Adaptable high-resolution real-time stereo tracking

Benjamin Busam

13th EMVA Business Conference, Athens, 13.06.2015

FRAMOS Research & Development

FRAMOS Key Facts

- Offices across Europe and North America
- ~ 35 M€ revenue
- 85 employees
- 4 EU research projects
- National research projects
- Close university relationships
- PhD programmes

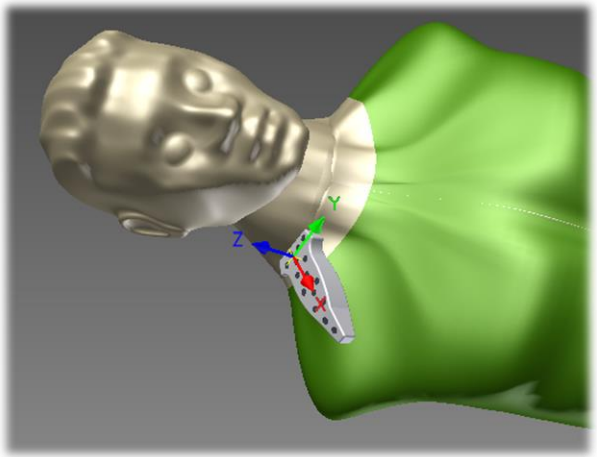
FRAMOS Research & Development

Imaging expert for over 30 years

- Research as basis for our technology and product developments
- Current research activities
  - 3D image processing
    - Logistics
    - Medical

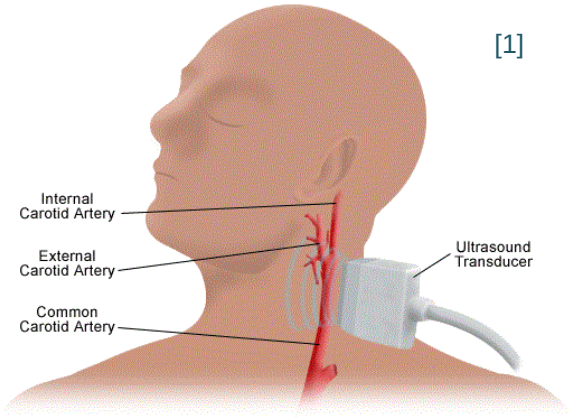
Starting challenge

- Enabling 3D ultrasound
  - Upgrade conventional ultrasound to 3D

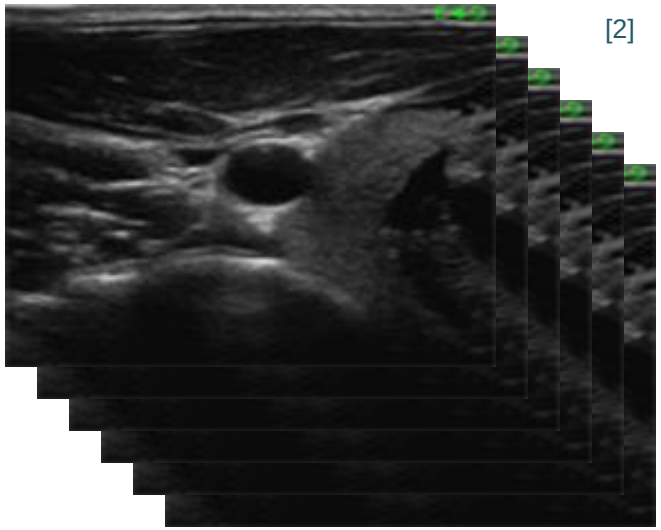


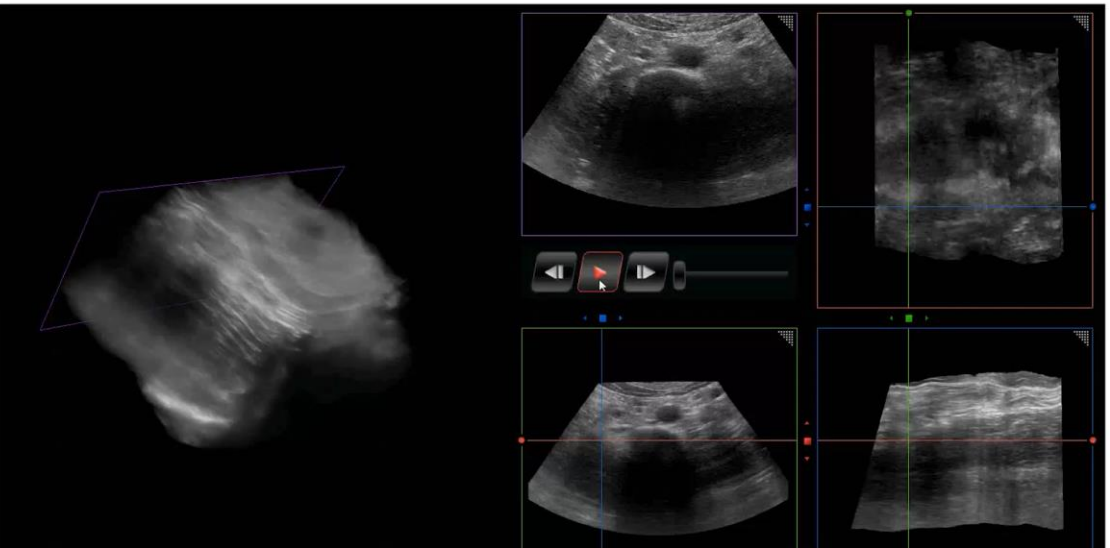
3D poses

[1]



[2]

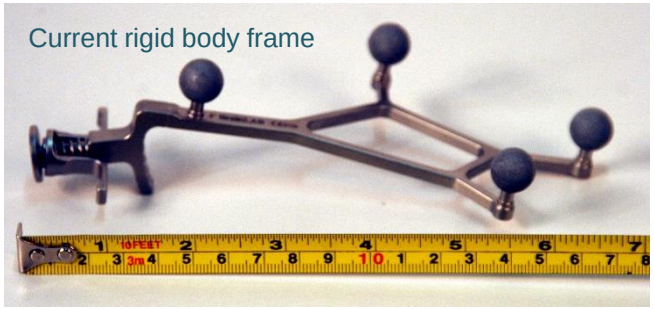




[1] : Carotid Artery Duplex Scan, J. H. Medicine, 2015

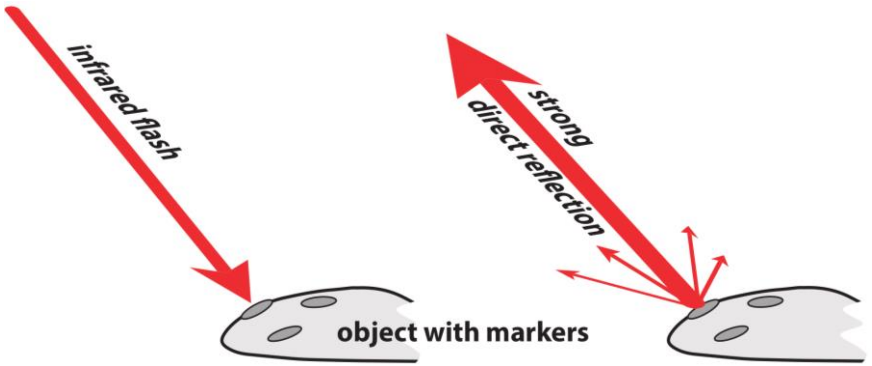
[2] : Curefab CS, CUREFAB, 2015

Imaging solution

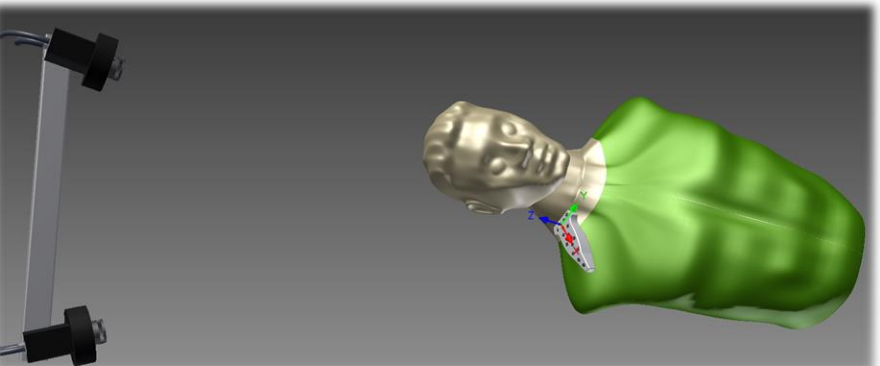


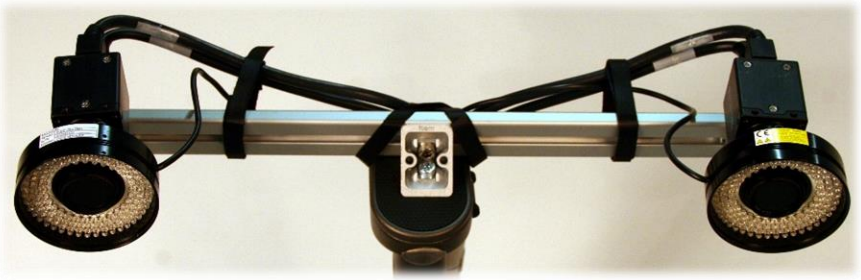
Hardware description

- Cost-efficient, passive circular marker
  - Self-adhesive, retro reflective
- Stereo camera setup
- LED ring light (NIR)
- IR band-pass filter
- ➢ Object representation with 3D point cloud



Our adaptable solution

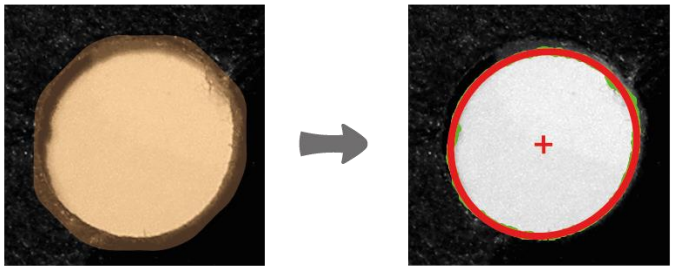


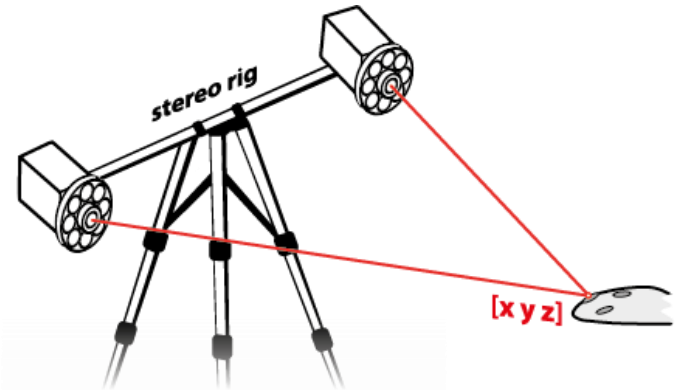


Imaging solution

Algorithm – 2D/3D Object recognition

- Acquire images
- Find object (ROI)
- Calculate marker positions
- Fit contours
- Compute centres
- Triangulate 3D points





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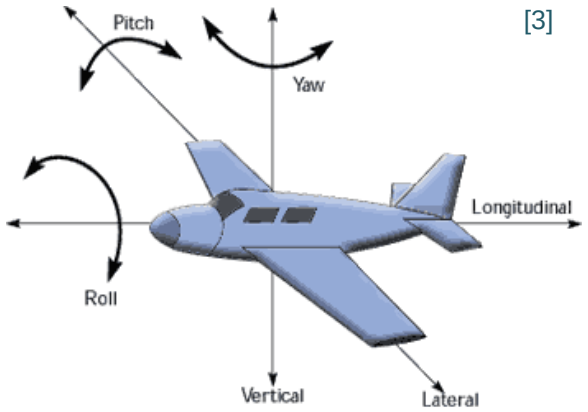


[3]

Algorithm – 3D pose estimation

- Arbitrary motion = 6 DOFs
- Minimize energy functional
  - High-precision in real-time
  - Robust recognition
  - Individual marker set-up
  - Online teaching

$$\mathrm{E}(\mathbf{M},\mathbf{R},\mathbf{t}) = \sum_{j=1}^{J}\sum_{k=1}^{K} \mathrm{m}_{jk} \left\| \mathbf{y}_k - \left(\mathbf{R}\mathbf{x}_j + \mathbf{t}\right)\right\|^2 - \alpha \sum_{j=1}^{J}\sum_{k=1}^{K} \mathrm{m}_{jk}$$

Constraints

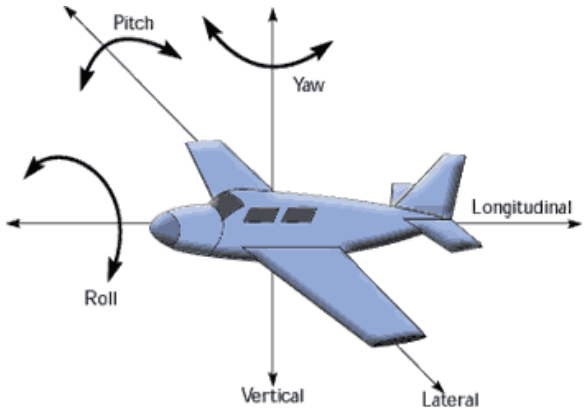
$$\sum_k \mathrm{m}_{jk} \le 1 \quad \forall\ j \in \{1,2,\ldots,J\}$$

$$\sum_j \mathrm{m}_{jk} \le 1 \quad \forall\ k \in \{1,2,\ldots,K\}$$

$$\mathrm{m}_{jk} \in \{0,1\} \quad \forall\ j \in \{1,2,\ldots,J\}, k \in \{1,2,\ldots,K\}$$

[3] : Freebody in space, roboticspedia, 2015-06-08

Imaging solution



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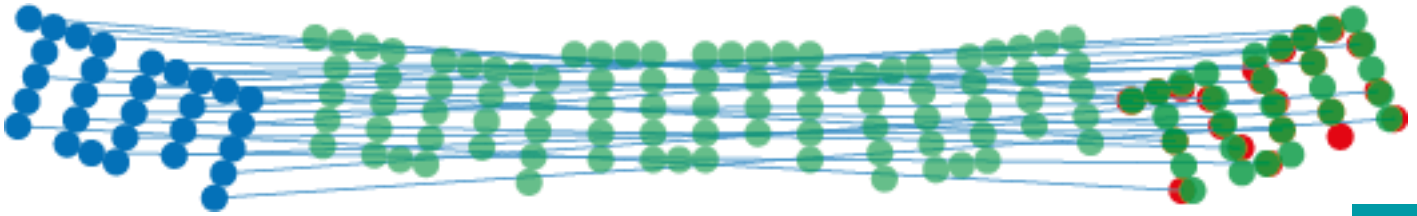

[4] : B. Busam: „Projective Geometry and 3D point cloud matching", MSc-Thesis, TUM, 2014

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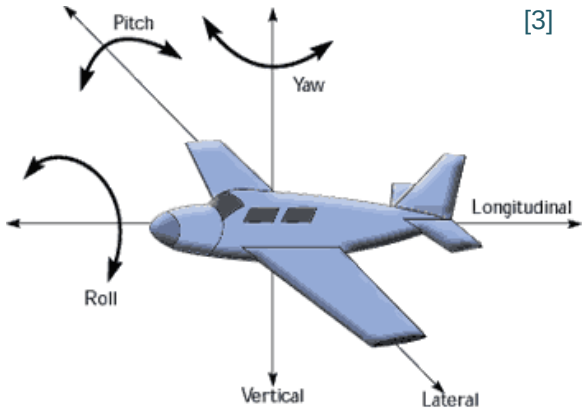

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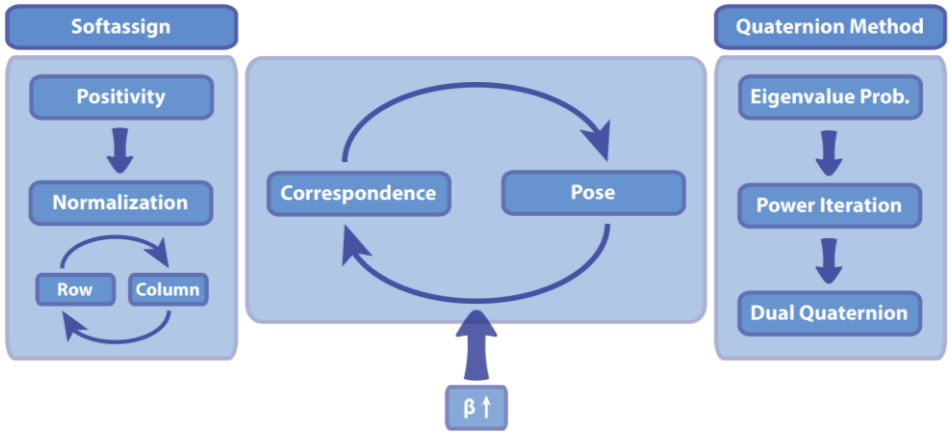

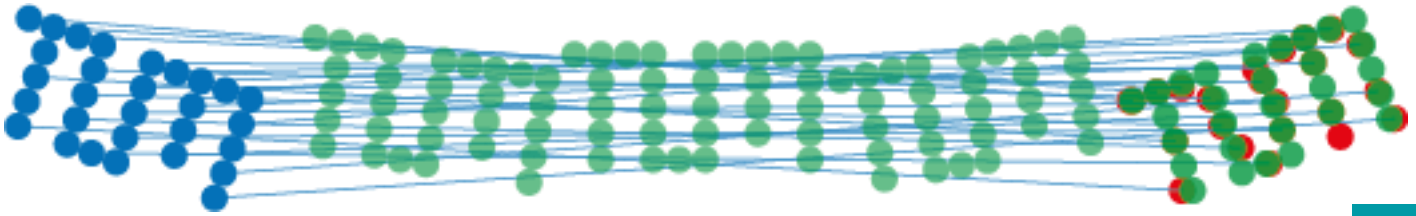

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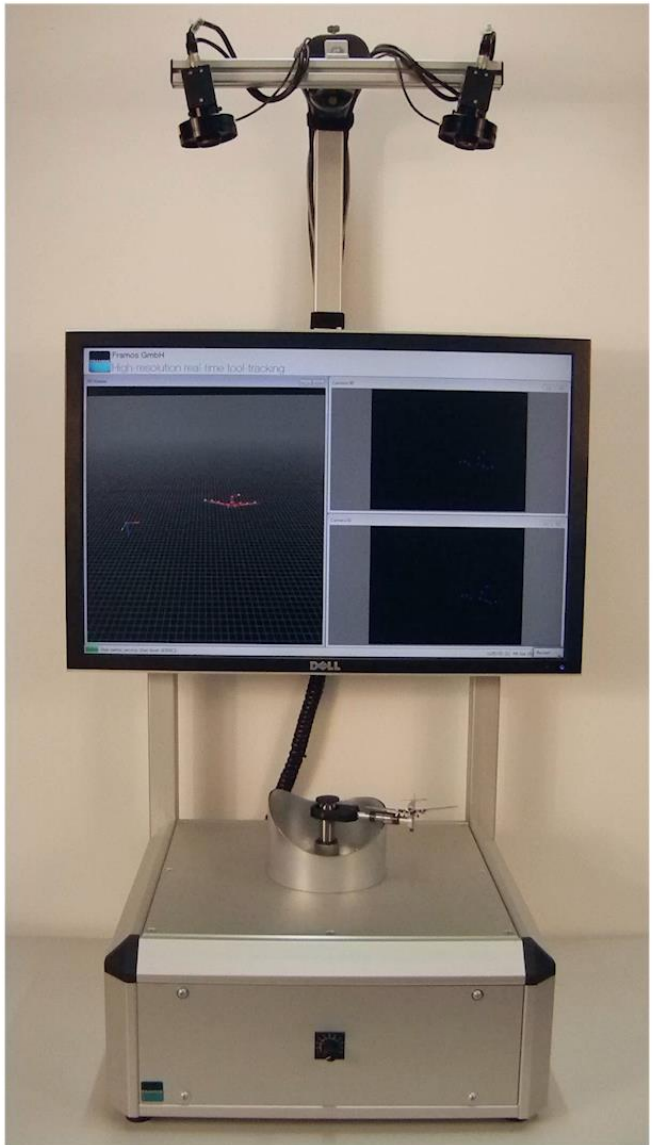
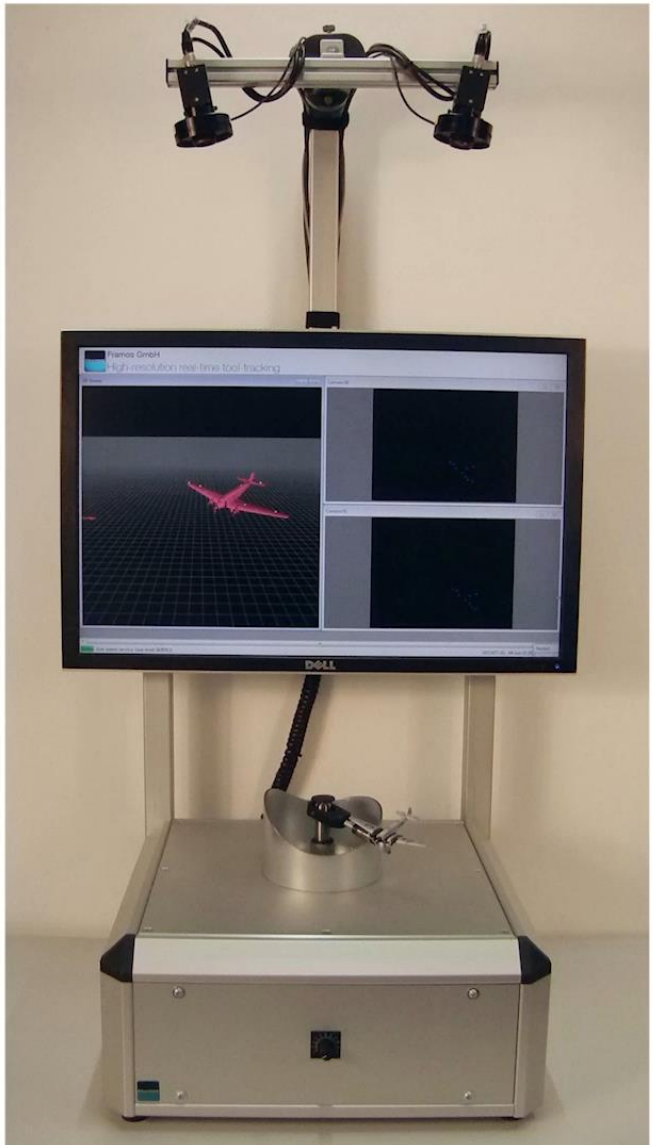
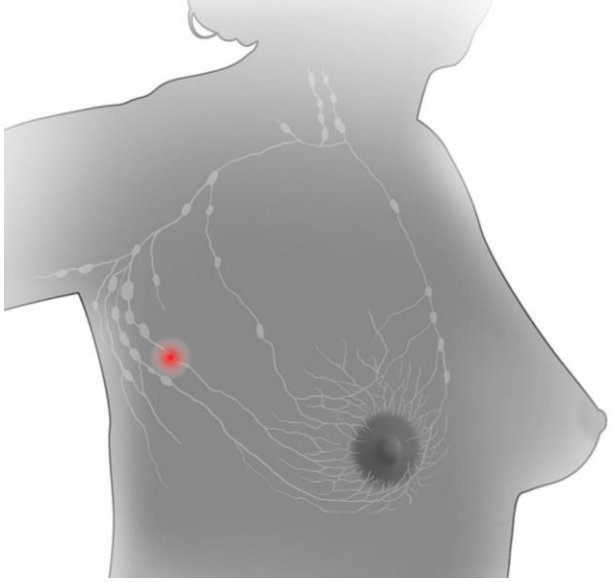




Medical Application



Sentinel Lymph Node Biopsy

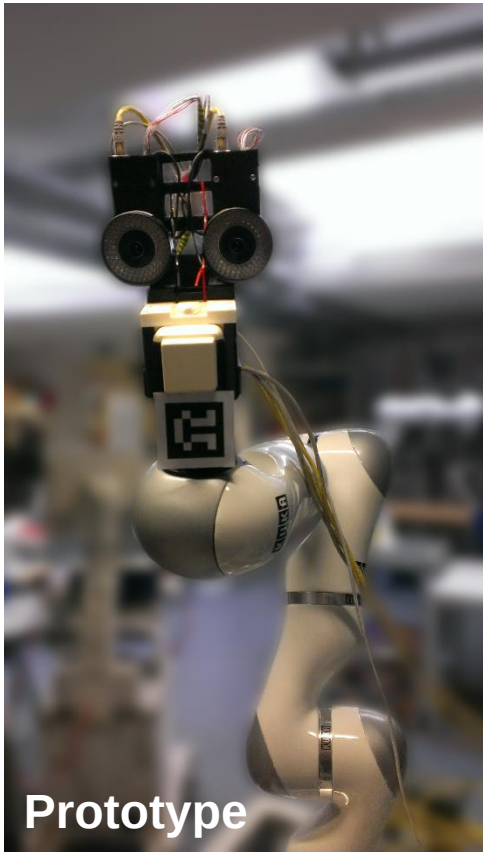
Current Workflow

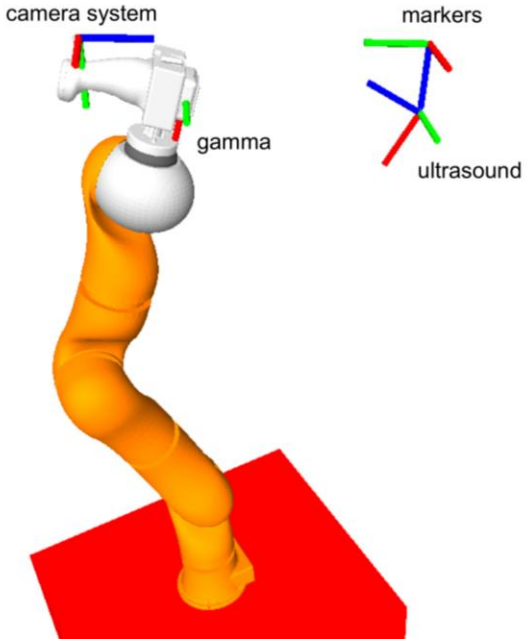
- Concurrent handling of two devices
- Two independent images
- Biopsy only with ultrasound image

[5] : M. Esposito, B. Busam et al.: “Cooperative Robotic Gamma Imaging: Enhancing US-guided Needle Biopsy”, MICCAI, 2015

Medical Application

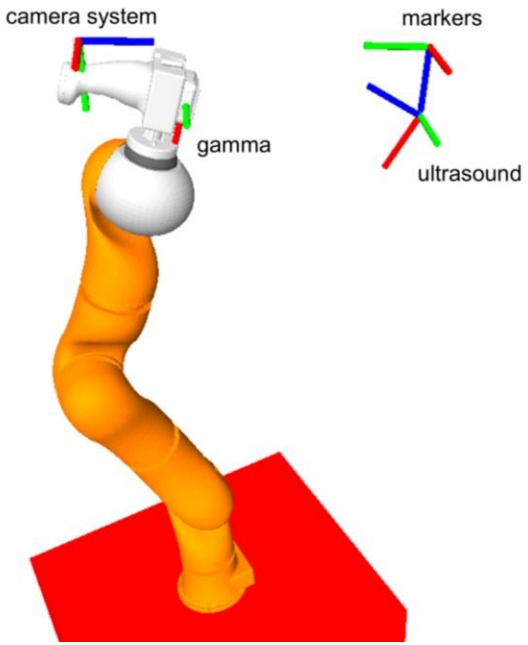
Robot-guided multimodal imaging



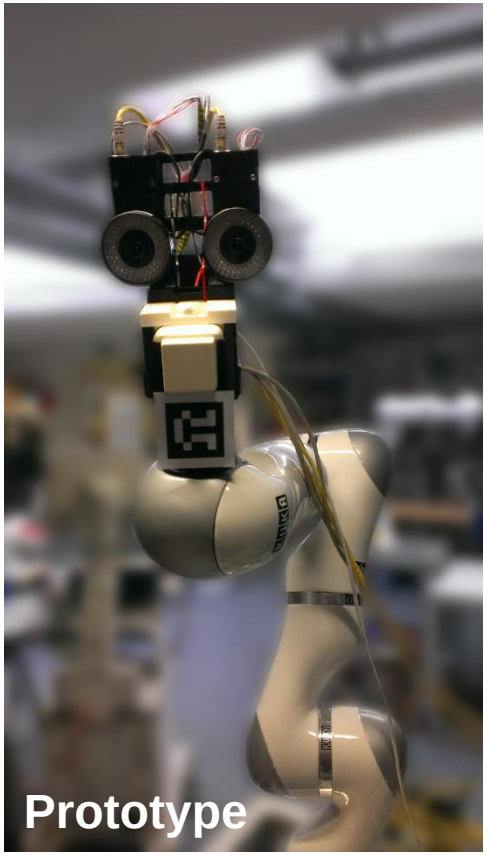


[5] : M. Esposito, B. Busam et al.: “Cooperative Robotic Gamma Imaging: Enhancing US-guided Needle Biopsy”, MICCAI, 2015

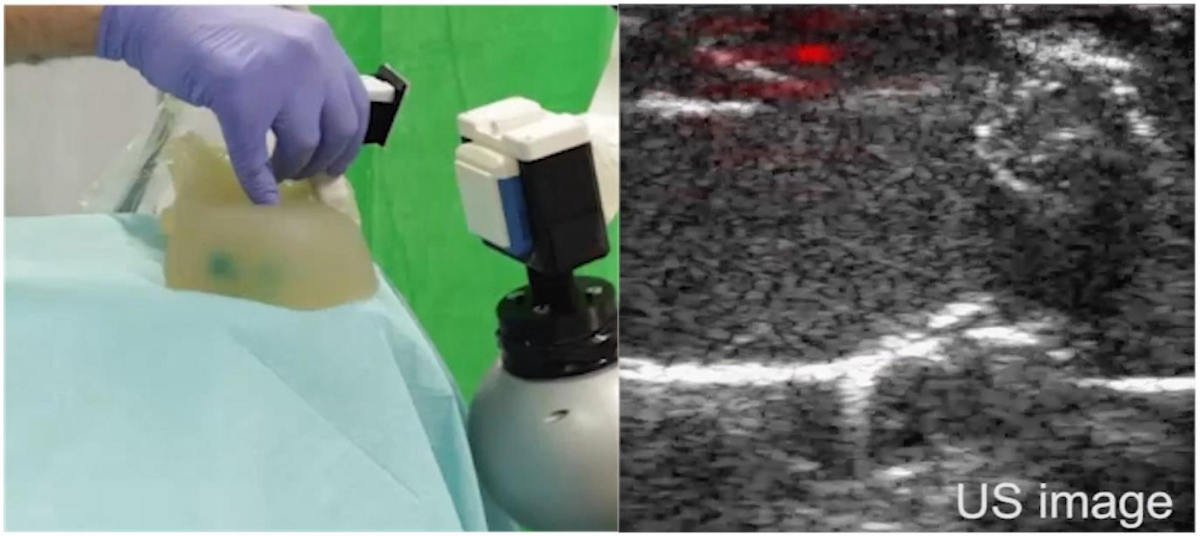
Medical Application



Proposed Workflow



Medical diagnosis



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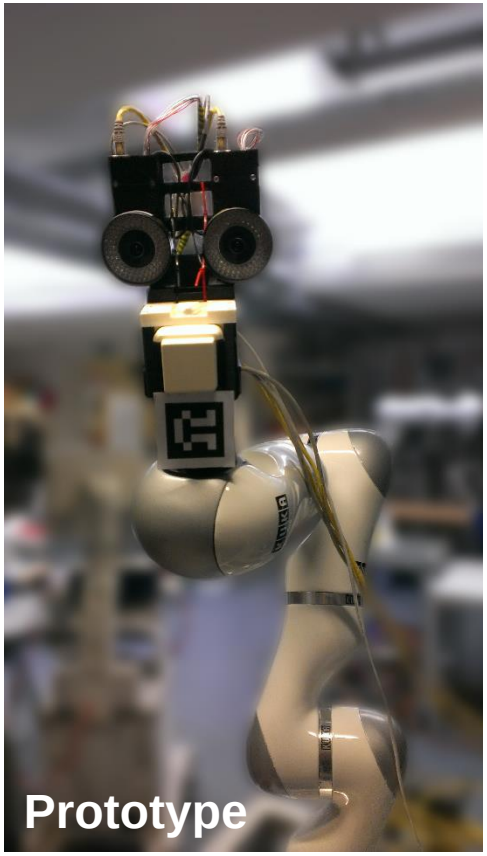
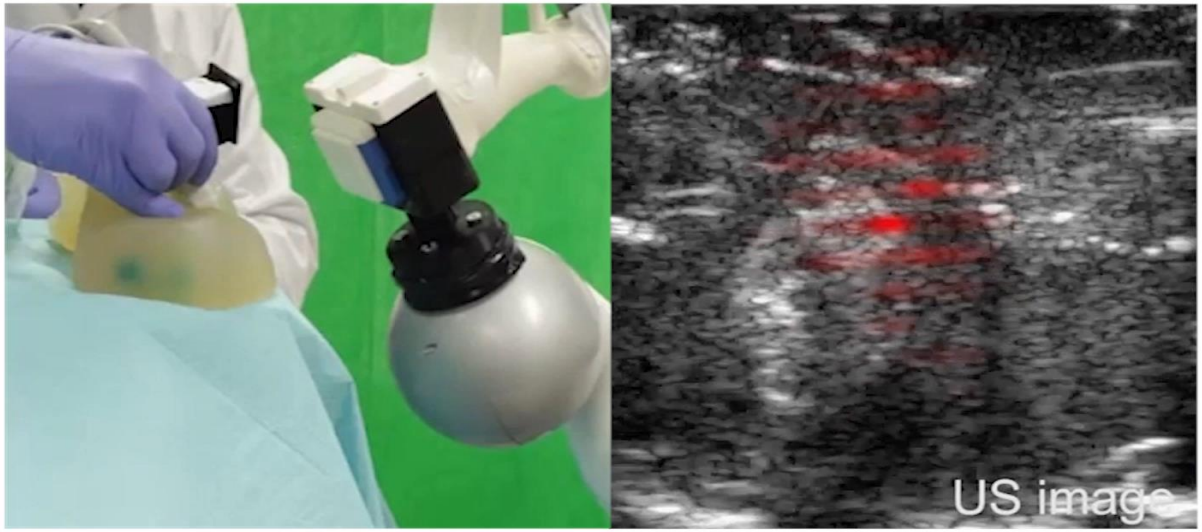
Medical Application

Sentinel Lymph Node Biopsy



- Inside-out tracking retrieves pose of US transducer
  - Robot positions gamma parallel to US image
  - GCam follows physician during intervention
  - Multi-modal visualisation possible



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Medical Application

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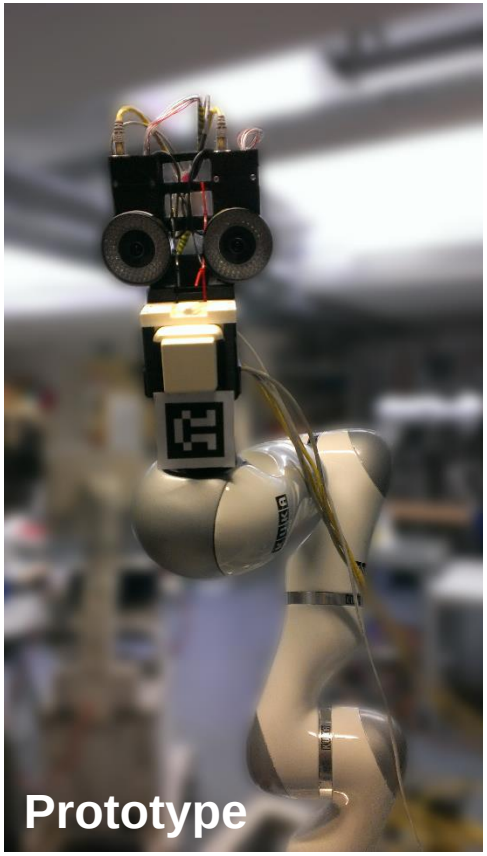
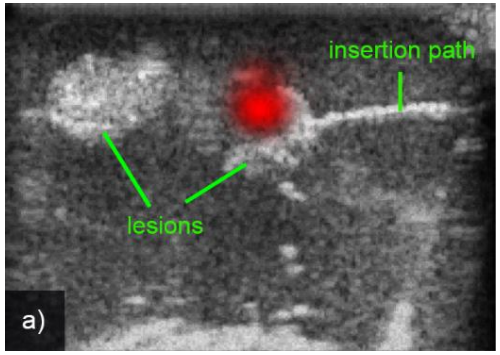
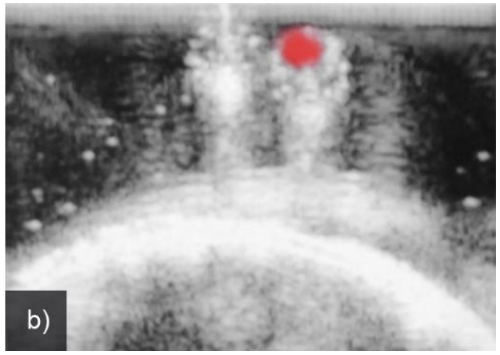


Advantages

- Spatially correct image fusion
- Free hand for biopsy
- Functional information throughout intervention
- Natural extension of existing workflow
- Reduce number of open lymph node resections





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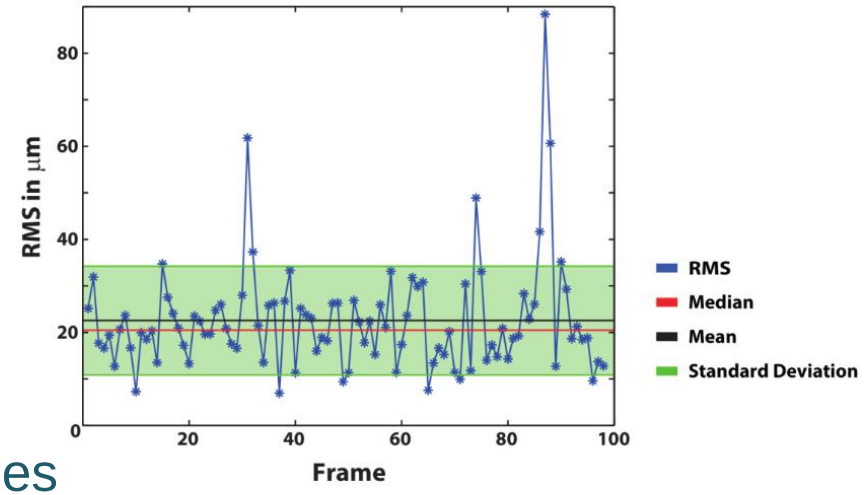
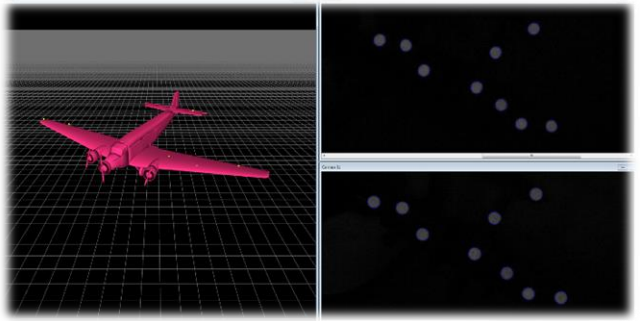
Conclusion



Technological advantages

- Works for many object geometries
- Not dependent on surface structure
- Enables high precision
- Handles self- and line-of-sight occlusion
- Scalable measurement volume
- Real-time applicability
- Outside-in and inside-out tracking



[6] : GE Probes, Usedultrasound, 2015-06-08

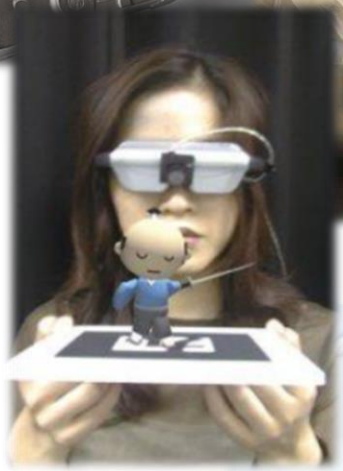
[6]

Commercialization areas

- Robot-guidance
- Tool-navigation
- 3D measurements
- Augmented Reality / Virtual Reality
- Head Mounted Displays
- Motion Capture

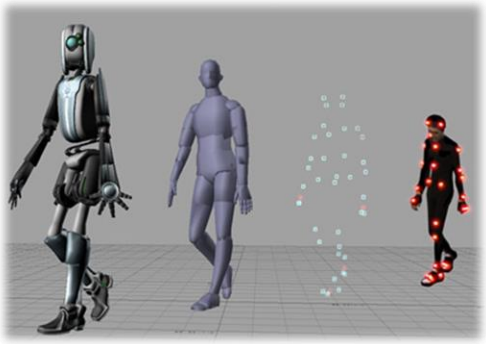
[7]

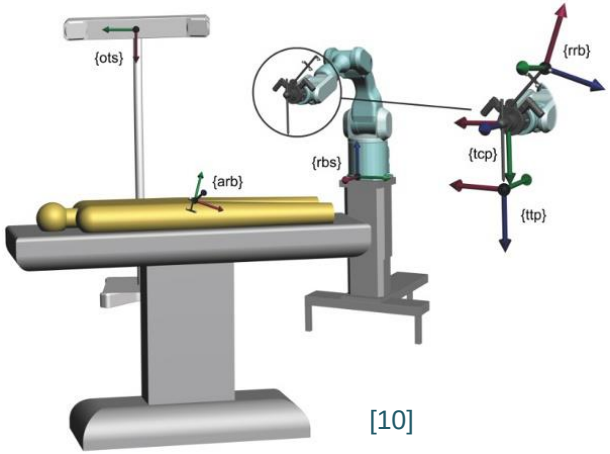
[8]



[9]

[11]





[10]

[7] : R-Design Studio, GOM, 2015-06-08

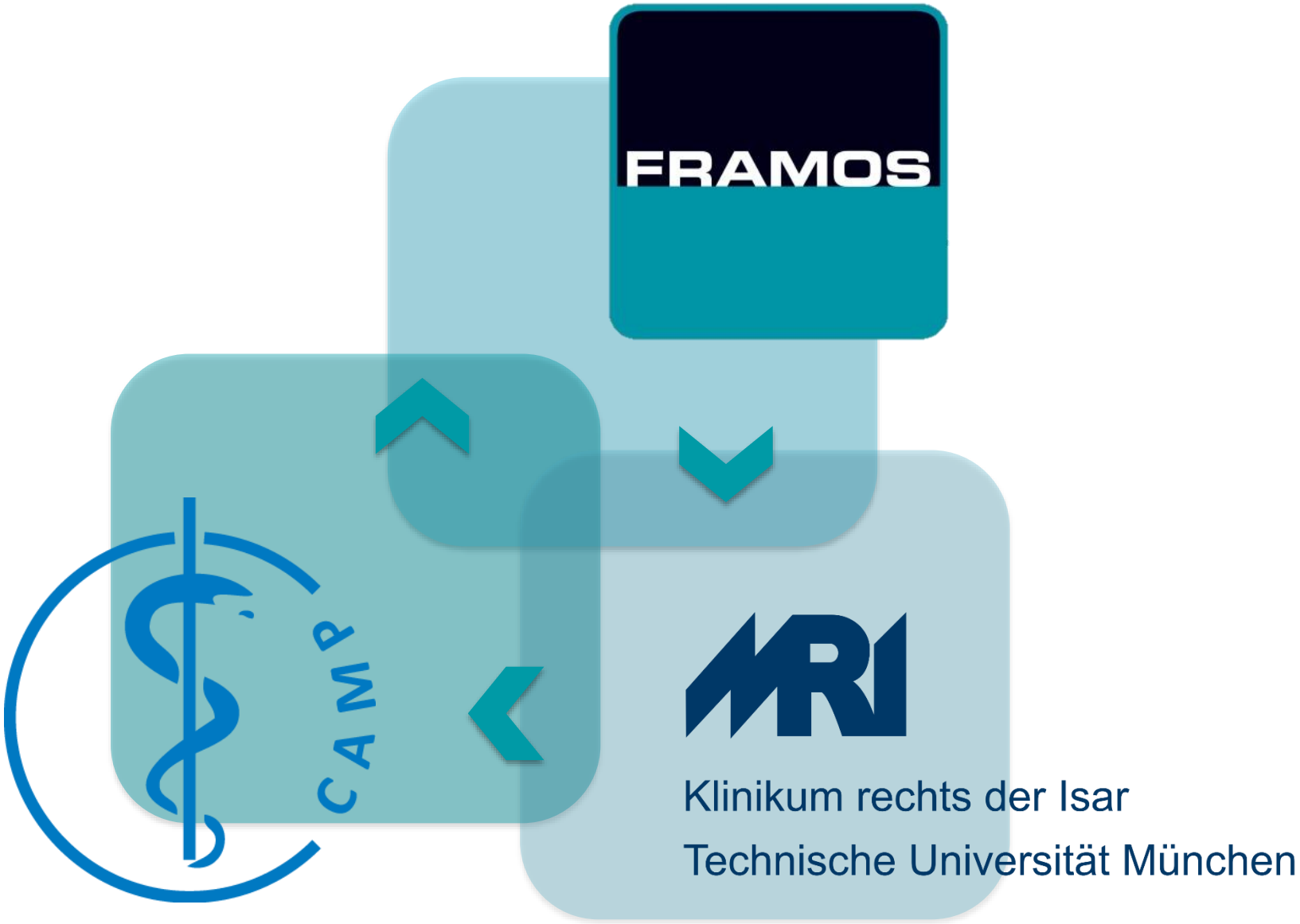
[8] : Surgical Robot System, University of Bern, 2015-06-08

[9] : P. Fallavollita: “Medical Augmented Reality”, CAMP, 2014

[10] : H.-C. Schneider, J. Wahrburg: “Simulation Model for the Dynamics Analysis of a Surgical Assistance Robot”, Robot Surgery, 2010

[11] : Augmented Reality in Medicine, CAMP, 2010

Cooperation Partners



THANK YOU!

Vielen Dank! ευχαριστώ πολύ!

We enable You!