Computational Surgineering

Introduction and Projects Announcement

Tutors

Technical University of Munich
CAMP - IN2106

Thomas Wendler
in.tum.de/campar/members/thomas-wendler/
wendler@tum.de

Ardit Ramadani
in.tum.de/campar/members/ardit-ramadani/
ardit.ramadani@tum.de

Kristina Mach
kristina.mach@tum.de

Michael Sommersperger
michael.sommersperger@tum.de

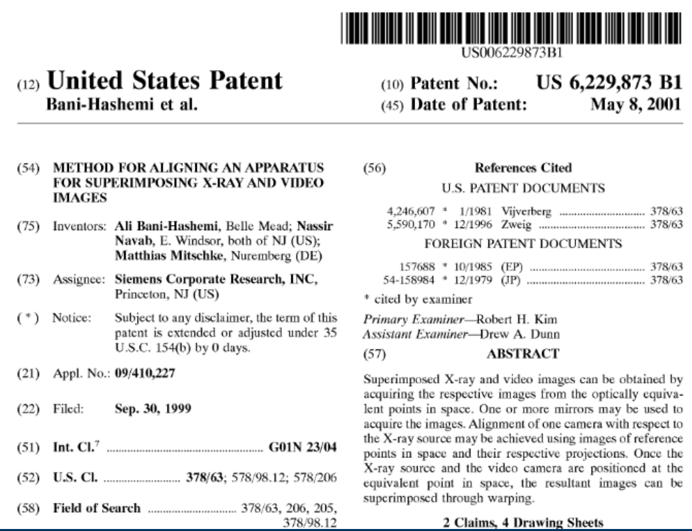
Dani Velikova
dani.velikova@tum.de

Yuan Bi
https://www.cs.cit.tum.de/camp/members/yuan-bi/
yuan.bi@tum.de

Heiko Maier
heiko.maier@tum.de

Motivation

"My main failure in life is having not brought more of my inventions to patients"



US006229873B1

(12) **United States Patent**
Bani-Hashemi et al.

(10) **Patent No.: US 6,229,873 B1**
(45) **Date of Patent: May 8, 2001**

(54) **METHOD FOR ALIGNING AN APPARATUS FOR SUPERIMPOSING X-RAY AND VIDEO IMAGES**

(75) Inventors: **Ali Bani-Hashemi**, Belle Mead; **Nassir Navab**, E. Windsor, both of NJ (US); **Matthias Mitschke**, Nuremberg (DE)

(73) Assignee: **Siemens Corporate Research, INC**, Princeton, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/410,227**

(22) Filed: **Sep. 30, 1999**

(51) **Int. Cl.**[7] **G01N 23/04**

(52) **U.S. Cl.** **378/63**; 578/98.12; 578/206

(58) **Field of Search** 378/63, 206, 205, 378/98.12

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,246,607 * 1/1981 Vijverberg 378/63
5,590,170 * 12/1996 Zweig 378/63

FOREIGN PATENT DOCUMENTS

157688 * 10/1985 (EP) 378/63
54-158984 * 12/1979 (JP) 378/63

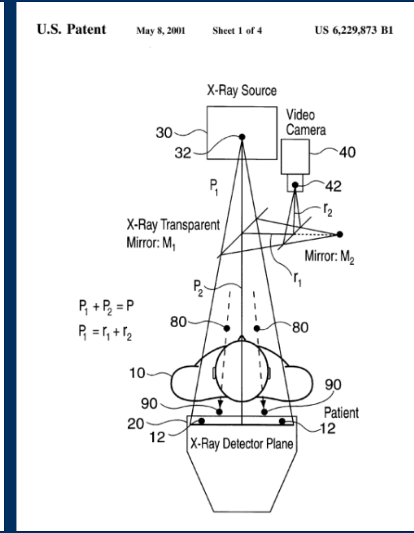
* cited by examiner

Primary Examiner—Robert H. Kim
Assistant Examiner—Drew A. Dunn

(57) **ABSTRACT**

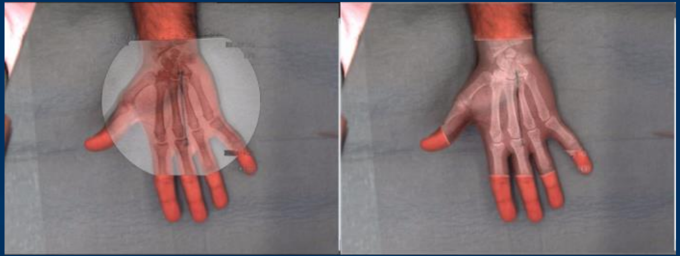
Superimposed X-ray and video images can be obtained by acquiring the respective images from the optically equivalent points in space. One or more mirrors may be used to acquire the images. Alignment of one camera with respect to the X-ray source may be achieved using images of reference points in space and their respective projections. Once the X-ray source and the video camera are positioned at the equivalent point in space, the resultant images can be superimposed through warping.

2 Claims, 4 Drawing Sheets



https://www.youtube.com/watch?v=Bv6nW48a8Zo - 2000 version

2014 version



Presentation Outline

- C(o)urse Structure
- Team Formation
- Grading
- Support and Infrastructure provided by the Chair
- Projects overview

Technical University of Munich

CAMP - IN2106

C(o)urse

General aspects

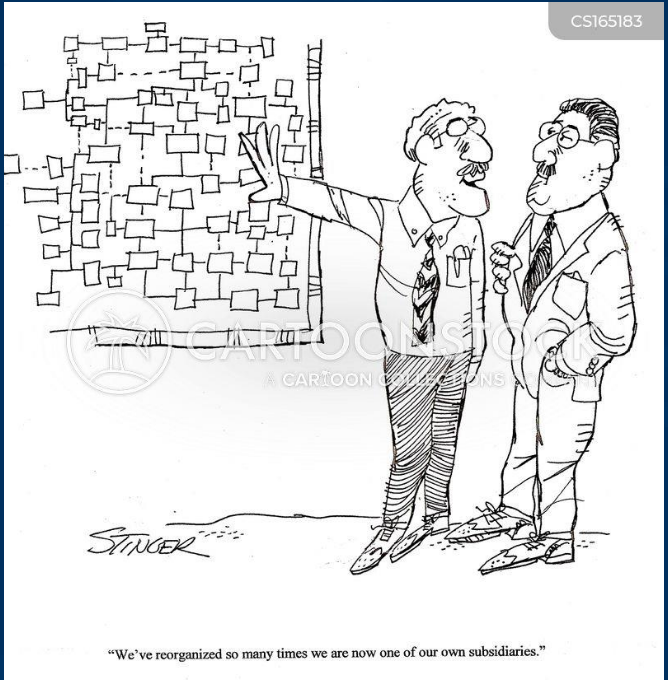
- Practical Course (every semester)
  - Biomedical Computing (Master) → elective in module Software Engineering and Programming
  - Informatics (Master)
  - Robotics, Cognition, Intelligence (Master)
  - Computational Science and Engineering (Master)
  - Biomedical Engineering and Medical Physics (Master)
- 6 SWS / 10 ECTS
- 18 students (working in groups of 3)
- Prerequisites
  - Required: Python and/or C++ experience
  - Ideally: CAMP 1, CAMP 2, IGS or equivalent

Learning outcomes

- **Use** a subset of **common software development tools** for medical image processing and computer-assisted interventions
- **Consider regulatory constraints** needed to be taken into account when developing medical software
- **Understand the daily clinical routine** within one specialty/clinical department
- **Refine a clinical solution** for an unmet clinical need to be able to **generate a prototype**
- **Analyze one clinical application** in order to generate a requirement specification for the chosen clinical challenge
- **Develop a clinical prototype** (mainly software, if applicable also involving hardware) and demonstrate it on phantoms, ex-vivo, or using retrospective data
- **Present the work** in front of an audience of medical technologists and clinicians

Structure of the Course

- Lectures (in-person or via zoom)
  - Mandatory attendance to all IGS and PMSD lectures
  - No registration required
- Hospitation at the clinical partner's department for at least one week
  - starting from week 3
- Presentation Requirements specification (via zoom)
  - Wednesday, 09.11. - presented to the doctors
- Reviews and discussion meetings
  - Starting in week 5, weekly or bi-weekly
- Prototype demonstration (in-person or via zoom)
  - Presented to the doctors
  - End of the semester (during exam period)



Lectures

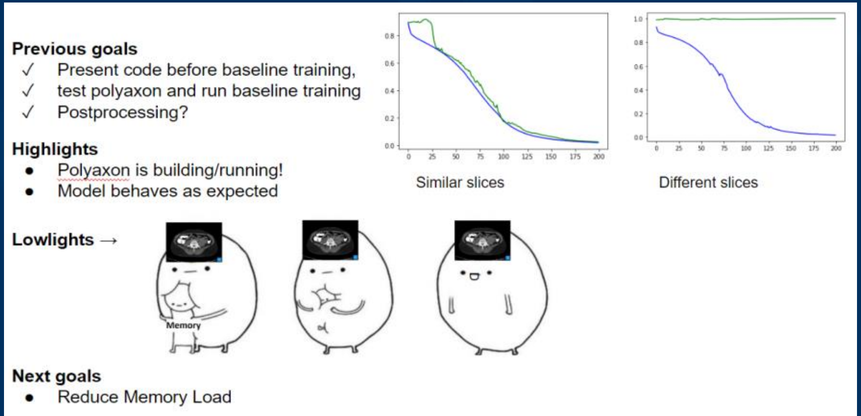
- Introduction (today)
- OR training
  - for students who missed that training in IGS
  - Wednesday, 26.10. from 14:00 - 16:00, MI 03.13.010 or via zoom
- Tools and methods for software development for medical image processing and computer-assisted interventions
  - for students who missed that training in PMSD
  - Tuesday, 08.11. from 10:00 - 12:00, via zoom
- Scheduled classes from IGS in different topics
  - from November onwards

Hospitation (planned)

- You will play the “shadow” of medical doctors and technologists in the hospital division related to your project
- You wear a white coat and learn the daily work of clinicians
- You will analyse their routine and get a better view of reality in a hospital
- You will attend ORs, participate in patient visits/examinations, get to know the personnel

Weekly meetings

- You will participate in weekly (or bi-weekly) meetings with 1 - 3 of the tutors and possibly other students working in related projects
- You will report on the status of the project
- You will get supervision, help with bug fixing, an advisor for administrative stuff, connections to experts
- Documentation using an ever-growing Google Slide
  - Previous goals
  - Lowlights of the week
  - Highlights of the week
  - New goals



Project / Group / Grading

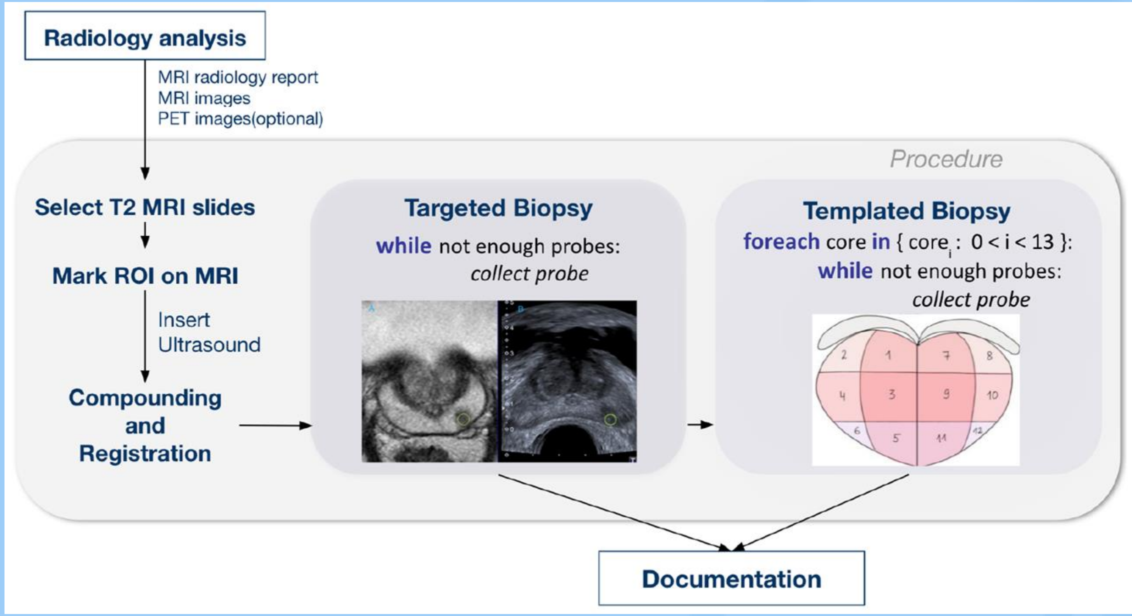
- Submit your project/group preferences in Moodle latest until **Thursday, 20.10.2022 midnight**
- The tutors will try to optimize wishes with know-how needed for the said projects
- First milestone
  - Understand clinical application and proposed solution by former IGS students
  - Update solution and generate a user requirement specification
- Final milestone
  - Present your implementation to clinical partners and Chair members
  - Software/Hardware demo highly recommended
- Grading
  - Individual grade for each team member
  - Grade based on code, demo (if possible), weekly reports (incl. attendance) and two presentations

Available (shared) infrastructure

- Access to:
  - one of our GPU clusters
  - anonymized data from Klinikum rechts der Isar and internal Chair databases
  - robots (da Vinci telemanipulator, Franka, and KUKA arms)
  - instrument tracking technologies (optical and electromagnetic)
  - an x-ray C-Arm (only under supervision) - almost ready to use
  - several ultrasound machines
  - 3D printer
- Licenses of a medical image analysis software, e.g., ImFusion Suite

Projects

1. Prostate Biopsy needle detection for optimized documentation

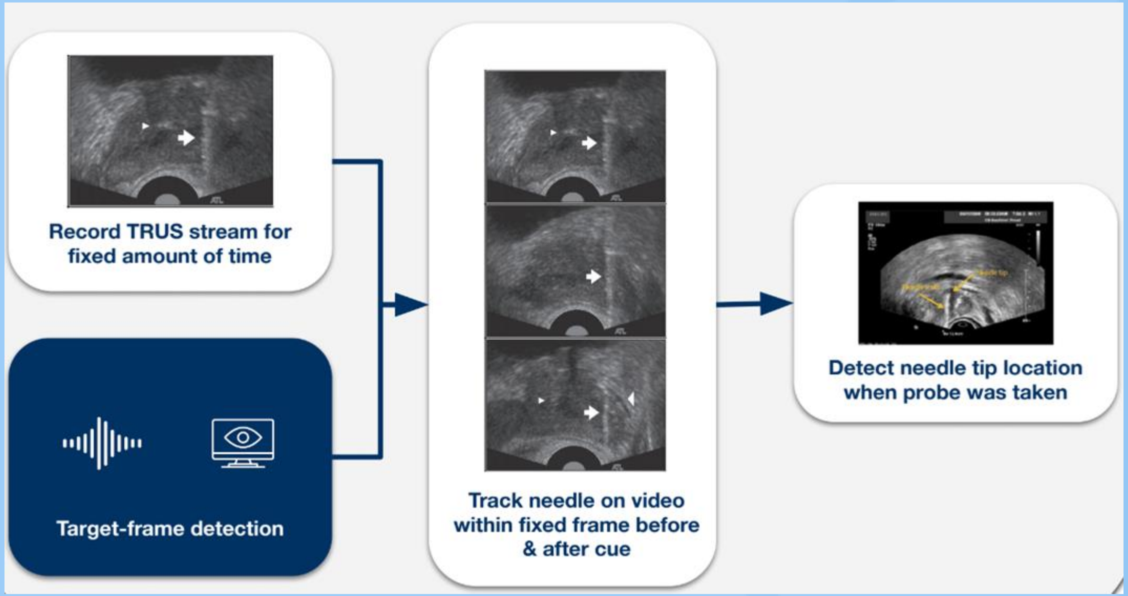


Treatment: Prostate biopsy of men suspected to have cancer.

Problem Statement: Imprecise assignment of biopsies to region of prostate.

Picture from IGS final presentation S. Misatian, V. Sutedjo and V. Markova

1. Prostate Biopsy needle detection for optimized documentation



Solution:

- Track and segment the needle in the US images.
- Automatic detection of the biopsy region.

Picture from IGS final presentation S. Misatian, V. Sutedjo and V. Markova

Potential Tasks:

- Prostate segmentation from US images.
- US-MRI registration
- Needle segmentation from US images

2. Improved vessel segmentation - liver

Liver cancer is the 2nd most cancer-related death in the world for men and the 6th leading cause of cancer-related death for women.

Application: Transcatheter arterial chemoembolization (TACE) procedure

Problem: Manually assessed guidance on CT-scans

Targeted delivery of chemotherapy and cutting off the tumor's blood supply to trap chemotherapy within the tumour and reduce spreading

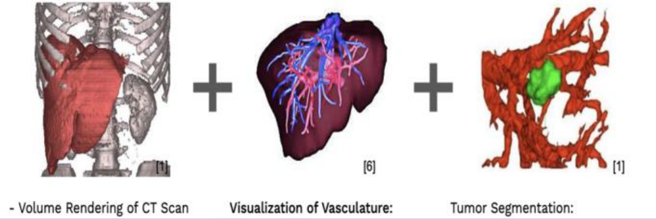
Procedure:

- Injects a catheter from the groin/thig guiding it into the hepatic artery.
- Navigate through preoperative CT-scans and fluoroscopy.
- A contrast agent is used to create an angiogram to detect branches of the artery feeding the tumor.
- The doctor needs to choose a well fitting micro catheter depending on the position of tumour and artery is then used to navigate to the optimal position close to the tumor.
- Adds the chemotherapy and block vessel with embolization.

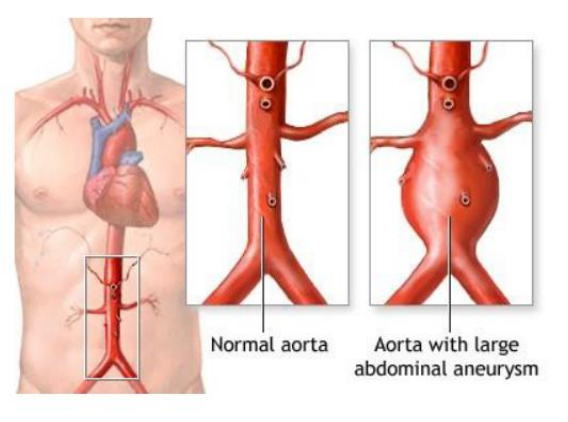
2. Improved vessel segmentation - liver

Solution: Segmenting the vessels on CT-Scans and visualize the structure

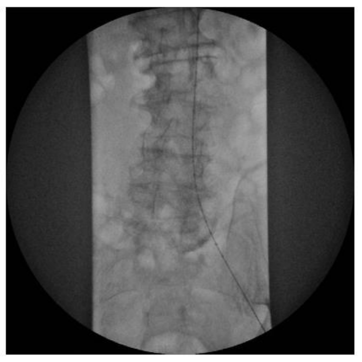
- Understanding of vessel structure and tumor location
  - find optimal position for chemoembolization
    - Save as much healthy liver tissue as possible
    - Block (all) blood supply to tumor
  - Find optimal tool to be used
- Visualize of the relevant vessel tree at all times



3. Planning of stent placement for abdominal aortic aneurysm (AAA)

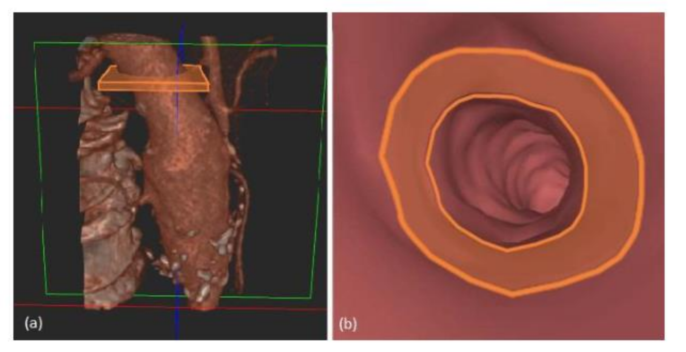


- Disease: Abdominal Aortic Aneurysm (AAA)
  - Pathological widening of abdominal aorta
  - Risk of rupture → severe complications/death
- Treatment: Endovascular Aortic Repair (EVAR)
  - Implantation of stent graft ("Endograft")
  - Placed minimally invasive into the aneurysm
    - guiding blood flow, reducing pressure on aortic wall
  - Guided using fluoroscopy & contrast agent injections



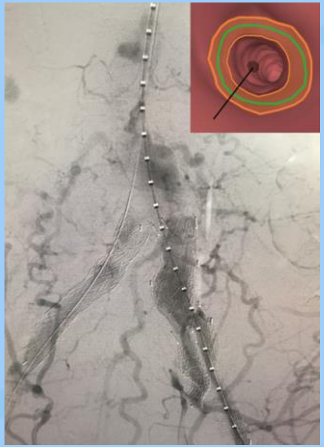
Pictures from IGS final presentation I. Hellali, M. Finger, F. Kögl

3. Planning of stent placement for abdominal aortic aneurysm (AAA)



- Problem Statement
  - Insufficient visualization during intervention
  - Danger of inadvertent covering of branching vessels
  - Missing bridge between planning and intervention

- Project Goal
  - Preoperative: Provide virtual angioscopy (VA) visualization for planning of stent placement
  - Intraoperative: Provide 3D guidance using VA view, by registering the 2D fluoroscopic image to the 3D model acquired preoperatively
  - Overall: Setting up a pipeline from 3D CTA segmentation to intraoperative registration and visualization



Pictures from IGS final presentation I. Hellali, M. Finger, F. Kögl

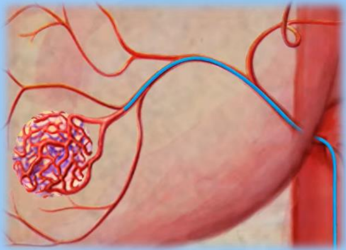
4. Robotic ultrasound of the liver

Medical Background:

- Hepatocellular carcinoma (HCC) most common liver cancer
- 5th for incidence and 3rd in cancer-related mortality

Treatment:

- Transcatheter arterial chemoembolization (TACE)
- MI procedure performed to restrict the tumor’s blood supply.
- Injection of chemotherapy microspheres in the artery that feeds the tumor.
- A catheter is inserted through the leg/arm
- Guidance is performed using fluoroscopy.
  - ⚠ Exposure to radiation for the patient and the medical staff



Catheter to Approach the Tumour Site

Angiogram

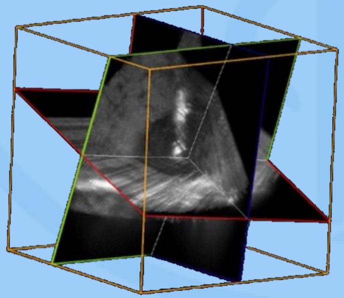
4. Robotic ultrasound of the liver - modify to 3D

<u>**Goal**</u>

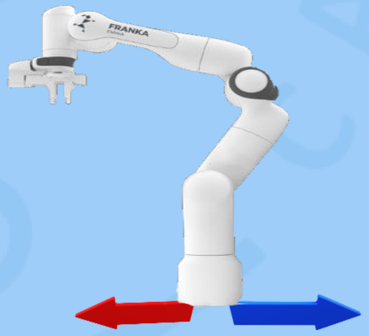
- Lowering the use of ionizing radiation and chemical substances by integrating ultrasound imaging (radiation-free imaging modality).

Project:

- Robotically-guided ultrasound system
- 3D Liver reconstruction
- Motion Planning method for scan between the ribs
    - Find optimal trajectory

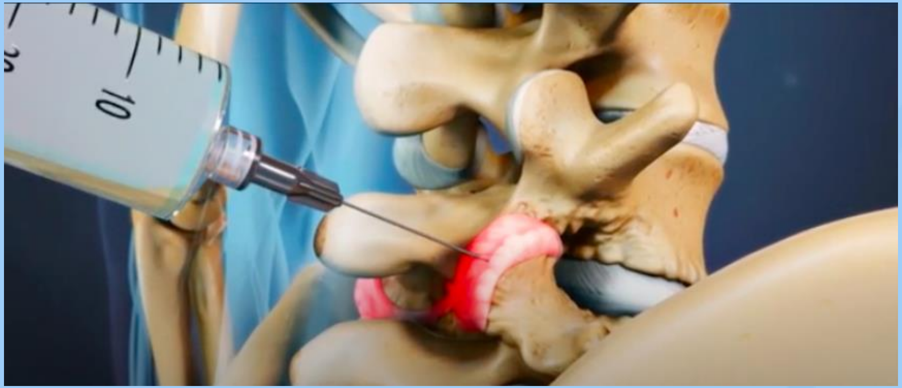


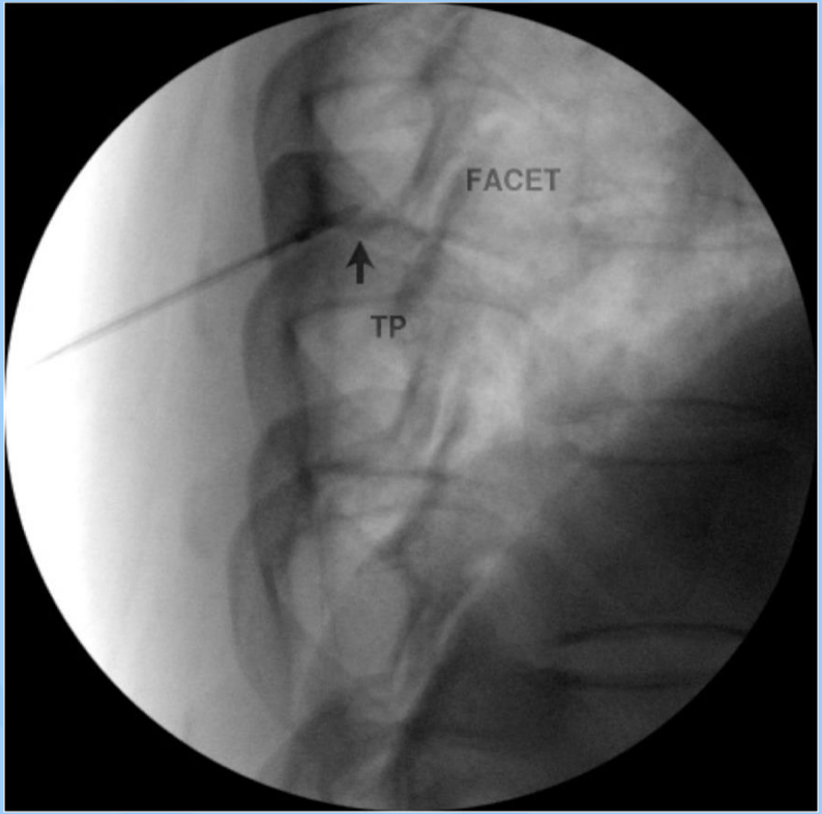
3D Ultrasound Compounding



Robot Trajectory Planning

5. Navigation of facet joint insertion





Application: Facet joint insertion

Problem: Guidance only possible under fluoroscopy resulting in radiation burden for patient and medical personnel.

5. Navigation of facet joint insertion

Solution:

Reduce fluoroscopy use by means of navigation

<u>Short-term:</u>

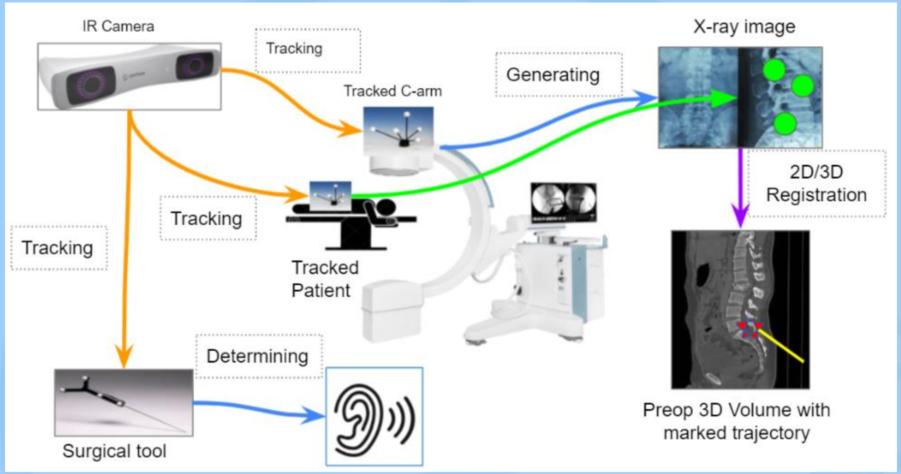
- (semi automatic) detection of facet joint in 3D preoperative CT

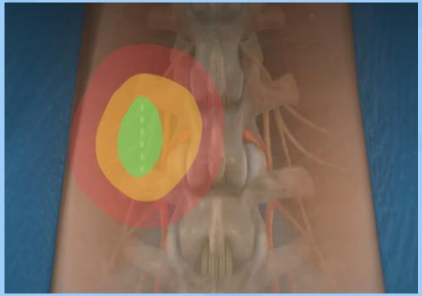
<u>Mid-term:</u>

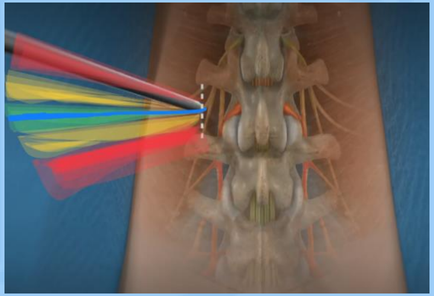
- Calibration of optically tracked C-arm
- 2D/3D registration of preoperative CT and intraoperative C-arm radiographs
- Optical tracking of instruments and C-arm

<u>Long-term:</u>

- Guidance to facets using AR/VR
- Sonification







IGS final presentation of M. Gafencu, A. Kumar, D.A. Voutyrakou

6. Tracking of endoscopic instruments

Application: Any laparoscopic or robotic surgery.

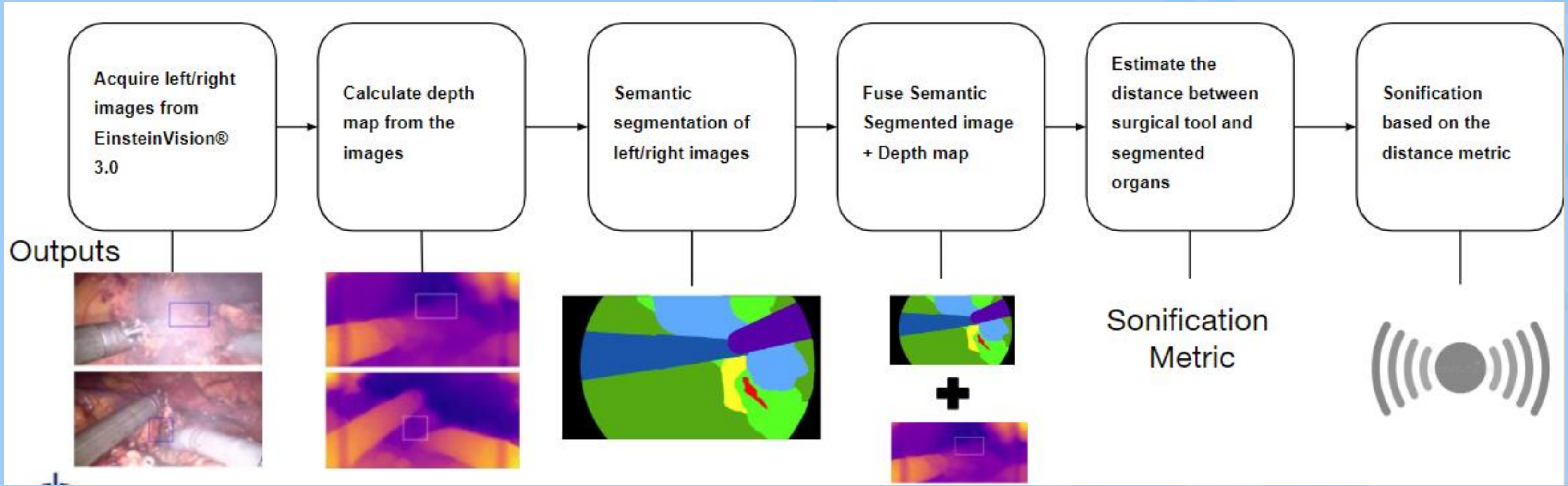
Problem: Detect, segment and track instruments to evaluate performance and (at a later stage) determine distance of instruments to structures at risk and enable navigation.

Solution: Use machine learning tools to track instrument

Short-term: Design weakly or unsupervised approach to annotate instruments in laparoscopic videos.

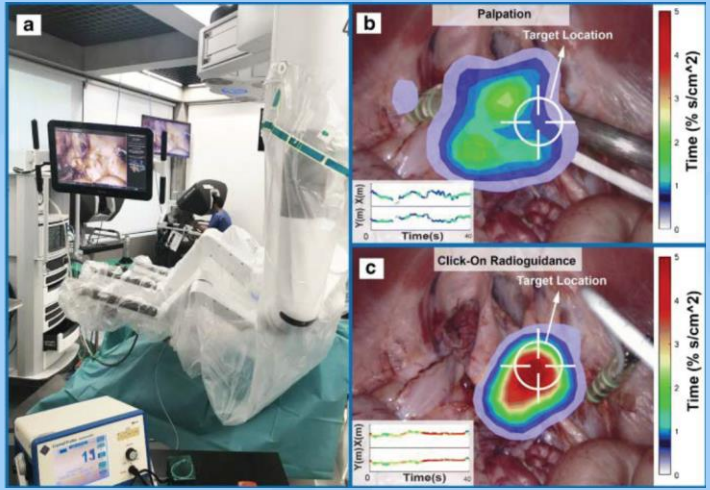
Mid-term: Semantic detection and segmentation of instruments.

Long-term: 3D surface reconstruction of anatomy and registration with tracked instruments for sonification.



IGS final presentation of F.M. Karali, M. Kiray and L. Kreitner

6. Segmentation of endoscopic instruments



Left: Exemplary laparoscopic video during radioguided resection of prostate cancer. Right: Robotic setup and performance evaluation of surgeons using pose of tracked instrument (courtesy of LUMC and AvL-NKI).

Leiden University Medical Center

ANTONI VAN LEEUWENHOEK
NEDERLANDS KANKER INSTITUUT

Questions ?