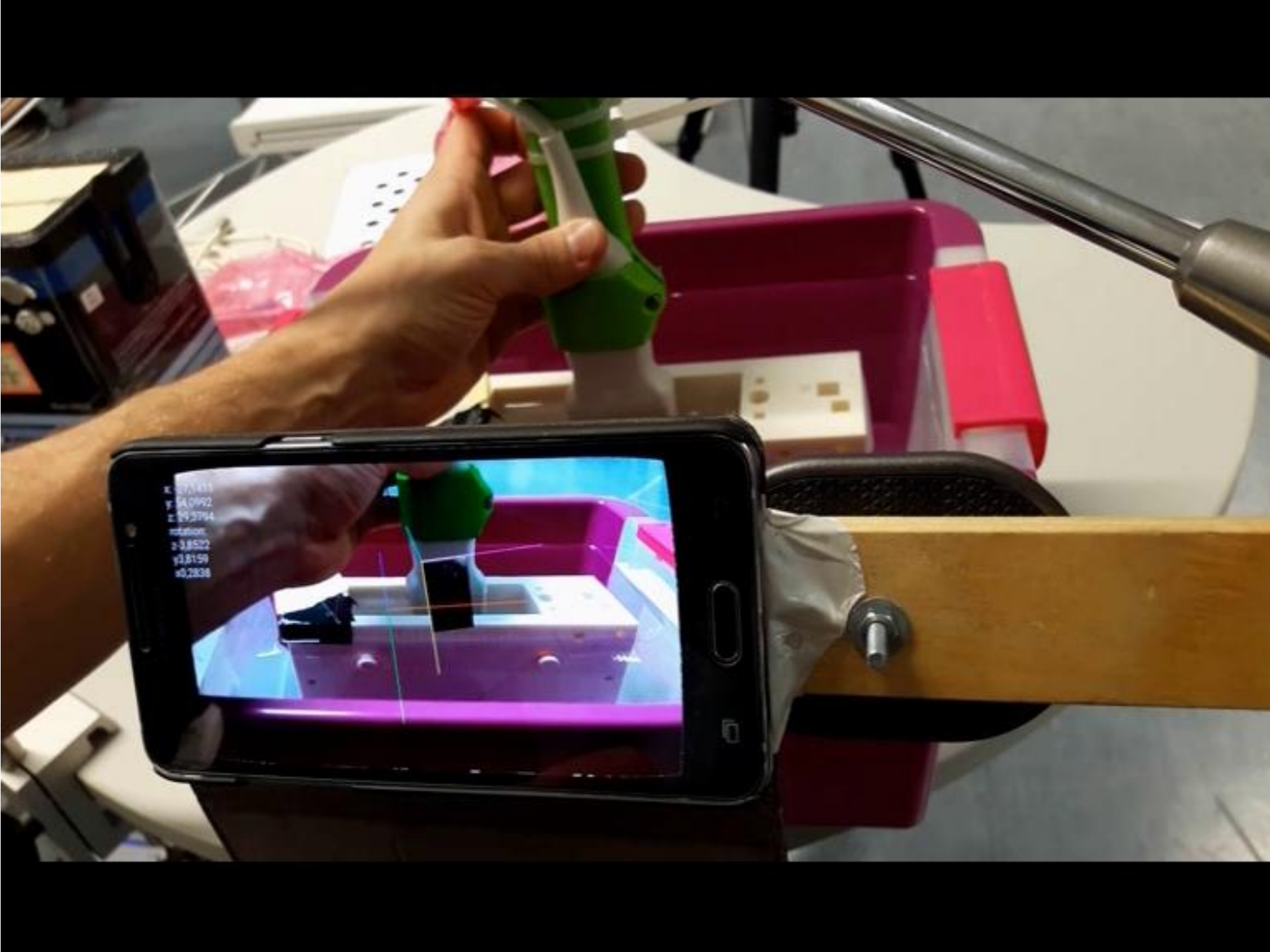
x: 1,3035
y: 17,3028
z: 2,8969
rotation:
z-1,0541
y1,0375
x0,5034

Textual Guidance:
Relative translation
X-Y-Z fixed-angles-rotation



Results

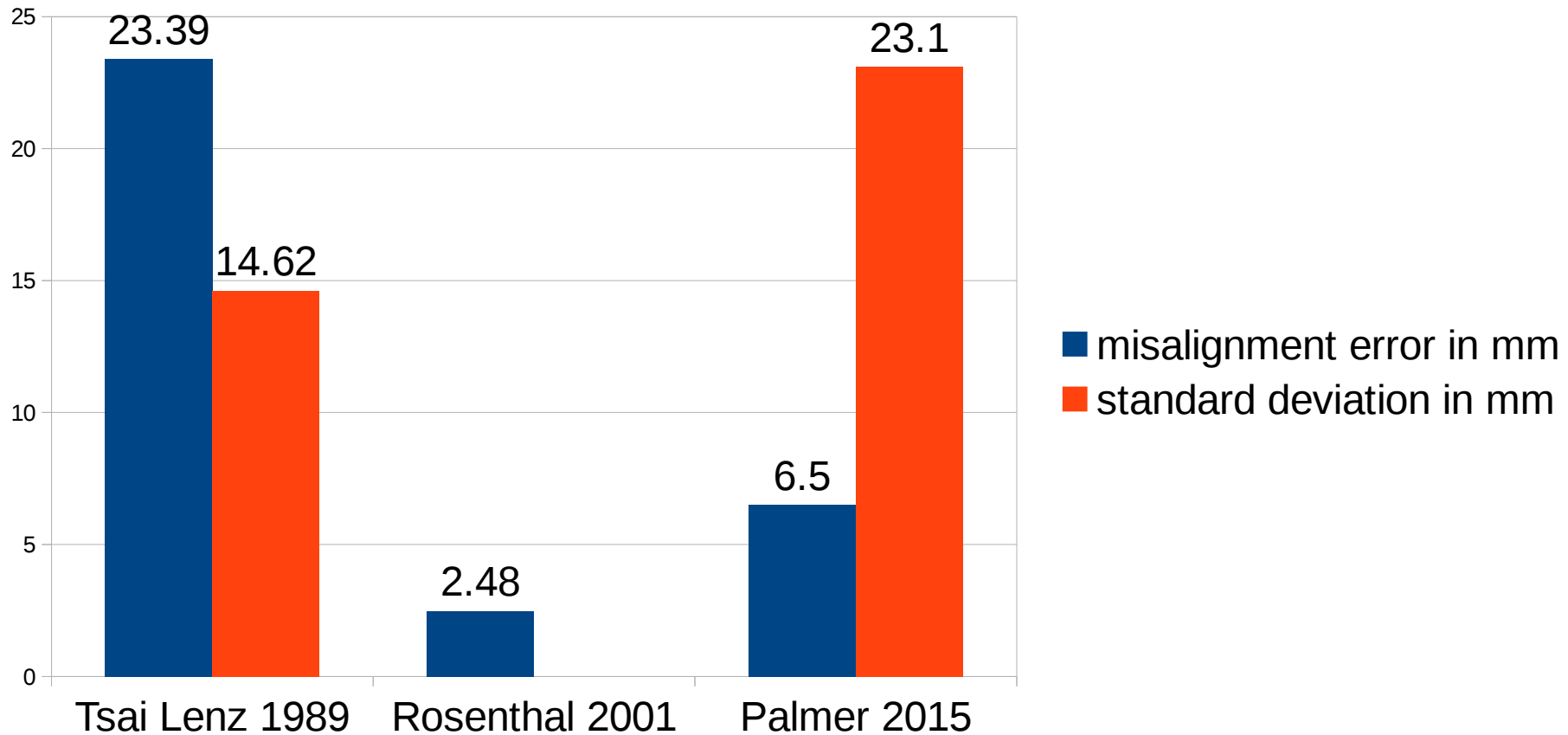




x: 07.1411
y: 04.0992
z: 09.5794
rotation:
a: 3.8522
y: 0.8159
x: 0.2808

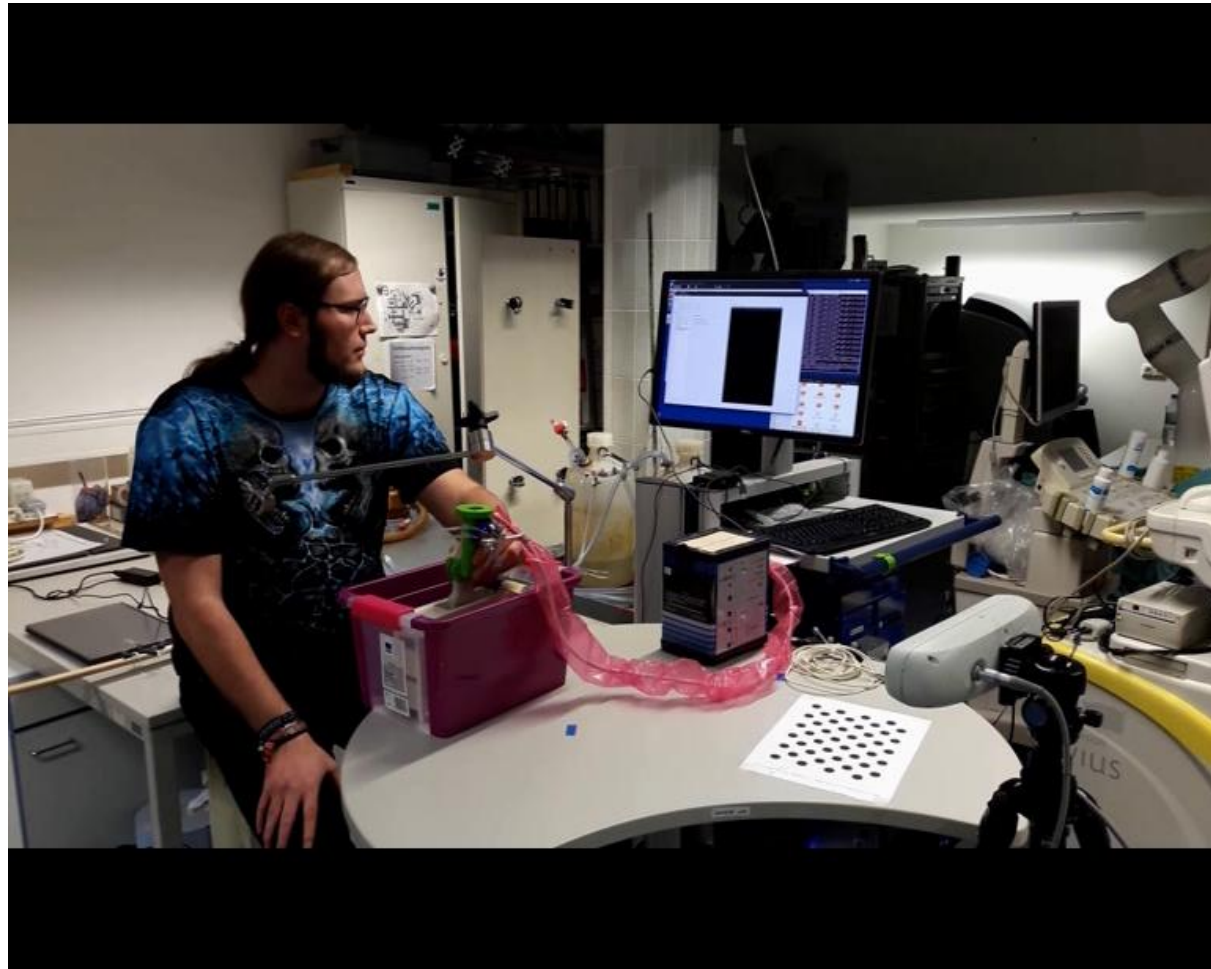
Results

- delay of 1.15s on average



Results

- Empirical Evaluation:
 - Standard: ~8.58s
 - AR: ~9.56s
 - Guided: ~9.4s



- Overall positive feedback (except delay, screen size)
- Task too easy



Questions?

