RONAF: Robot-based Navigation for Milling at the Lateral Skull Base

Robotergestützte Navigation zum Fräsen an der lateralen Schädelbasis

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- Motivation: The RONAF Project Overview
- Application Area, Scope
- The four RONAF cycles
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Motivation: The RONAF Project Overview

RONAF

- **Cooperation project of:**
  - **Lehrstuhl für Angewandte Informatik III (Robotik und Eingebettete Systeme)**, **University of Bayreuth**
    - Prof. Dr. Dominik Henrich
    - Philipp J. Stolka
    - Michel Waringo

    

  - (former Arbeitsgruppe Eingebettete Systeme und Robotik (AG RESY), University of Kaiserslautern)
  - **Hals-Nasen-Ohrenklinik, Universitätsklinikum Heidelberg**
    - Prof. Dr. med. P. Plinkert
    - Dr. med. Ph. Federspil
    - Dr. med. B. Plinkert

- Funded by the Deutsche Forschungsgemeinschaft (DFG) since 2001 as part of the Schwerpunktprogramm „Navigation und Robotik“ (SPP 1124)

Application Area, Scope

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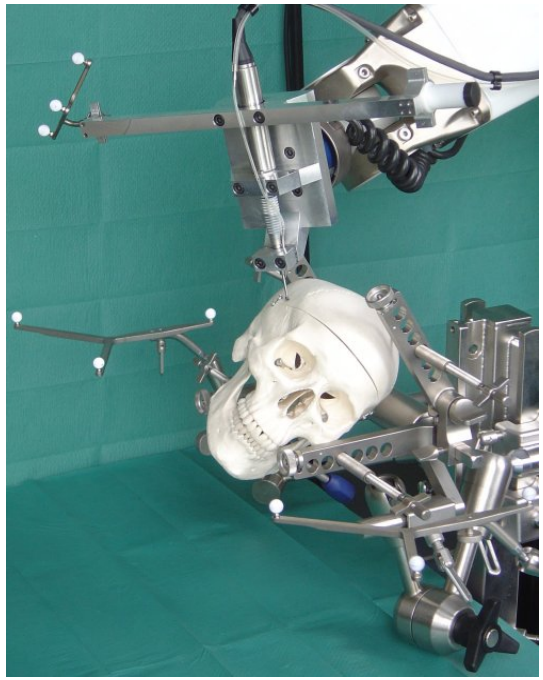
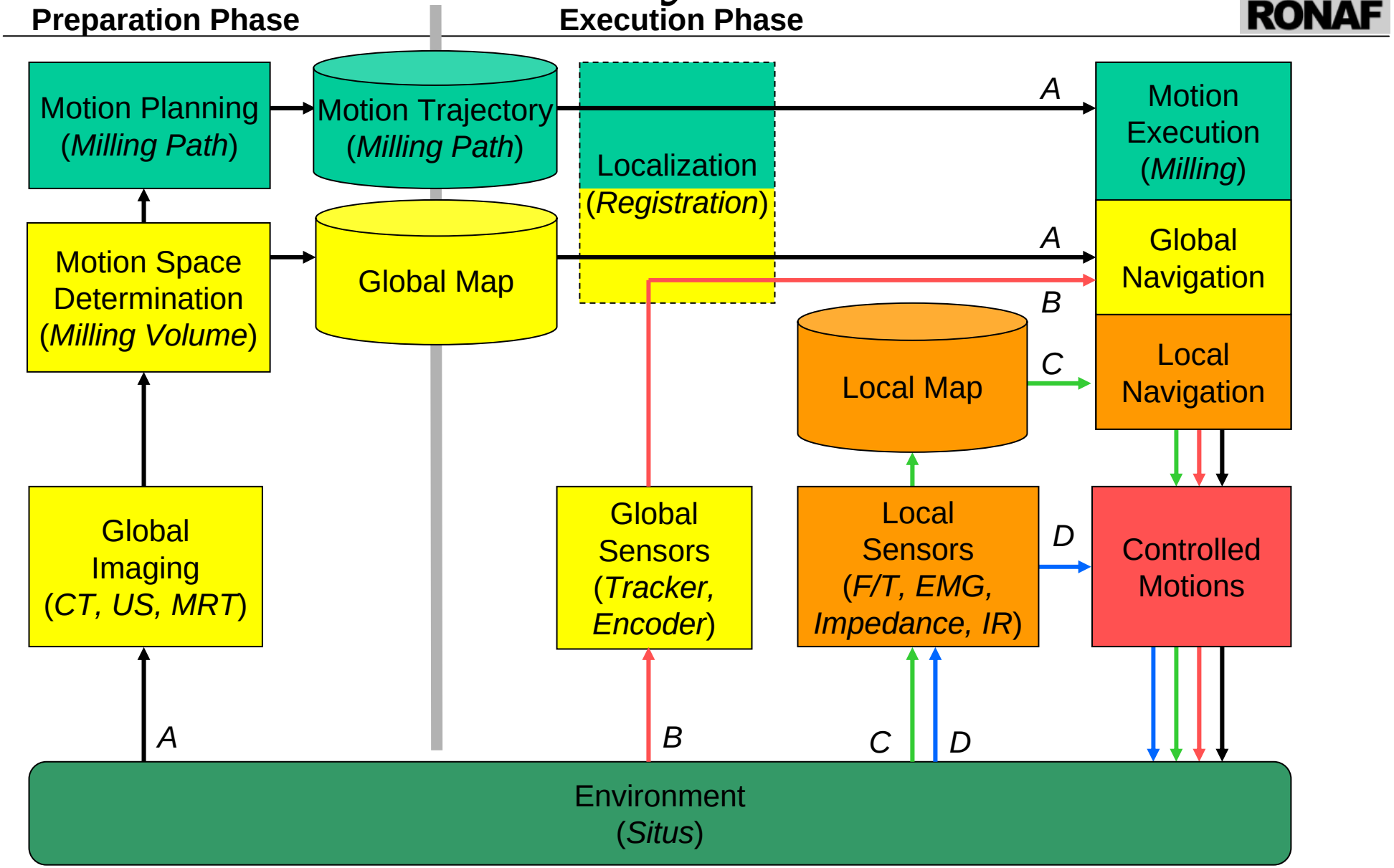
- **What's the scientific goal?**
  - Explore multisensory (tactile, CT, US, EMG) *navigation and path planning*
  - Use robotics to combine planning precision with execution *precision*
  - Implement *security* measures for the patient and the surgeon
  - Perform milling autonomously and intraoperatively update milling path

  Link for the movie: http://ai3.inf.uni-bayreuth.de/projects/ronaf/videos/dmw.fraesvideo_seife_konzentrische_bahnen_kurz_klein.avi

- **Milling at the Lateral Skull Base: What are the applications?**
  - 1. Milling a hearing aid implant bed in the calotte bone
  - 2. Performing a mastoidectomy
  - 3. Providing complex access paths to inner skull base



The four RONAF cycles



Different Subtasks

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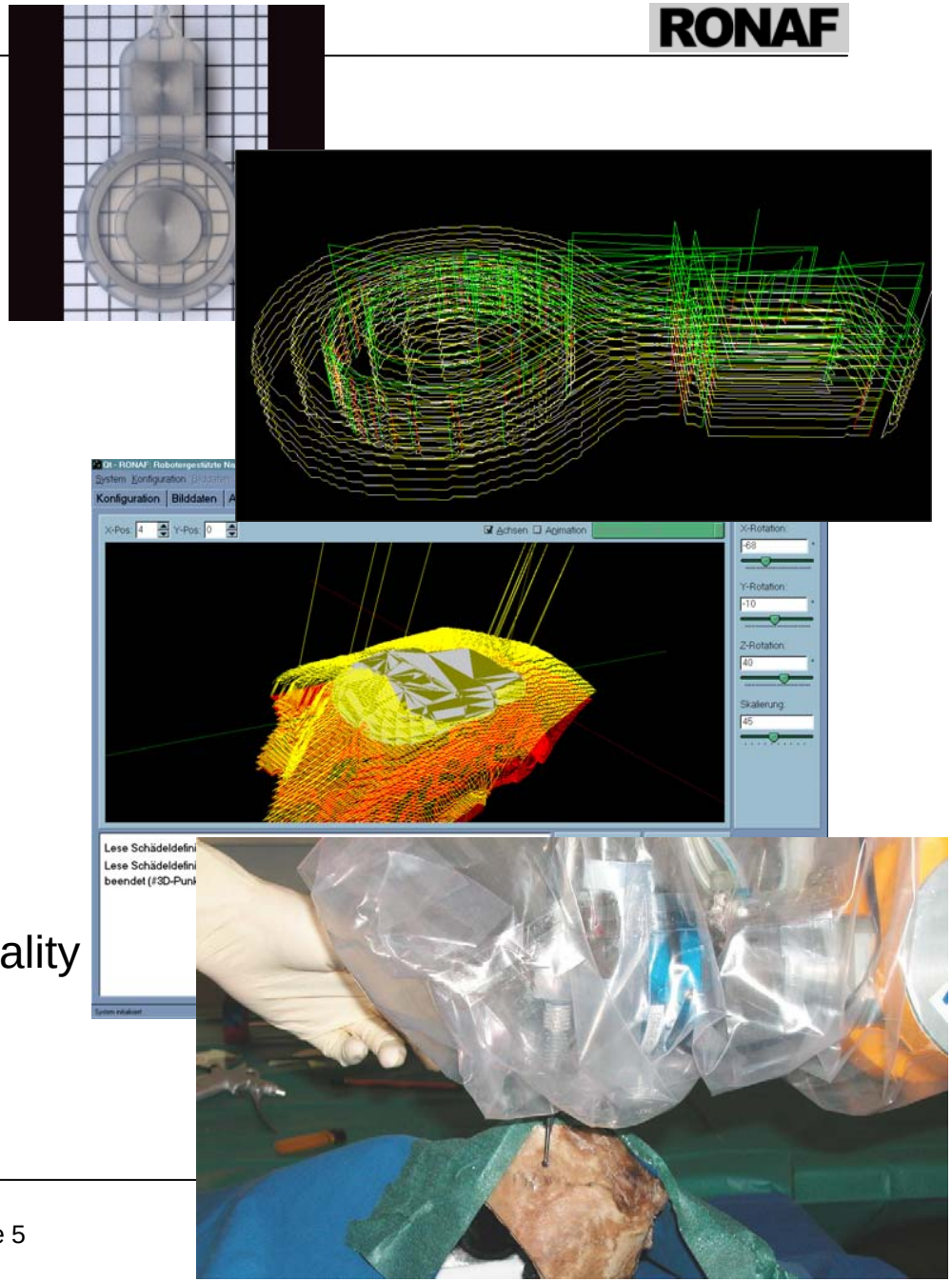
- **Intervention Type: Implant bed milling**
  - *Planning* of milling path, based on preoperative image data:
    - Image registration
    - Implant position optimization
    - Optimal path planning
  - Intraoperative *registration* of the patient:
    - tactical, ultrasound, optical
    - point-based, surface-based
    - Integration of Polaris tracking system
  - *Execution* of milling path:
    - Force-controlled for optimal process quality
    - Intraoperative path correction, re-optimization



Safety Considerations

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- **Safety in surgical robotics is paramount, surpassing performance and even completion in importance!**

- **„Safety“ for the surgeon:**
  - Robot is alien object in the operating room, so it must be
    - cooperative
    - predictable

- **„Safety“ for the patient:**
  - Unable to react (immobilized, anaesthetized)
  - Expects at least human-like intervention quality

My work

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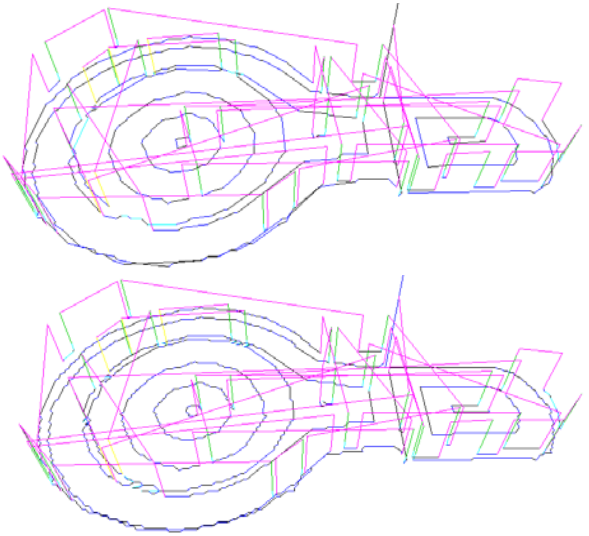
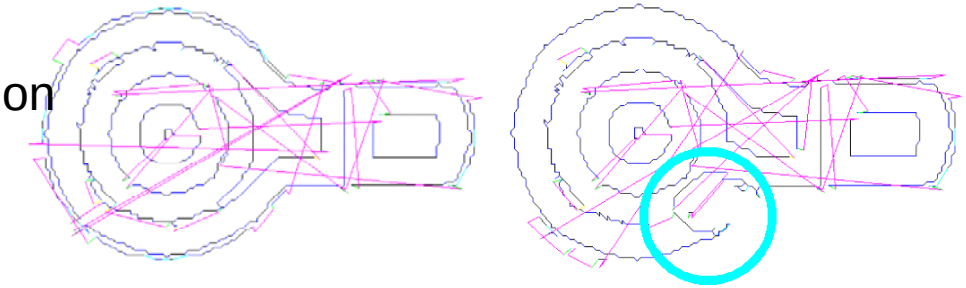
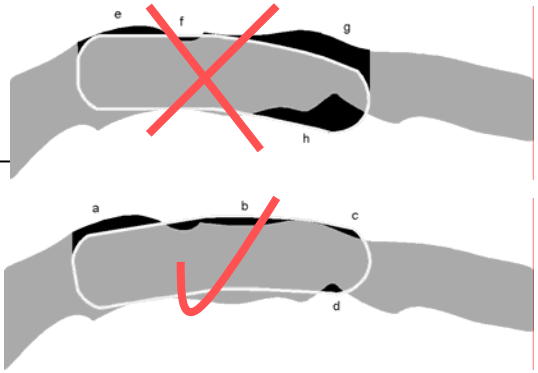
- **Plan a 5-dimensional path in work space for milling applications**
  - Fast and safe
  - Consider tool geometry to find optimal tool orientation
  - Reduction of path points (submitted, ICRA2006)
  - Different structures are taken into account



- **Find a suitable robot position**
  - No singularities, no configuration changes, no collisions
- **Compute a collision-free path in C-space**
  - Use the robot's additional degrees of freedom
  - Preserve a small tolerance in order to allow replanning without repositioning
- **Replan the path intraoperatively**
  - Sensors indicate a changed engagement region
  - Planning must be fast

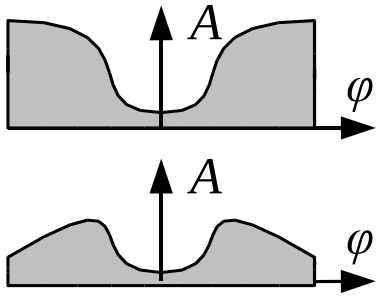


Additional considerations



- **Location optimization**
  - 6 degrees of freedom, is performed cooperatively
- **Geometry limitation up to now**
  - 2.5-dimensional
  - Must be non undercutting

- **Miller considerations**
  - Speed of removal depends on orientation
  - Precision and speed are two contradictory goals
  - Tearing of dura if spherical miller is not oriented vertically
  - Bending of miller's shaft must be considered



Discussion

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Thank you for your attention!

Are there any questions?