MIA – Medical Image Analysis

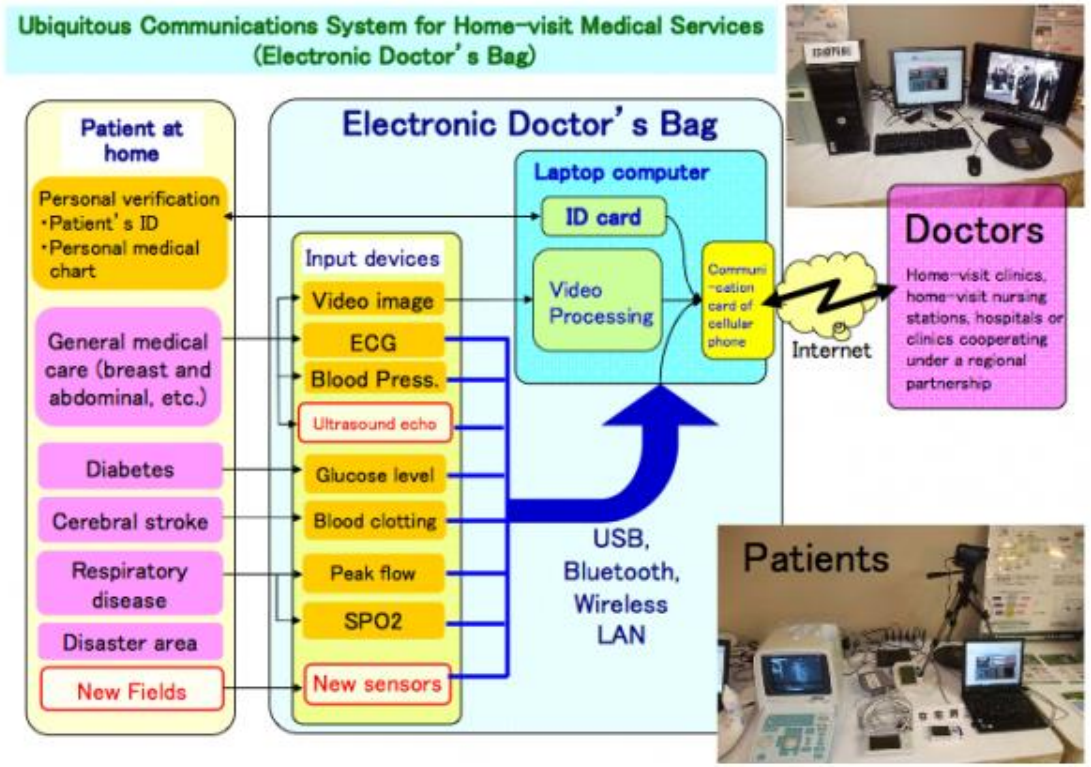
CAD - CARS

Master VIBOT – University of Girona

2016-2017

CAD: Computer-Aided Diagnosis

- Aim:
  - Update the old dream of merging medicine and computer science into an “electronic doctor”.



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  - Update the old dream of merging medicine and computer science into an “electronic doctor”.
  - Stop trying to make computers act like diagnosticians.
  - Develop techniques that can **help radiologists** accurately interpret images and identify potential findings to avoid incorrect interpretation or overlooking of lesions due to subjective judgment.

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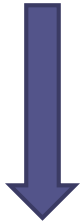


  - **Assist** doctors in the interpretation of medical images.

CAD: Computer-Aided Diagnosis

- Historical overview:
  - 1959: Early symbolic logic and probability theory to provide diagnoses similar to those speculated by physicians' complex reasoning (Ledley and Lusted).
  - 1960s: Early attempts at computerized analysis of medical images.
  - 1980s: Serious and systematic investigation on CAD leads to a fundamental change in the concept for utilization of the computer output, from automated computer diagnosis to computer-aided diagnosis.
  - 1990s: First scientific evidences for the benefits of CAD in the detection of lesions.

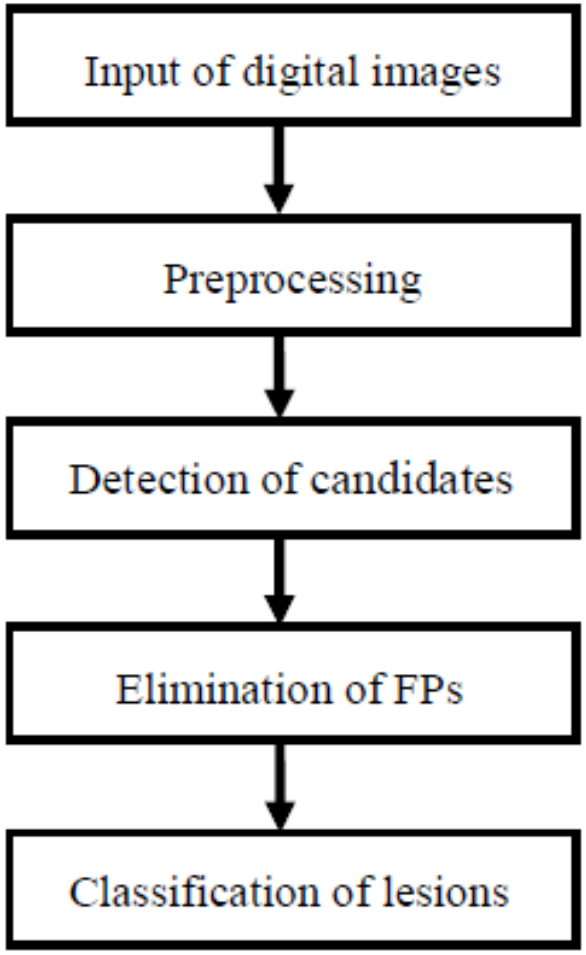
CAD: Computer-Aided Diagnosis

- Historical overview:
  - 1990s: First scientific evidences for the benefits of CAD in the detection of lesions:
    - Clustered microcalcificactions and masses in mammograms
    - Lung nodules and interstitial opacities in chest radiographs
    - Lung nodules in CT
    - Intracranial aneurysms in MRI
  - Current: Practical CAD in screening examinations for the detection of cancer in the breast, lung, and colon.

    Analysis of performance level in terms of sensitivity at a given false positive ratio per image.
  - Computer-Aided Detection (CADe) and Diagnosis (CADx).

CAD: Computer-Aided Diagnosis

- Typical flowchart of CAD



CAD: Computer-Aided Diagnosis

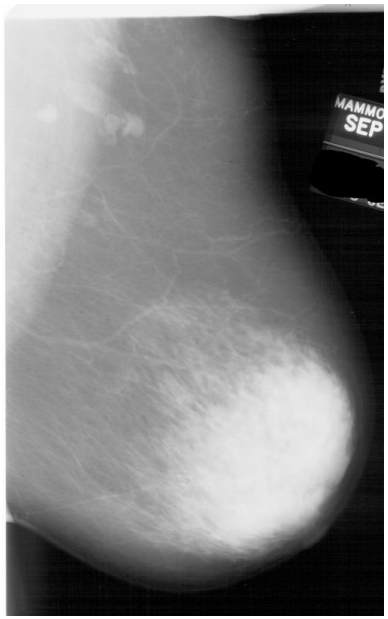
- Components of a CAD systems: restrictions
  - Not all data from imaging modalities can be obtained in digital formats.
  - With the use of computed radiography (CR) and flat panel detector (FPD), digitizing images are not longer required.
  - Important factor for the hardware: **diagnostic time during inspection**.
  - Computer workstation with powerful calculating capacity.
  - Some time-consuming calculations could be realized by using hardware instead of software.

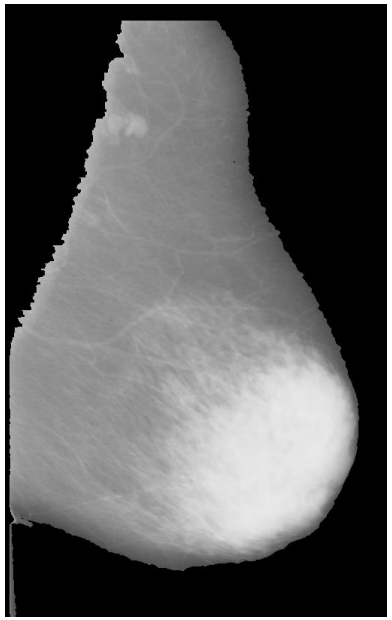
CAD: Computer-Aided Diagnosis

- Components of a CAD systems:
  - Image acquisition and **data preprocessing** for noise reduction and removal of artifacts.
  - Image **extraction** and representation.
  - Detection of the region of interest (ROI) by **image analysis** on the basis of segmentation and matching.
  - Evaluation and classification using an appropriate **decision-making** scheme.

CAD: Computer-Aided Diagnosis

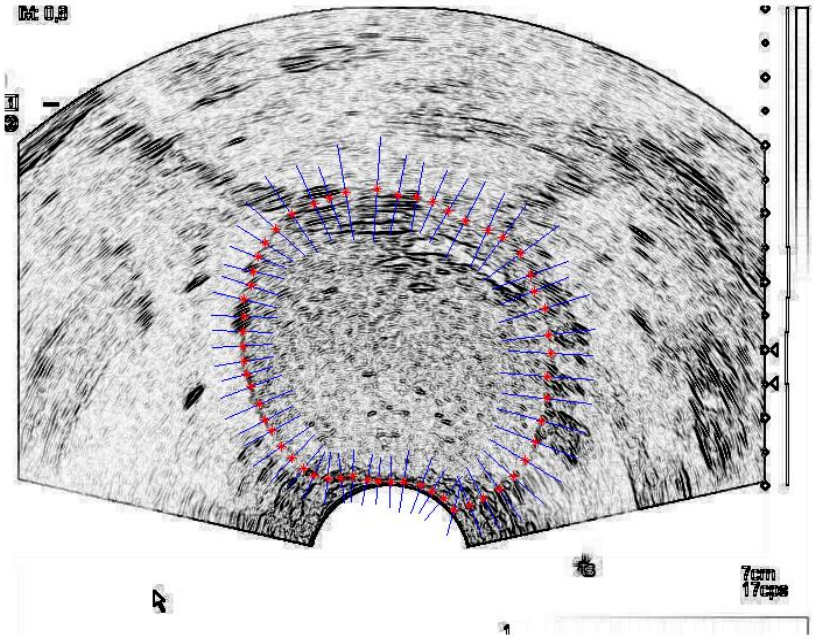
- Image acquisition and data preprocessing:
  - Image noise reduction.
  - Removing (reduction) of artifacts: labels, …
  - Harmonization of image quality for clearing the image's different basic conditions (exposure parameters).

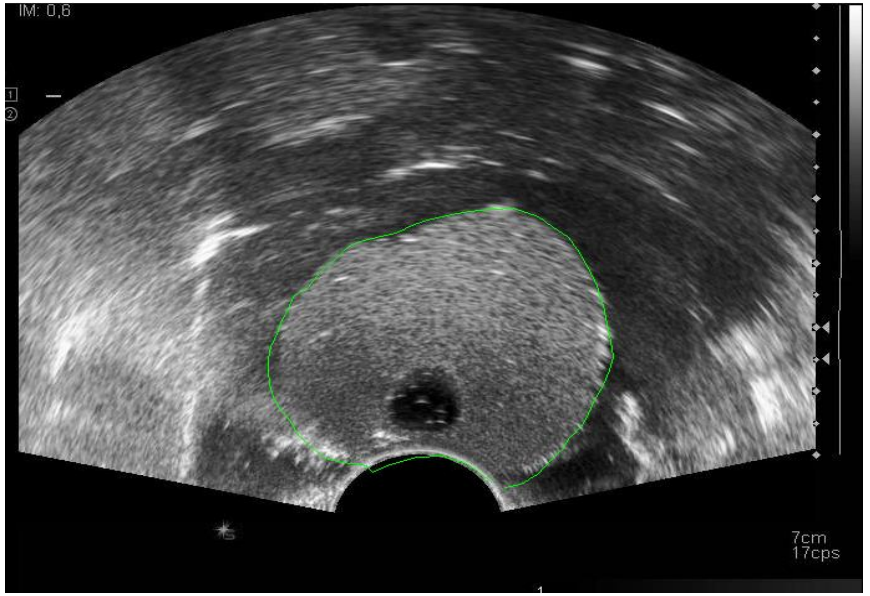




CAD: Computer-Aided Diagnosis

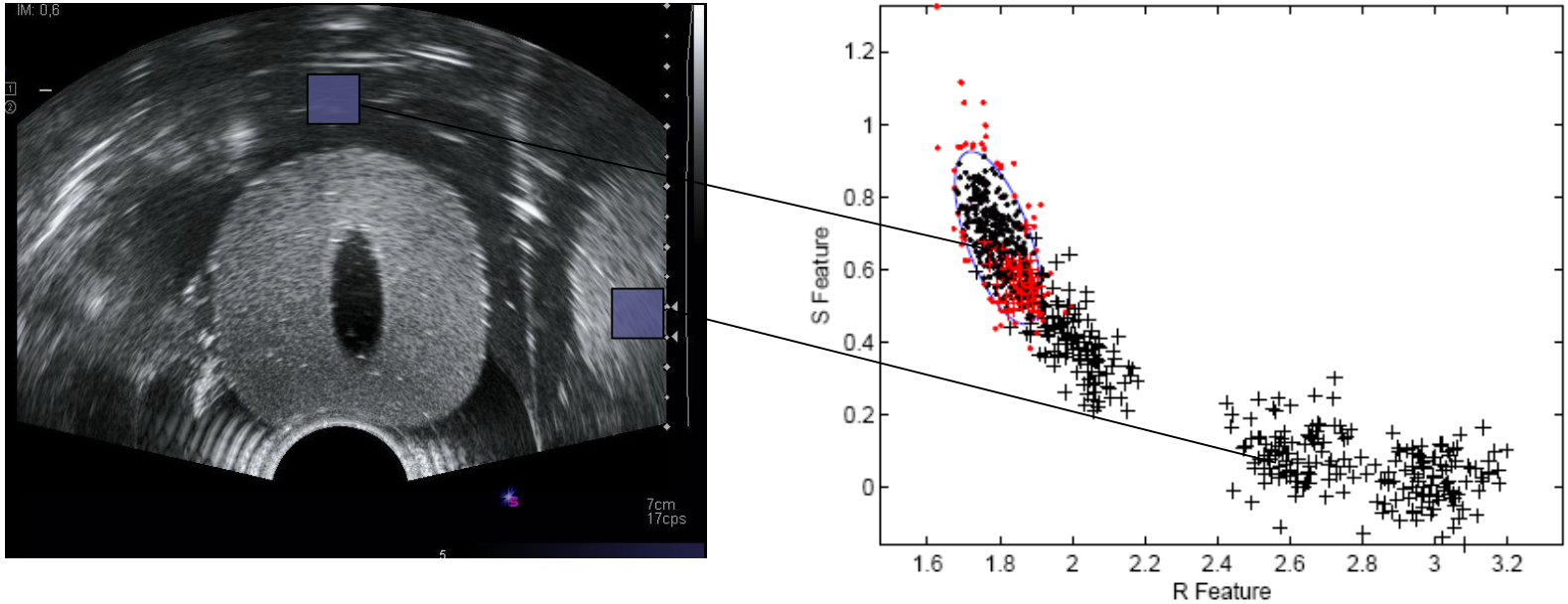
- Segmentation:
  - Differentiation of structures in the image: heart, lung, prostate, breast, nipple, …
  - Matching with anatomic databank.





CAD: Computer-Aided Diagnosis

- Analysis of the region of interest (ROI):
  - Shape, size and location.
  - Greylevel values.
  - Texture analysis.
  - Reference to close-by structures / ROIs



CAD: Computer-Aided Diagnosis

- Evaluation / Classification:
  - Every ROI is individually evaluated in order to score for the probability of a TP, according to different procedures:
    - NN rule
    - Minimum distance classifier
    - Bayesian classifier
    - Multilayer perception
    - Support-Vector Machine (SVM)
    - …

CAD: Computer-Aided Diagnosis

- Evaluation / Classification:
  - Sensitivity and specificity
  - Number of True Positives (TP) and False Positives (FP)
  - True-negative fraction (TNF) and False-negative fraction (FNF)
  - FP/image
  - ROC (Receiver Operating Characteristic)
  - FROC (Free-Response Receiver Operating Characteristic)
  - A_z/AUC (Area under the curve)
  - Recall rate

CAD: Computer-Aided Diagnosis

- Commercial CAD products:
  - ImageChecker™ (mammography, produced by R2 Technology, USA).
  - SecondLook™ (mammography, produced by iCAD Technology, USA).
  - CADStream™ (breast MRI, produced by Confirma, USA).
  - RapidScreen™ (lung cancer, produced by Riverain Medical, USA).
  - MeVis Visia™ CT Lung System (lung cancer, produced by Mevis Medical Solutions AG, Germany).

CAD: Computer-Aided Diagnosis

- Experimental CAD products:
  - Intelligent Assistance in diagnosis of Multi-dimensional Medical Images project (Gifu University, Japan).
  - CAD for dental panoramic radiography (City Area Program in Japan).
  - Automatic Breast Ultrasound – ABUS (Radboud University Nijmegen, The Netherlands).
  - Multi-view and temporal mammographic system (Universitat de Girona, Catalonia).
  - Interactive CAD.

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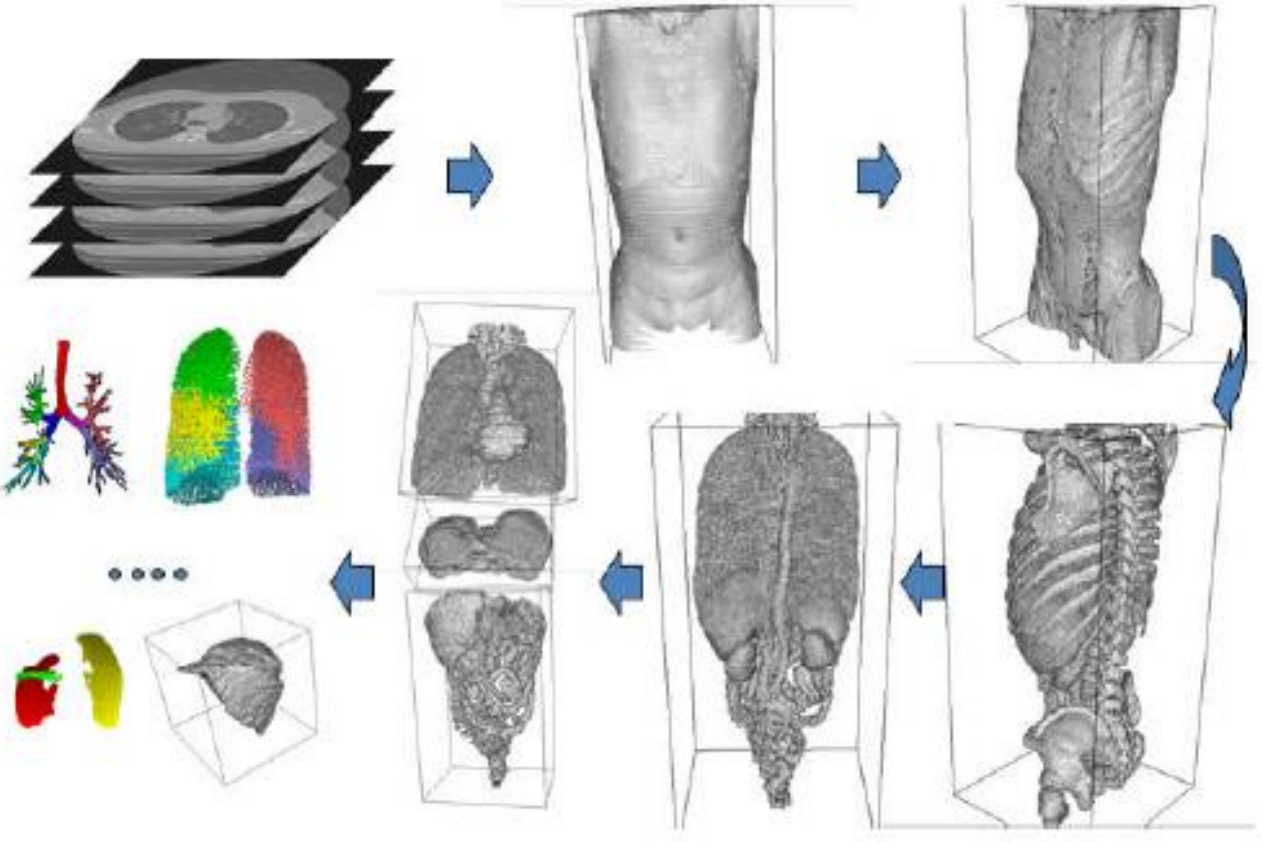

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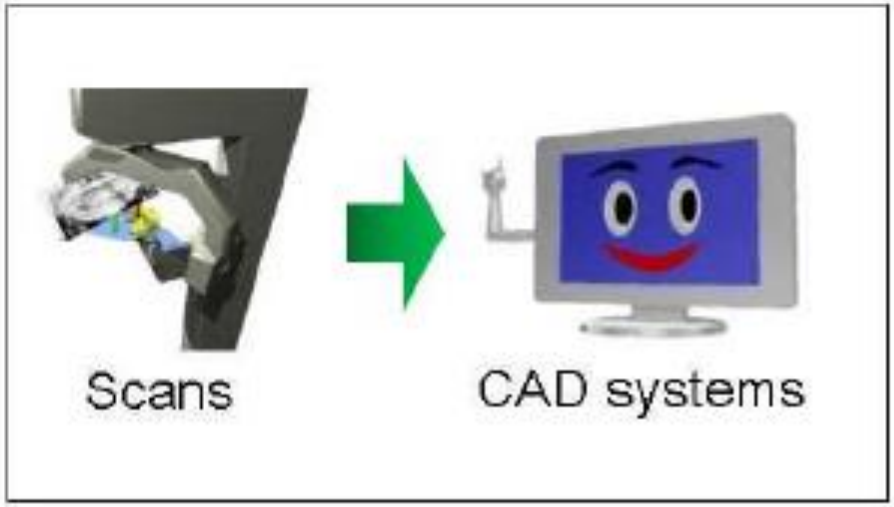
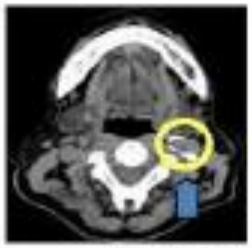




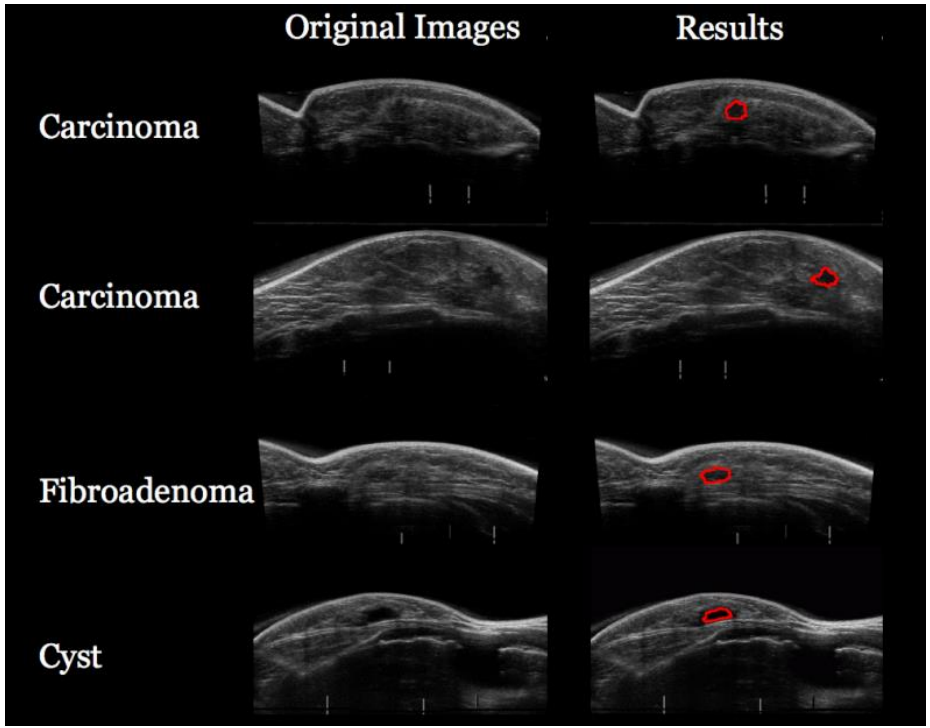
CT (gold standard)

One CAC example

Illustration of CAC detection

CAD: Computer-Aided Diagnosis

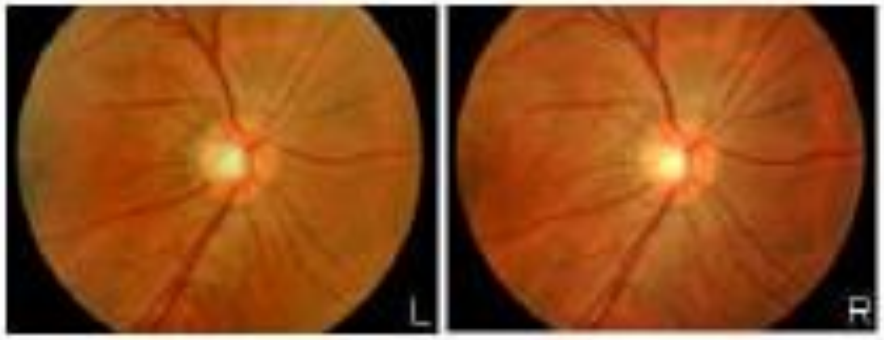
- Experimental CAD products:
  - Automatic Breast Ultrasound – ABUS (Radboud University Nijmegen, The Netherlands).
  - Whole breast (109 Vol, 80% sens @ 3.8 FP/vol).



CAD: Computer-Aided Diagnosis

- Experimental CAD products:
  - Retinal fundus images (Kowa Company, Japan).

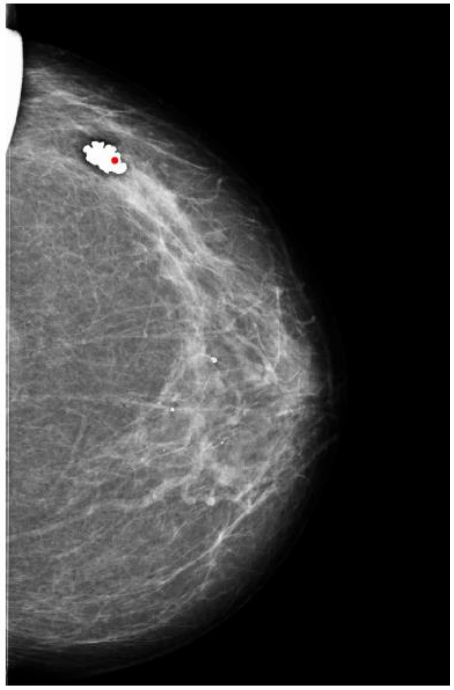
Stereo Fundus Camera

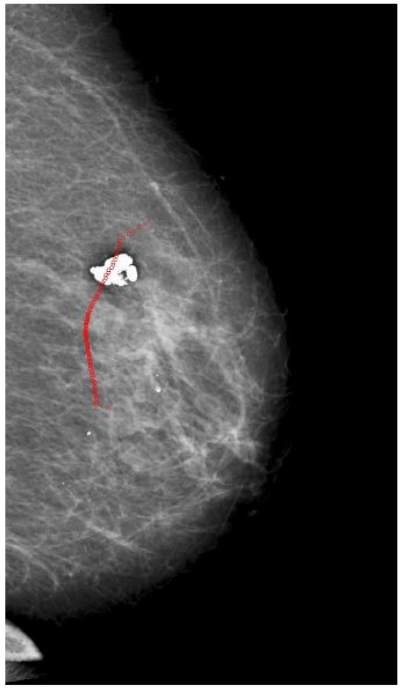


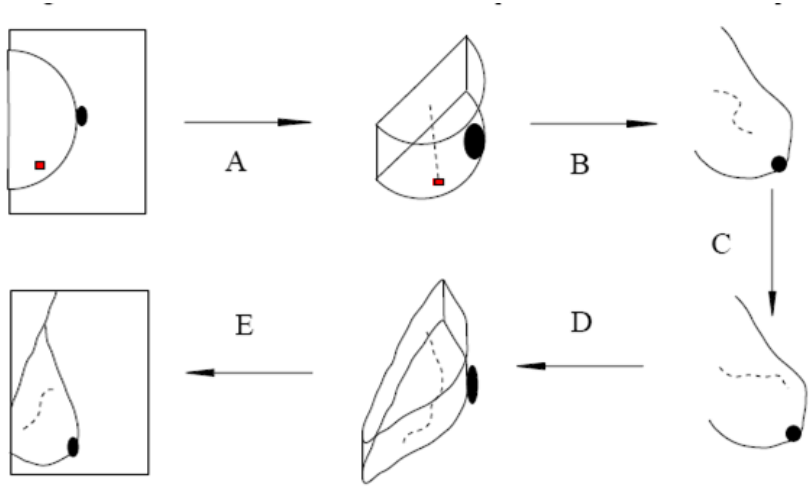
Stereo Fundus Image Pair

CAD: Computer-Aided Diagnosis

- Experimental CAD products:
  - Multi-view and temporal mammographic system (Universitat de Girona, Catalonia).
  - CC-MLO correspondence.

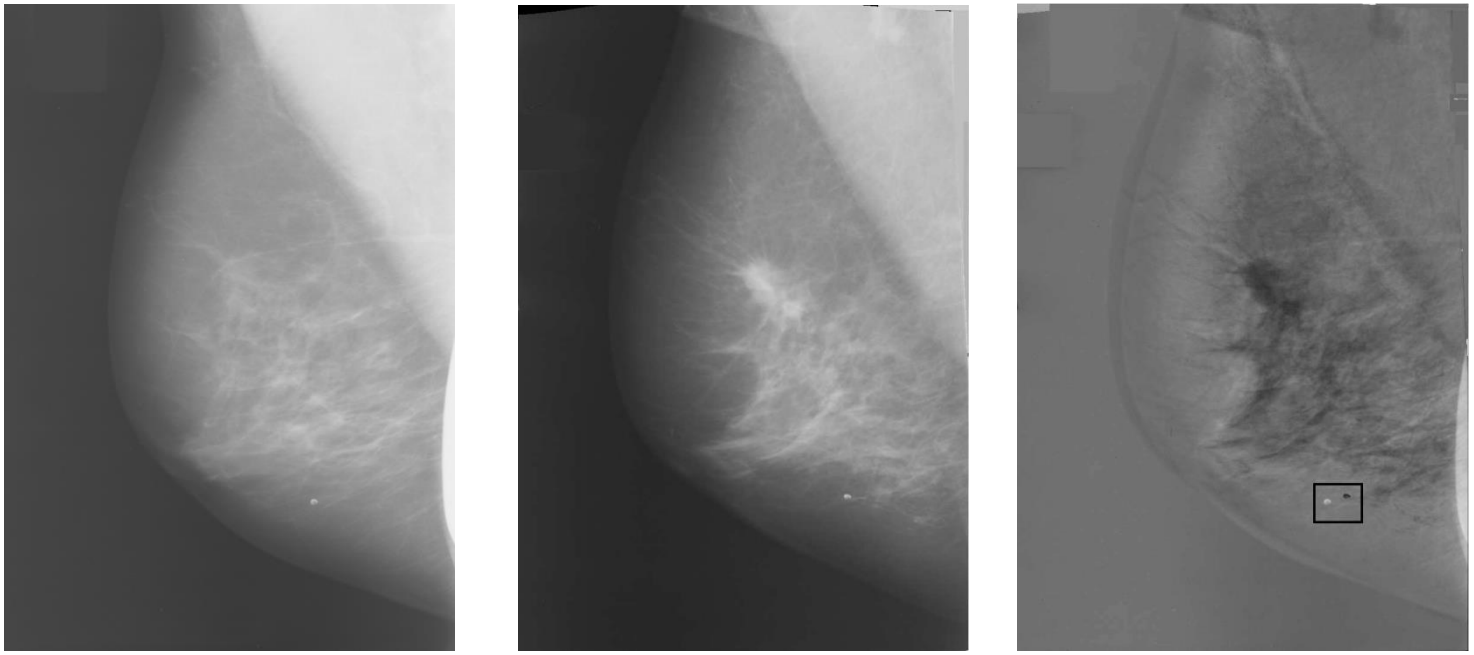






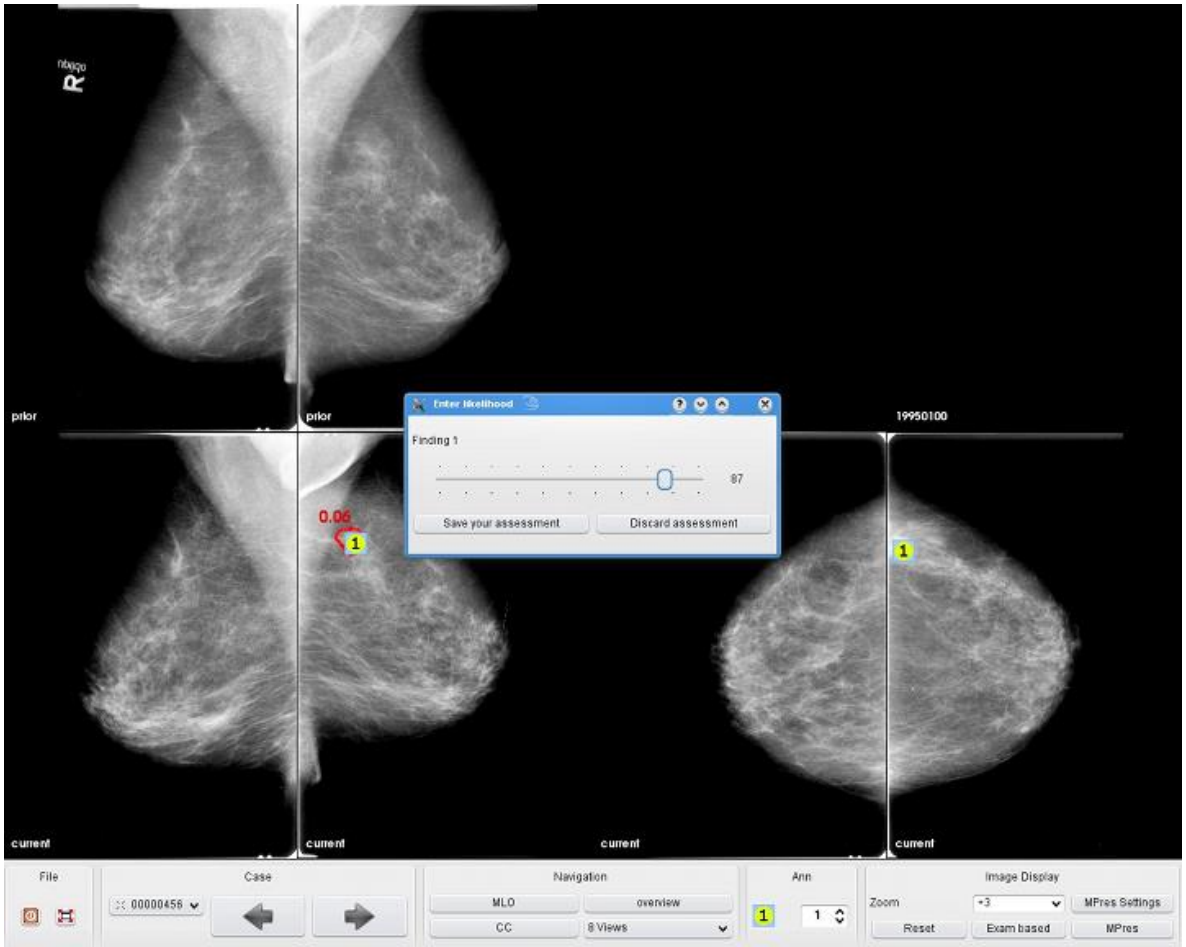
CAD: Computer-Aided Diagnosis

- Experimental CAD products:
  - Multi-view and temporal mammographic system (Universitat de Girona, Catalonia).
  - Image Registration.



CAD: Computer-Aided Diagnosis

- Experimental CAD products:
  - Interactive CAD



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- "Computer-Aided Diagnosis: How to Move from the Laboratory to the Clinic". Bram van Ginneken et al. Radiology: vol 261, number 3, December 2011, 719-732.
- "Clinically Missed Cancer: How Effectively Can Radiologists Use Computer-Aided Detection?" Robert M. Nishikawa et al. AJR: 198, March 2012, 708-716.

CARS: Computer-Assisted Radiology and Surgery

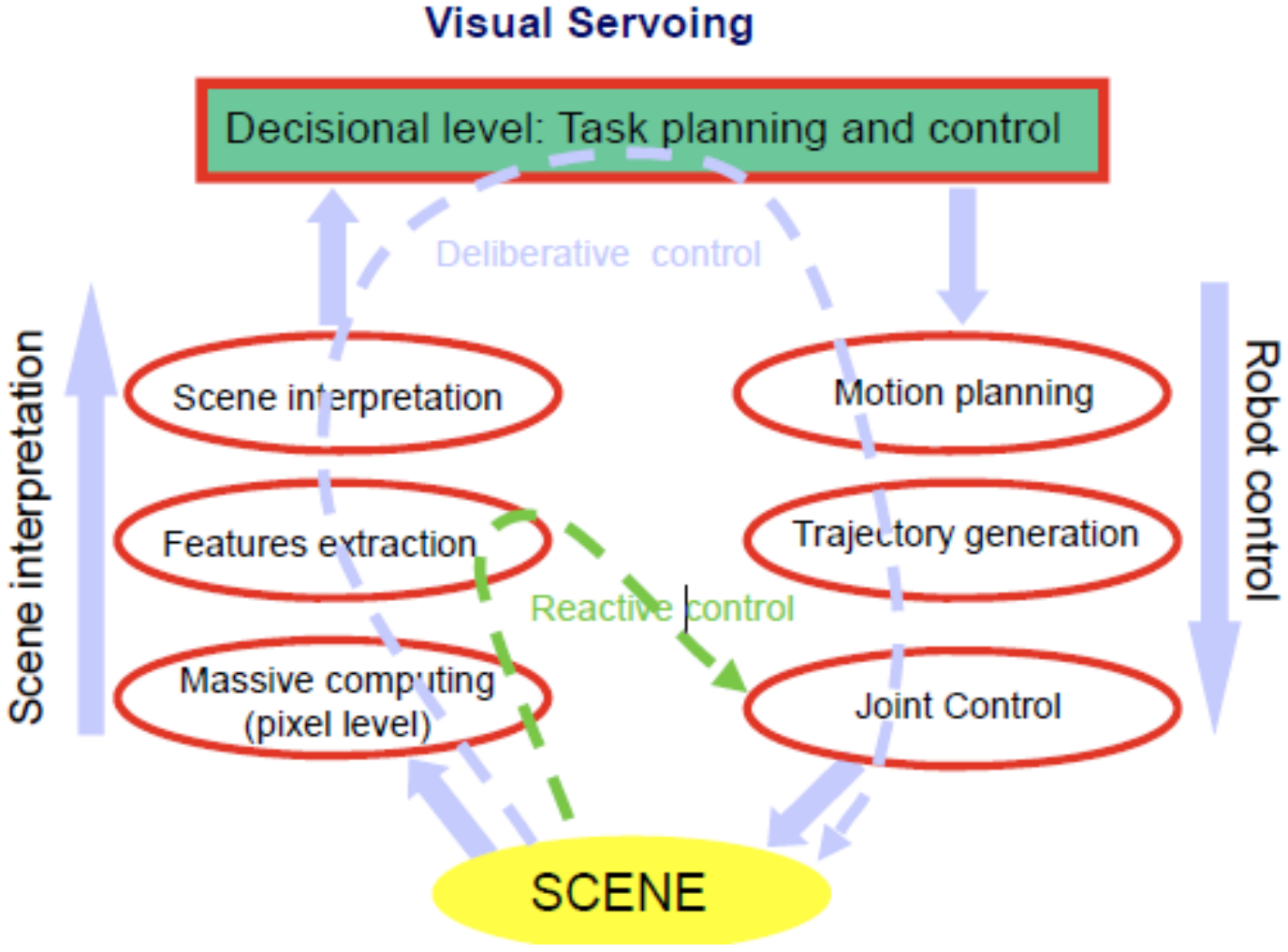
- Robotics in Medicine
- Rehabilitation and Assistant Robots
- Robotics in Surgery

CARS: Computer-Assisted Radiology and Surgery

- Robotics in Medicine
  - Motivation:
    - Need of improvement of surgical and diagnostic procedures.
    - Need of increasing the capabilities of disabled people.
    - Need of improving rehabilitation techniques.
  - Systems / Technologies:
    - Robots
    - Perception systems
    - Interaction devices and interfaces
  - Human-Robot Cooperation levels
    - Manual operation
    - Teleoperation
    - Synergistic-Shared control
    - Autonomous

CARS: Computer-Assisted Radiology and Surgery

- Robotics in Medicine



CARS: Computer-Assisted Radiology and Surgery

- Rehabilitation and Assistant Robots
  - Robotics and disability
  - Rehabilitation robotics
  - Prosthetic and orthotic devices
  - Assistant robots
  - Human machine interface

CARS: Computer-Assisted Radiology and Surgery

- Rehabilitation and Assistant Robots

Hand exciser (Salford University, 2004)
4 fingers, 7 DoF. Finger flexion monitoring

Cyberhand

Stand-alone assistant robot: ProVAR Professional Vocational Assistant Robot, Stanford University, 1998). Industrial robot arm PUMA 260 used. PC interface

CARS: Computer-Assisted Radiology and Surgery

- Robotics in Surgery:
  - CAS: Computer Aided Surgery
  - MIS: Minimally Invasive Surgery
  - IOR: Intelligent Operating Room

CARS: Computer-Assisted Radiology and Surgery

- Robotics in Surgery:
  - Hard tissues: non deformable and static.
  - Hard tissues: non deformable but not fixed frames.
  - Soft tissues: Deformable part and not fixed references

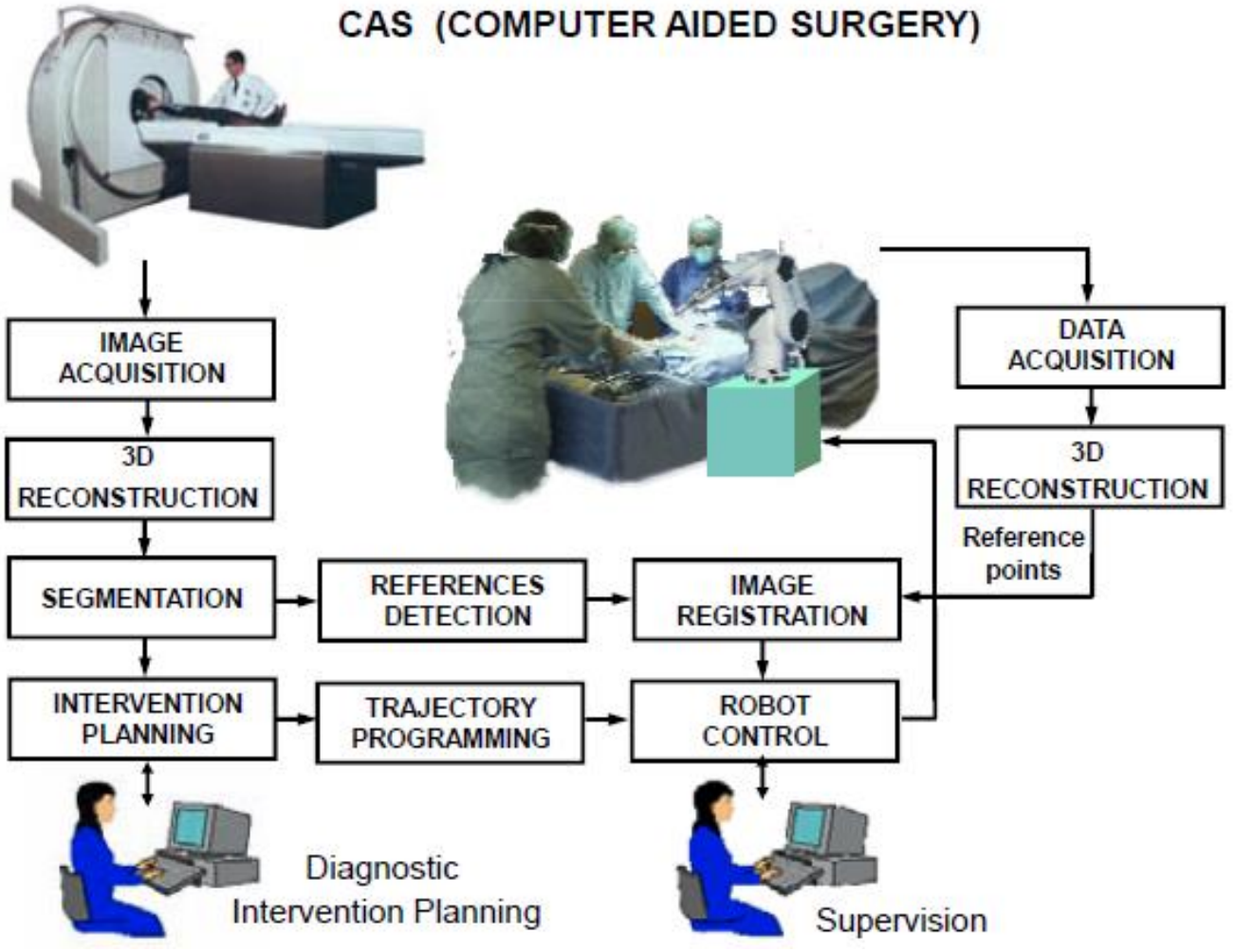
Stereotaxis

Variable reference frames

Variable RF & deformable

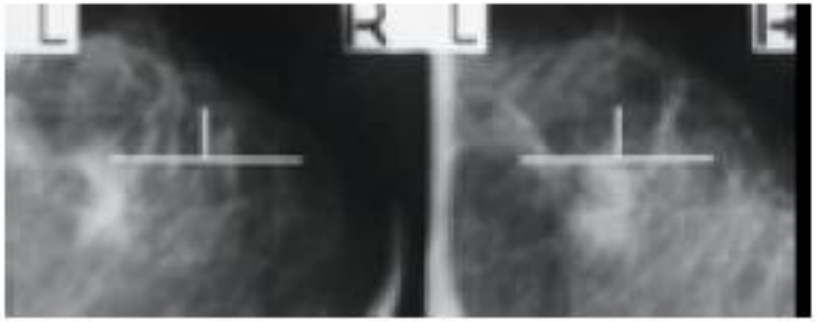
CARS: Computer-Assisted Radiology and Surgery

- Robotics in Surgery:



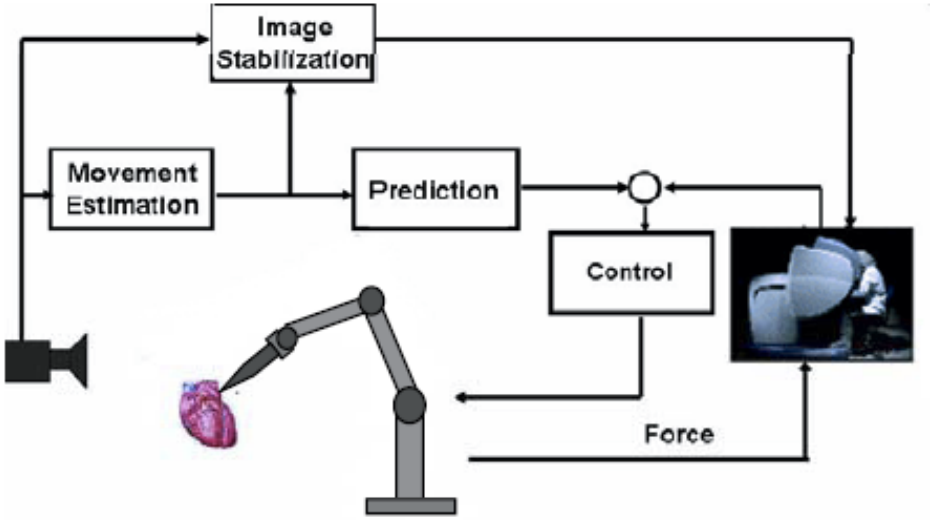
CARS: Computer-Assisted Radiology and Surgery

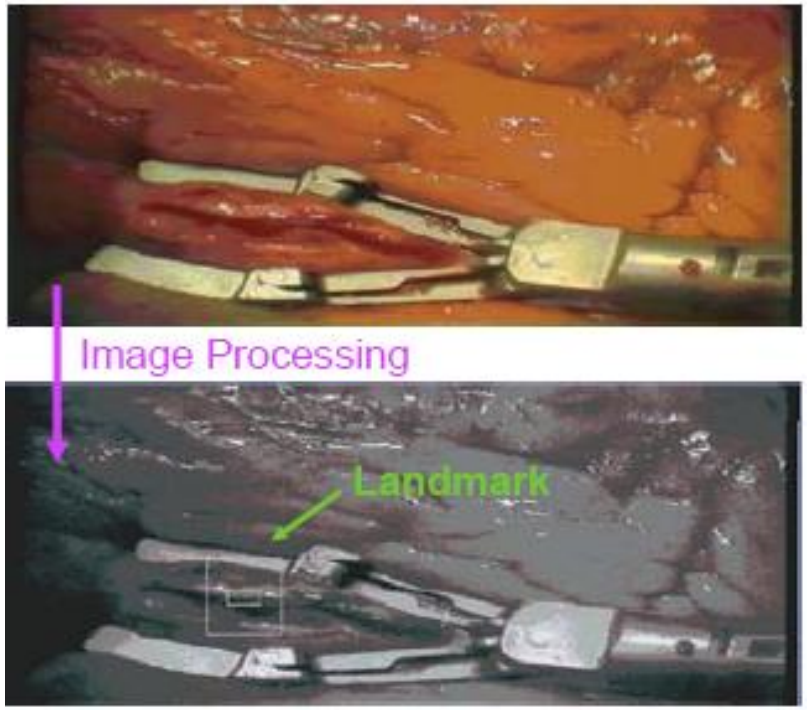
- Robotics in Surgery:
  - Image guided surgery: mammographic biopsy



CARS: Computer-Assisted Radiology and Surgery

- Robotics in Surgery:
  - Motion compensation in minimally invasive heart surgery





CARS: Computer-Assisted Radiology and Surgery

- Robotics in Surgery:
  - Da Vinci: teleoperated robot 3 arms, 3D imaging, laparascopic surgery, prostate surgery

Robot

Set-up

H-M interface

CARS: Computer-Assisted Radiology and Surgery

- Robotics in Surgery: Da Vinci surgical robot

http://www.youtube.com/watch?v=RJcRABevyCk

References

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- "Medical Robots: Current Systems and Research Directions". Ryan A. Beasley. Journal of Robotics Volume 2012, Article ID 401613, 14 pages. Doi:10.1155/2012/401613

MIA – CAD-CARS

Questions?