NSF Engineering Research Center
for Computer Integrated Surgical
Systems and Technology

LABORATORY FOR
Computational
Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

Medical Robotics and Computer-Integrated Interventional Systems:

Integrating Imaging, Intervention, and Informatics to Improve Patient Care

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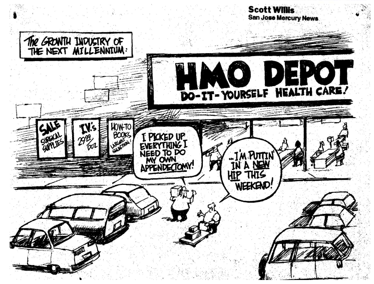
WHITING SCHOOL OF ENGINEERING
THE JOHNS HOPKINS UNIVERSITY

Acknowledgments

- **This is the work of many people**
- Some of the work reported in this presentation was supported by fellowship grants from Intuitive Surgical and Philips Research North America to Johns Hopkins graduate students and by equipment loans from Intuitive Surgical, Think Surgical, Philips, Kuka, and Carl Zeiss Meditec.
- Some of the work reported in this talk incorporates intellectual property that is owned by Johns Hopkins University and that has been or may be licensed to outside entities, including Intuitive Surgical, Varian Medical Systems, Philips Nuclear Medicine, Virtuoso Technologies, Galen Robotics and other corporate entities. Prof. Taylor and the University are entitled to royalty distributions related to this technology, and Dr. Taylor has received or may receive some portion of these royalties. Also, Dr. Taylor is a paid consultant to and owns equity in Galen Robotics, Inc. These arrangements have been reviewed and approved by JHU in accordance with its conflict of interest policy.
- Much of this work has been funded by Government research grants, including NSF grants EEC9731478 and IIS0099770 and NIH grants R01-EB016703, R01-EB007969, R01-CA127144, R42-RR019159, and R21-EB0045457; by Industry Research Contracts, including from Think Surgical and Galen Robotics; by gifts to Johns Hopkins University from John C. Malone, Richard Swirnow and Paul Maritz; and by Johns Hopkins University internal funds.

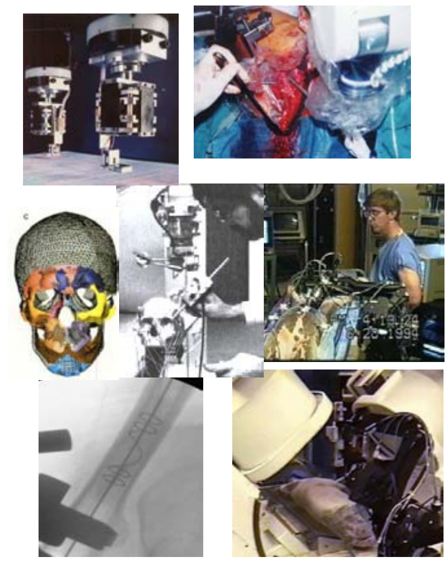
BY STAYSKAL FOR THE TAMPA TRIBUNE

Scott Willis
San Jose Mercury News



A short personal background: Russ Taylor

- **1970: BES from Johns Hopkins**
- **1976: PhD in CS at Stanford**
- **1976-1988: Research/management in robotics and automation technology at IBM**
- **1988 - 1996: Medical robotics & computer-assisted surgery at IBM**
  - Robodoc
  - Surgical navigation
  - Robotically assisted MIS and percutaneous interventions (with JHU)
- **1995: Moved to JHU**
  - CS with joint appts in ME, Radiology, Surgery (2005)
  - X-ray guided MIS & orthopaedics
  - “Steady Hand” microsurgery
  - Radiation therapy
  - Modeling & imaging
  - Etc.
- **1997 - now: NSF ERC; LCSR**
- **Disclosures:** Some of the work reported in this talk incorporates intellectual property that is owned by Johns Hopkins University and that has been or may be licensed to outside entities, including Intuitive Surgical, Varian Medical Systems, Philips Nuclear Medicine, Virtuoso Technologies, Galen Robotics and other corporate entities. Prof. Taylor and the University are entitled to royalty distributions related to this technology, and Dr. Taylor has received or may receive some portion of these royalties. Also, Dr. Taylor is a paid consultant to and owns equity in Galen Robotics, Inc. These arrangements have been reviewed and approved by JHU in accordance with its conflict of interest policy



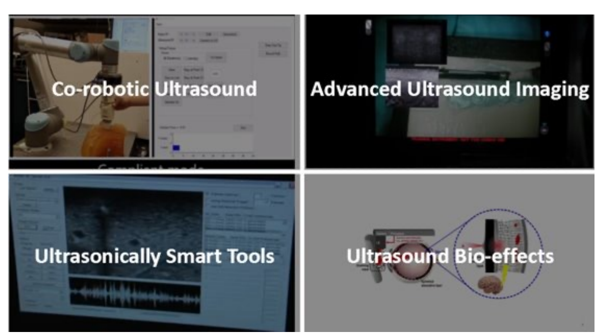
A short personal background: Emad Boctor

- Emad Boctor received Master’s and Doctoral degrees in 2004 and 2007 from the Computer Science Department of Johns Hopkins University.

- In 2007, he joined both The Russell H. Morgan Department of Radiology and Radiological Science and the Whiting School of Engineering, where he initiated a research program in the field of advanced ultrasound imaging.

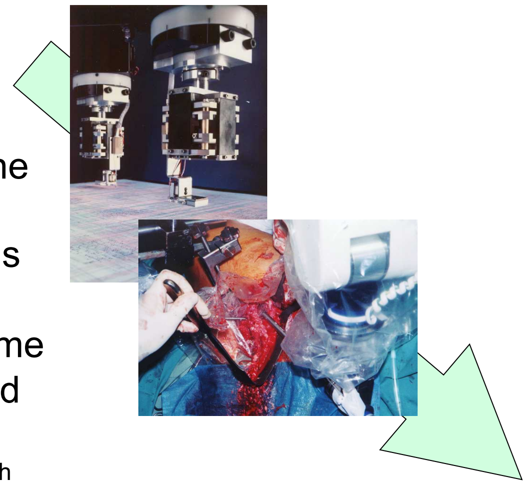
- Since 2009, founder and director of the Medical Ultrasound Imaging and Intervention Collaboration (MUSiiC) research laboratory.

- Dr. Boctor’s research focuses on brain imaging, early detection of aggressive cancer, and image-guided therapy and surgery, a subject in which he has authored and co-authored over 78 peer-reviewed manuscripts and 150 conference articles, has filed more than 40 pending and issued patents, and has been recognized with numerous awards and fellowships including the National Science Foundation CAREER award.



Motivating Insight

A partnership between human clinicians and computer-based technology will fundamentally change the way surgery and interventional medicine is performed in the 21st Century, in much the same way that computer-based technology changed manufacturing in the 20th Century



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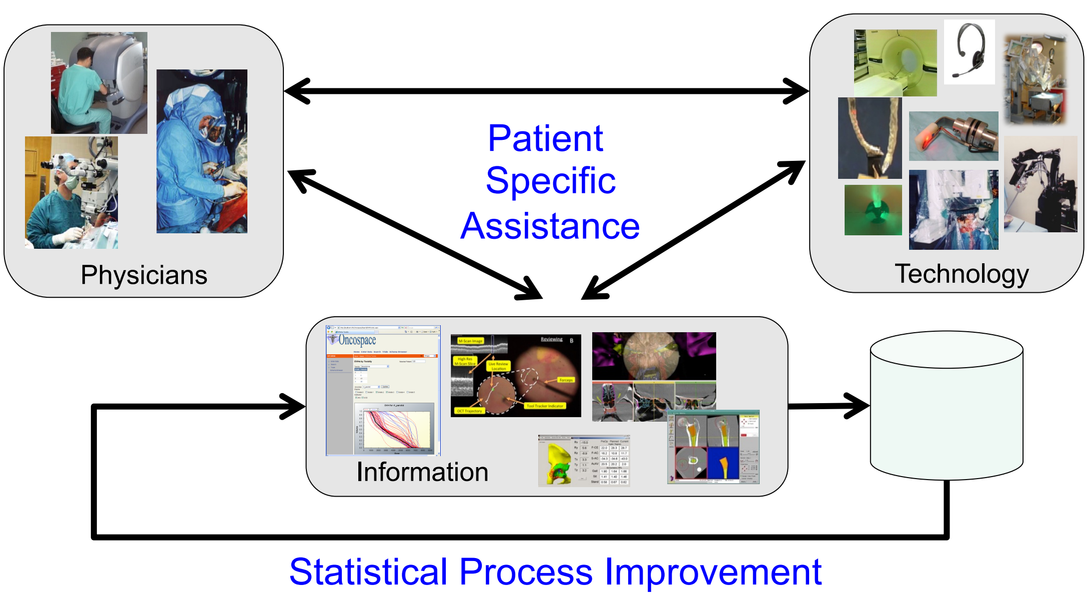
Human-machine partnership to fundamentally improve interventional medicine



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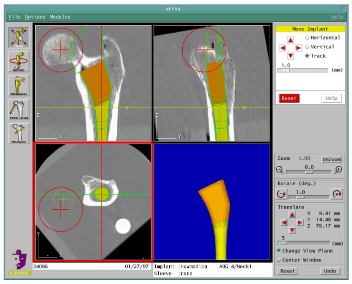
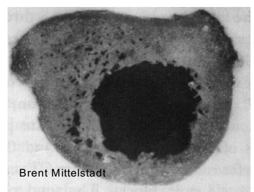
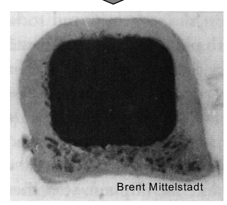
Over 25 years ago: Robotic Joint Replacement Surgery



Taylor, Kazanzides, Paul, Mittelstadt, *et al.*



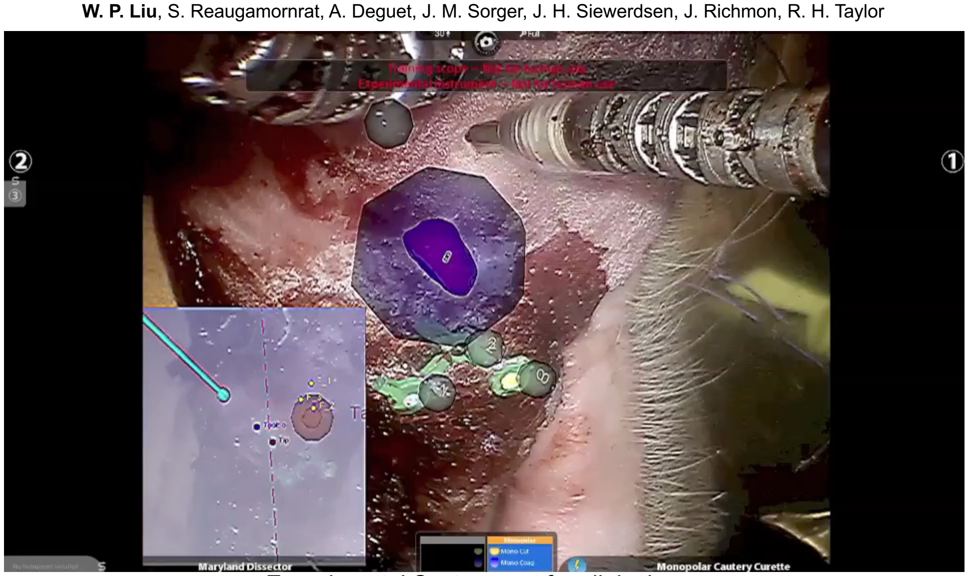
Manual Surgery



Robotic Surgery

Emerging: Information-Augmented Robotic Surgery

W. P. Liu, S. Reaugamornrat, A. Deguet, J. M. Sorger, J. H. Siewerdsen, J. Richmon, R. H. Taylor



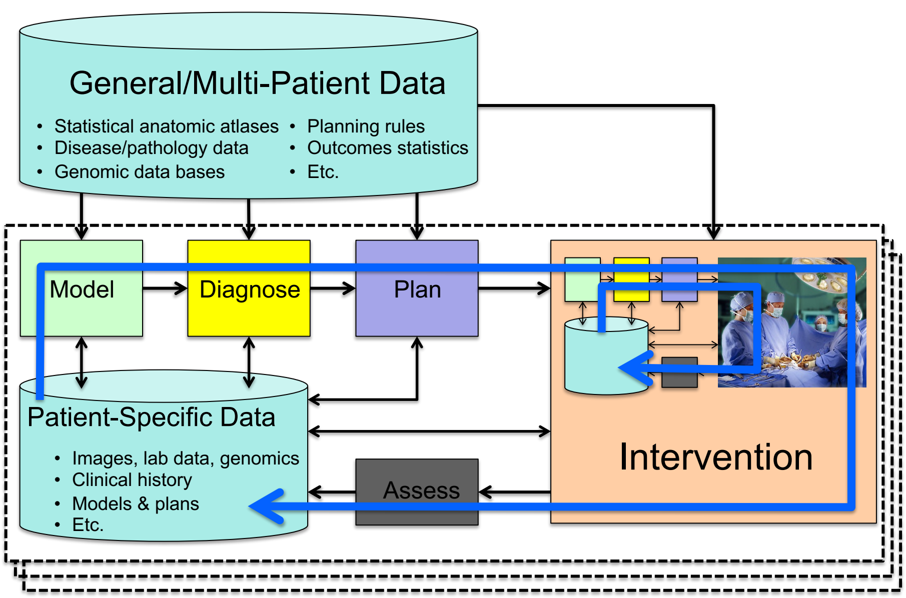
Experimental System: not for clinical use

Emerging: Augmented Reality in the OR

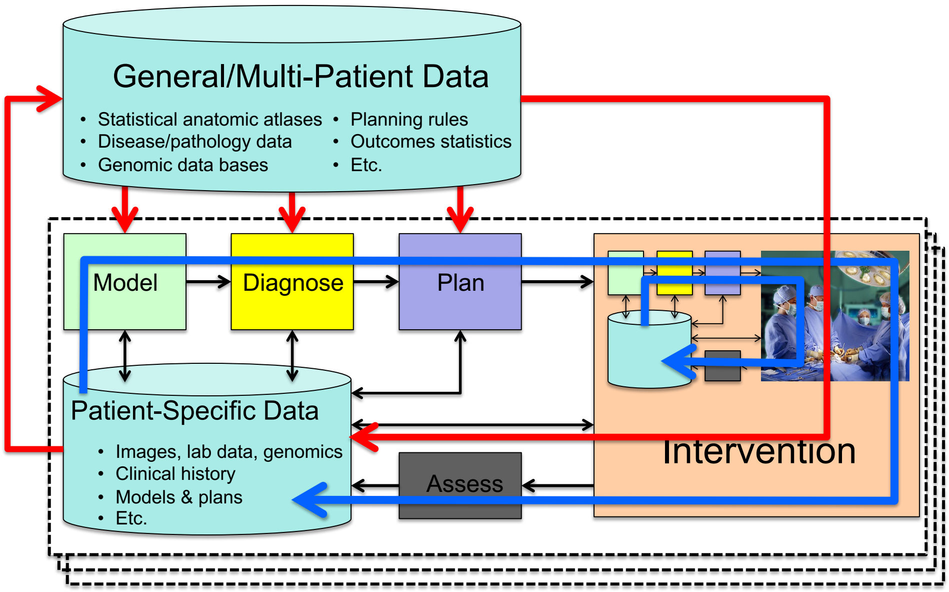
M. Unberath* , J. Fotouhi* , J. Hajek* , A. Maier, G. Osgood, R. Taylor, M. Armand, N. Navab. “Augmented Reality-based Feedback for Technician-in-the-loop C-arm Repositioning” To appear in *2018 AE-CAI MICCAI workshop*.

* Joint first authors

Computer-Integrated Interventional Medicine



Computer-Integrated Interventional Medicine



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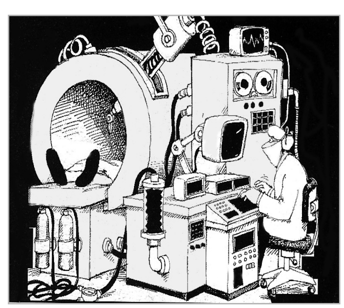
This Paradigm has not changed since Imhotep's day

27th Century BCE

But medical robots and computer-integrated interventional systems will make it much more effective



21st Century CE

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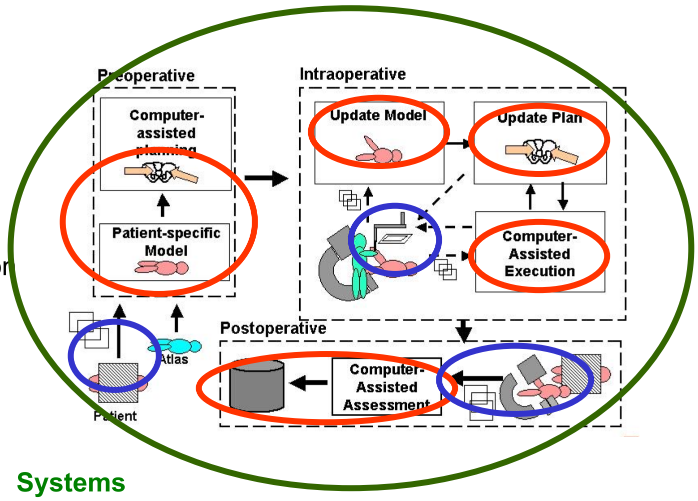
Multidisciplinary Integration is Crucial

Modeling & analysis
- Segmentation
- Registration
- Atlases
- Optimization
- Visualization
- Task characterization
- *etc.*



Interface Technology
- Sensing
- Robotics
- Human-machine interfaces

Systems
- Safety & verifiability
- Usability & maintainability
- Performance and validation

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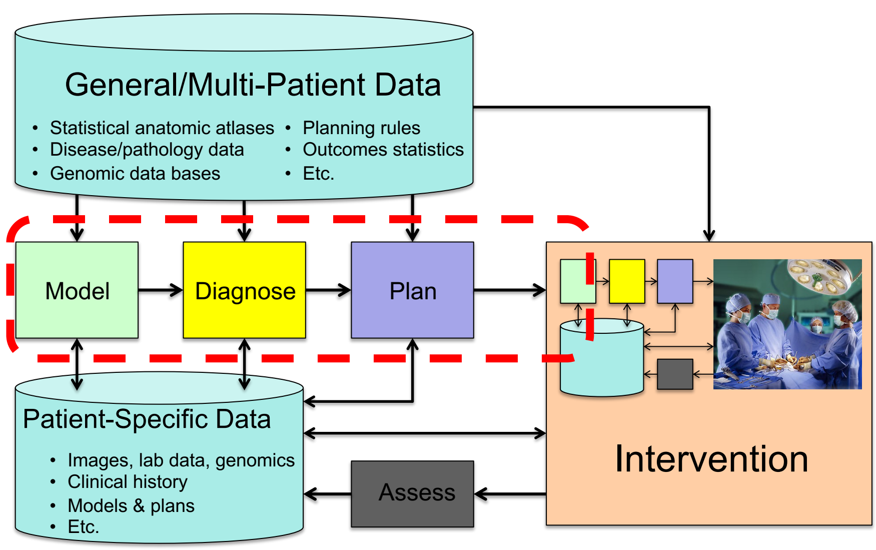
Image-based modeling & analysis



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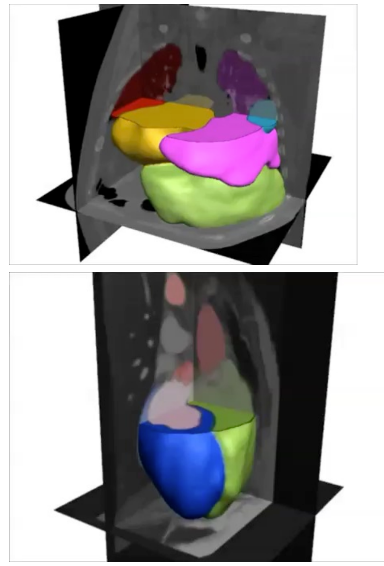
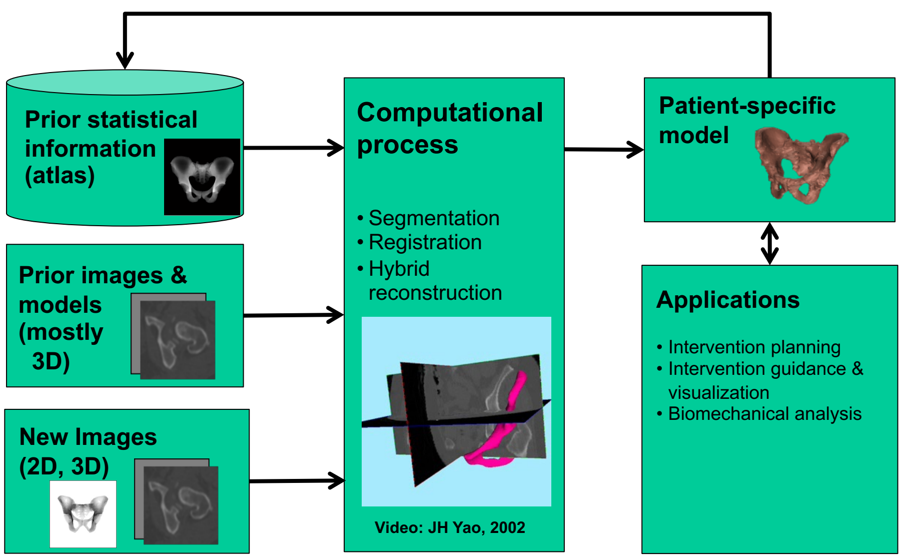
Patient-Specific Models for Interventions

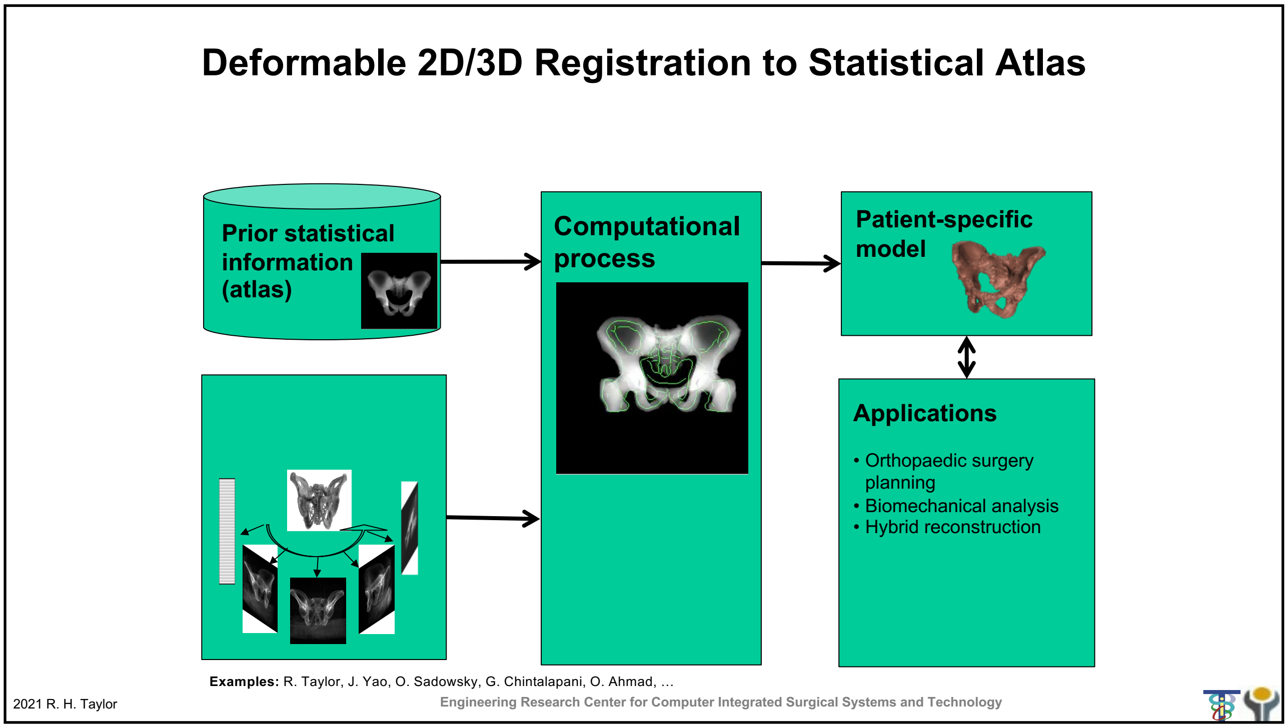
- Computationally efficient **representation of patient** enabling computer to assist in planning, guidance, control, and assessment of interventional procedures
- Generally focus on **anatomy**, but may sometimes include biology or other annotations
- Predominately derived from medical images and image analysis
- Increasingly reference statistical "**atlases**" describing patient populations



Video: Blake Lucas, "SpringLS…", *MICCAI 2011* & subsequent papers.
Data courtesy of Terry Peters and Eric Ford

Combining prior knowledge with online images




Deformable 2D/3D Registration to Statistical Atlas
Prior statistical information (atlas)
Computational process
Patient-specific model
Applications
• Orthopaedic surgery planning
• Biomechanical analysis
• Hybrid reconstruction
Examples: R. Taylor, J. Yao, O. Sadowsky, G. Chintalapani, O. Ahmad, …
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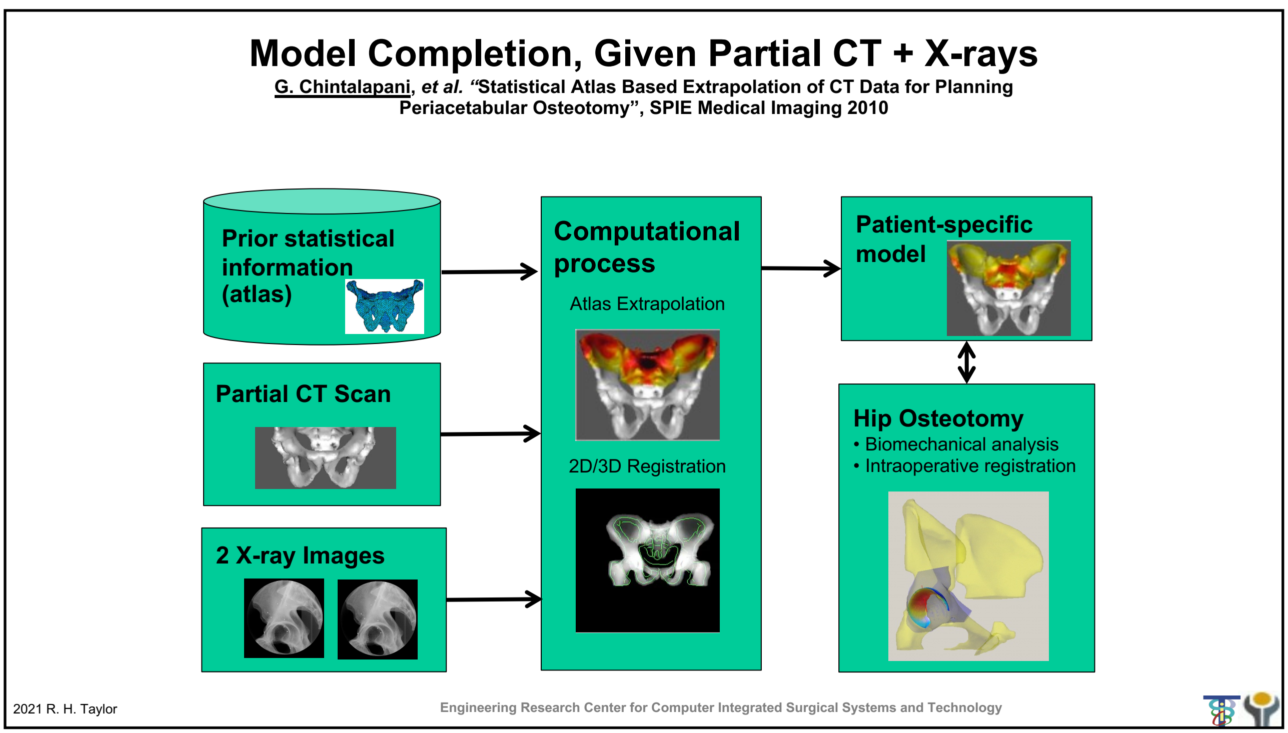
Model Completion, Given Partial CT + X-rays
G. Chintalapani, et al. "Statistical Atlas Based Extrapolation of CT Data for Planning Periacetabular Osteotomy", SPIE Medical Imaging 2010
Prior statistical information (atlas)
Partial CT Scan
2 X-ray Images
Computational process
Atlas Extrapolation
2D/3D Registration
Patient-specific model
Hip Osteotomy
• Biomechanical analysis
• Intraoperative registration
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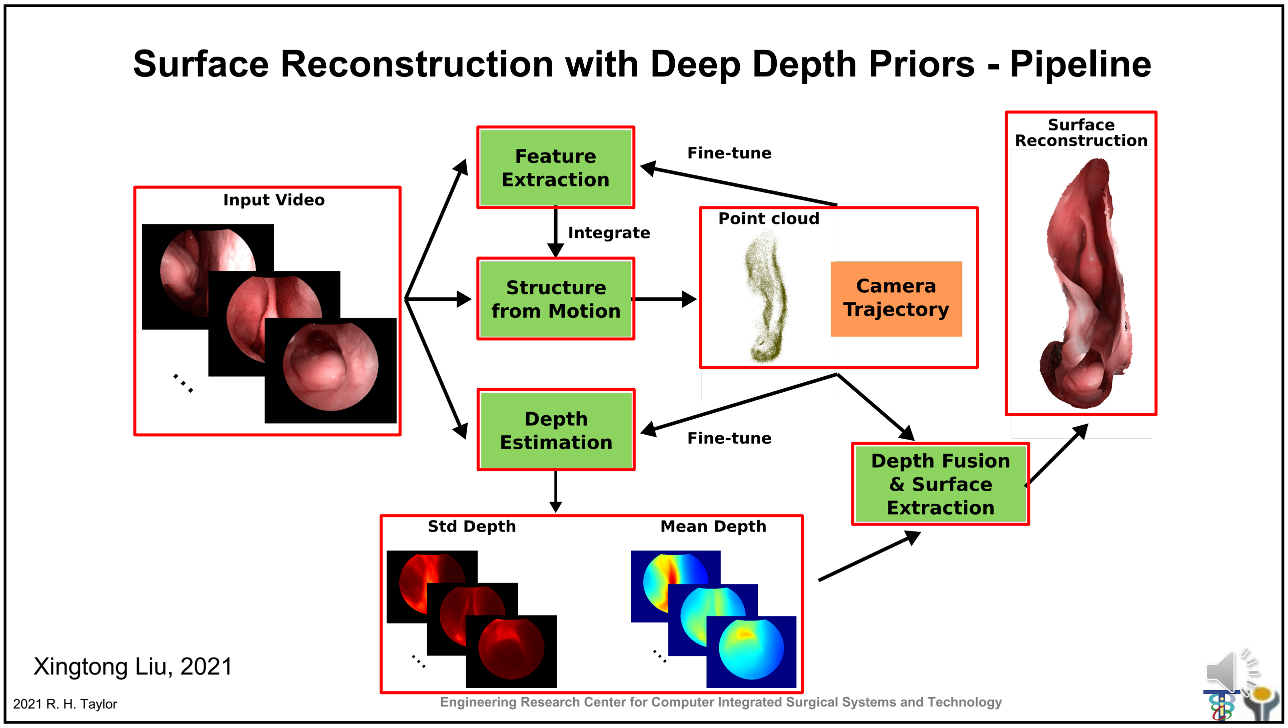

Surface Reconstruction with Deep Depth Priors - Pipeline
Input Video
Feature Extraction
Fine-tune
Integrate
Structure from Motion
Point cloud
Camera Trajectory
Surface Reconstruction
Depth Estimation
Fine-tune
Depth Fusion & Surface Extraction
Std Depth
Mean Depth
Xingtong Liu, 2021
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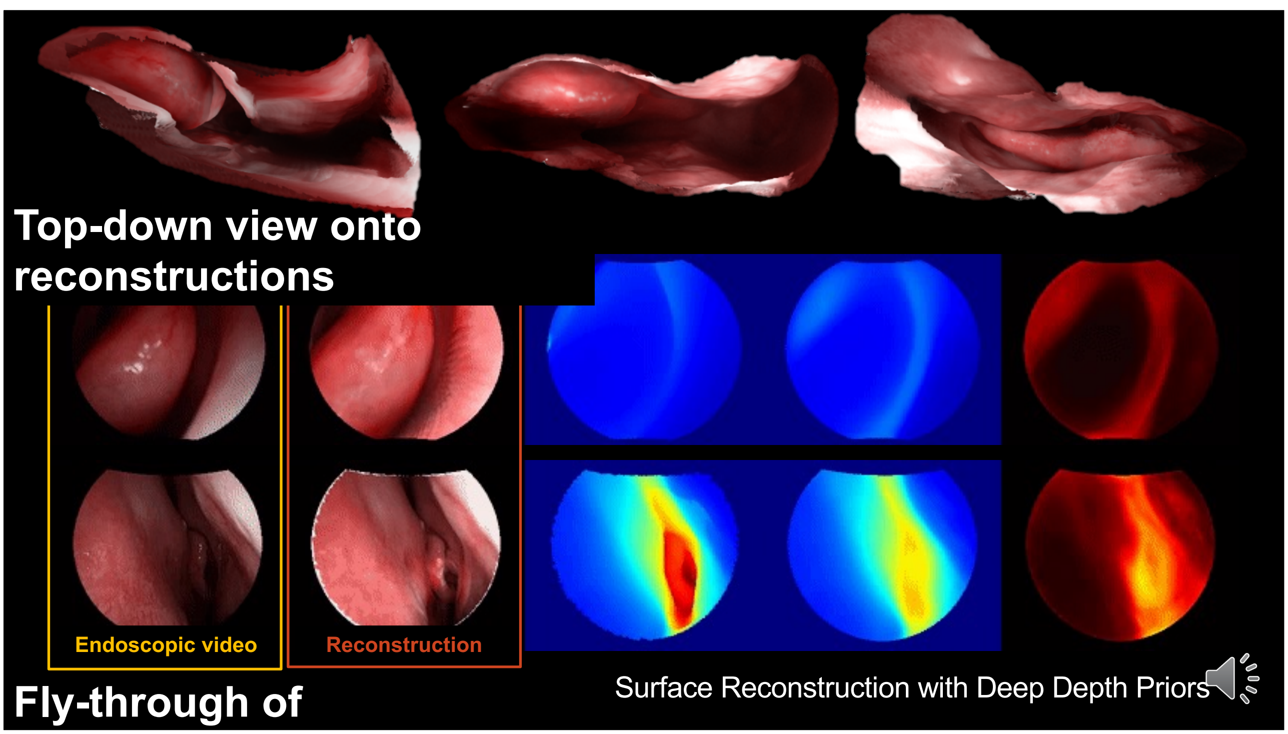

Top-down view onto reconstructions
Endoscopic video
Reconstruction
Fly-through of
Surface Reconstruction with Deep Depth Priors

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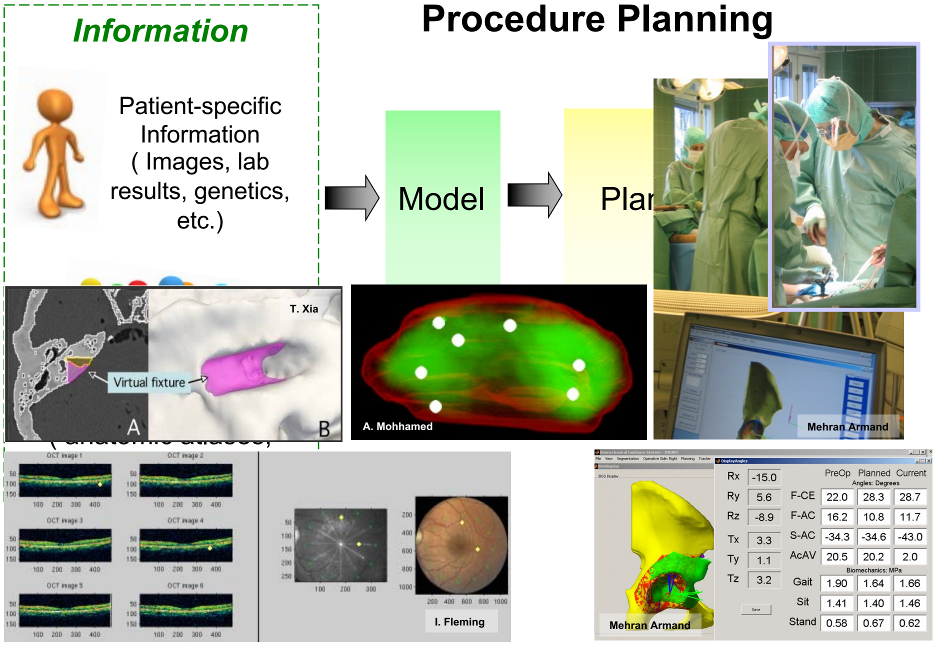
Procedure Planning



Procedure Planning

- **Highly procedure-specific**
- **Occurs at many time scales**
  - Preoperative
  - Intraoperative
  - Preop. + intraop. update
- **Typically based on images or segmented models**
- **May involve:**
  - Optimization
  - Simulations
  - Visualization & HCI

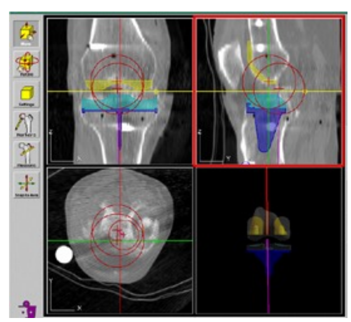


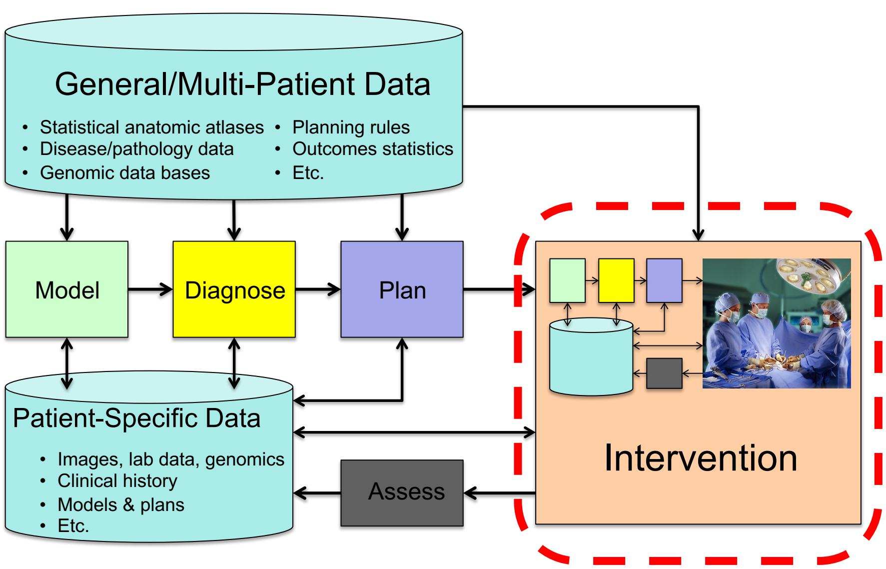
Photo: Integrated Surgical Systems

Procedure Planning

- **Typical outputs**
  - Target positions (seeds, biopsies, ablation sites, etc.)
  - Tool paths
  - Desired geometric relationships
  - Key-frame visualizations
  - Images, models & control parameters
- **Emerging themes**
  - Atlas-based planning
  - Statistical process control & integration of outcomes into plans
  - Dynamic, interactive replanning

Photos: Mehran Armand

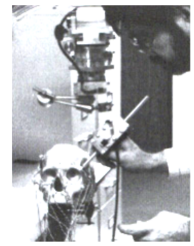
Procedure Execution



Procedure Execution

- **Highly procedure-specific**
- **Don't always have a robot**
  - Surgical Navigation
  - Image Overlay
- But robots can transcend human limitations
  - to make procedures less invasive,
  - more precise,
  - more consistent,
  - and safer

Medtronic



Taylor

Masamune, Fischer, Deguet, Csoma, Taylor, Sauer, Iorchidata, Masamune, Zinreich, Fichtinger, …

Procedure Execution

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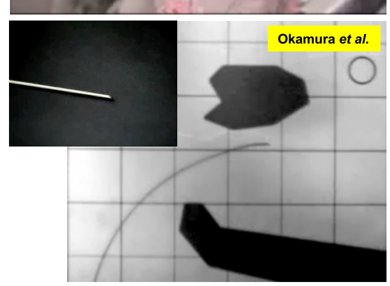

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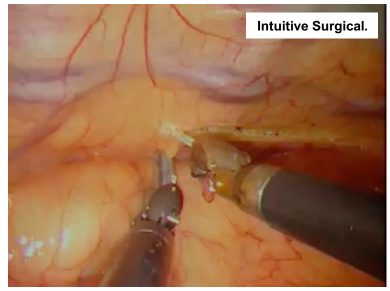

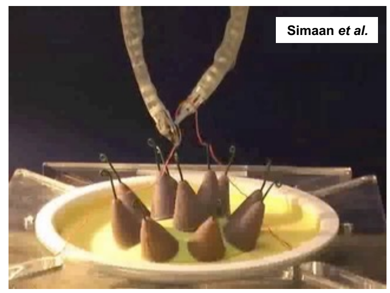

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  - and safer

Taylor, Hager, Handa, Kazanzides, Kang, Iordachita, Gehlbach, *et al.*

Procedure Execution

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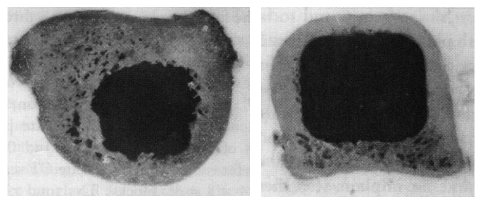

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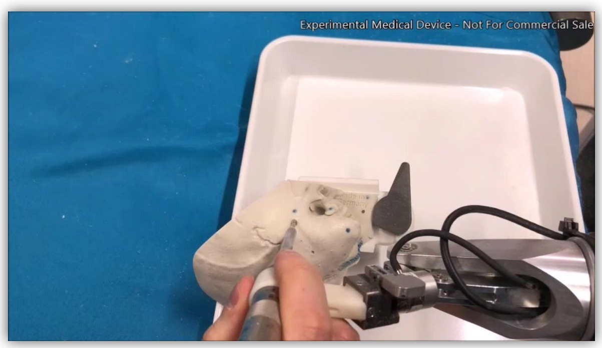
Procedure Execution

GALEN ROBOTICS

- Highly procedure-specific
- Don't always have a robot
  - Surgical Navigation
  - Image Overlay
- **But robots can transcend human limitations**
  - to make procedures less invasive,
  - more precise,
  - more consistent,
  - and safer



Francis X. Creighton, Christopher R. Razavi, Paul R. Wilkening, Rui Yin, Nicholas Lamaison, Russell H. Taylor, John P. Carey, "Image-Guided Mastoidectomy with the Robotic ENT Microsurgery System (REMS)", *AAO Conference*, October 7, 2018.

Disclosure: Under a license agreement between Galen Robotics, Inc. and the Johns Hopkins University, Dr. Taylor and the University are entitled to royalty distributions on technology related to technology described in the study discussed in this publication. Dr. Taylor also is a paid consultant to and owns equity in Galen Robotics, Inc. This arrangement has been reviewed and approved by the Johns Hopkins University in accordance with its conflict-of-interest policies.

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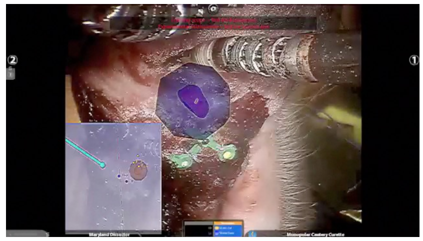
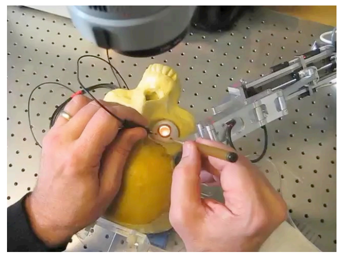
Procedure Execution

- **Intraoperative systems typically combine multiple elements**
  - Imaging
  - Information fusion
  - Robotics
  - Visualization and HMI
- **Issues**
  - Design
  - Imaging compatibility
  - OR compatibility
  - Safety & sterility
  - Intelligent control
  - Human-machine cooperation



W. Liu, J. Sorger, J. Richmon, R. Taylor, *et al*



I. Iordachits, R. Taylor, *et al*

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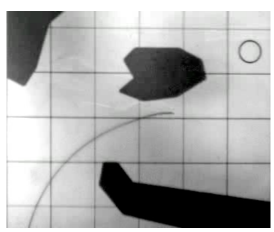
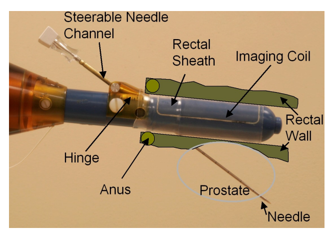
Image-guided needle placement

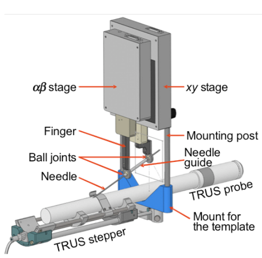
Masamune, Fichtinger, Iordachita, …



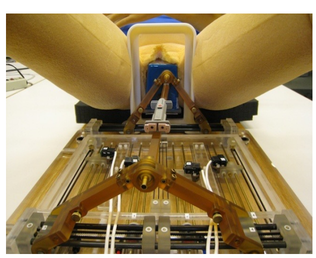
Okamura, Webster, …



Krieger, Fichtinger, Whitcomb, …



Fichtinger, Kazanzides,Burdette, Song …



Iordachita, Fischer, Hata…

Taylor, Masamune, Susil, Patriciu, Stoianovici,…

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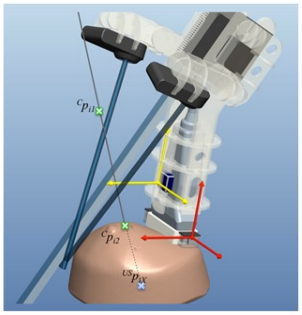
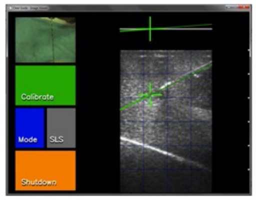
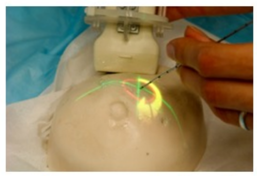
Example: Ultrasound-guided needle placement

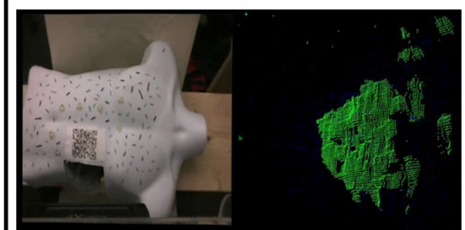




Traditional ultrasound screen AND on-screen guidance overlay



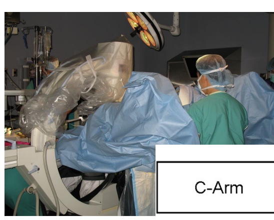
As well as on-patient projection



Real-time multi-modal fusion

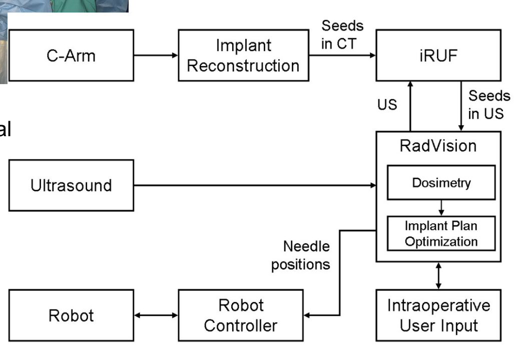
TRUS Robot for Prostate Brachytherapy

Kazanzides, Iordachita, Burdette, Song, et al. *NSF SECO 1246356*

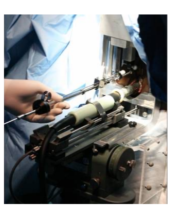


Current efforts:

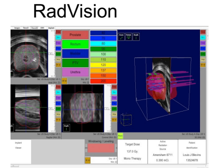
- Integration with RadVision / RUF project
- Needle quick-release mechanism
- Intraoperative user interface (sterile touchscreen)



Robot clinical trial

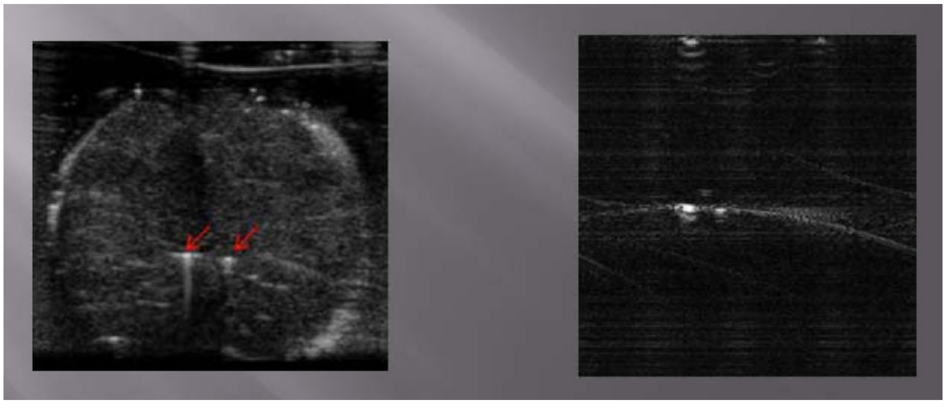


RadVision



Prototype sterile touchscreen: Digital Dash

Prostate brachytherapy seed localization using combined photoacoustic and ultrasound imaging
Boctor/Kang/Prince (JHU), Burdette (AMS)



B-mode PA-mode

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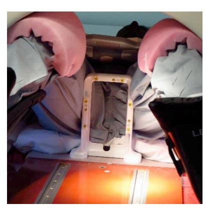
MRI-guided Surgical Manipulator for Transperineal Prostate Interventions - Clinical Workflow

Patient ready on scanner table

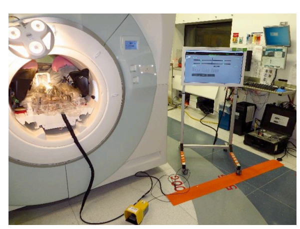


Z-frame in position

Drape robot, attach needle guide

Slide in robot until hit Z-frame

Lock robot in place



Robot ready for targeting

NIH 2R01CA111288: C. Tempany, Iordachita, Fischer, Tokuda, Hata, …

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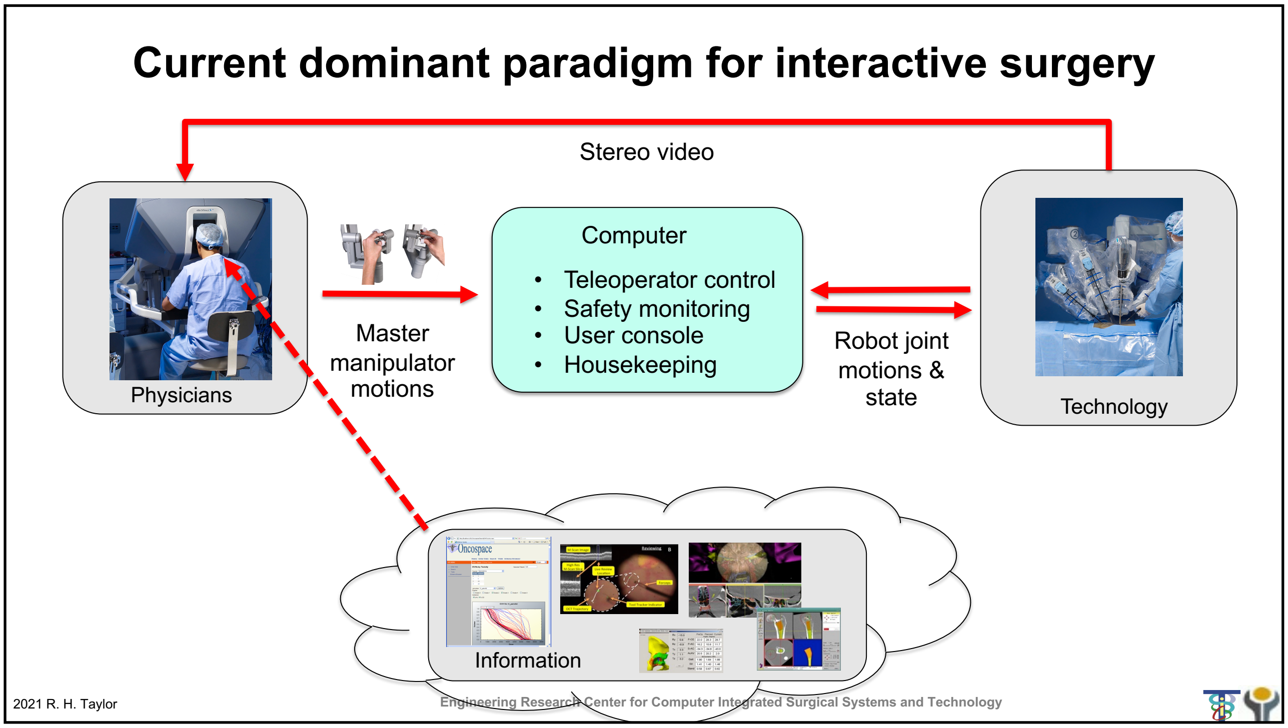
Current dominant paradigm for interactive surgery
Stereo video
Physicians
Master manipulator motions
Computer
• Teleoperator control
• Safety monitoring
• User console
• Housekeeping
Robot joint motions & state
Technology
Information
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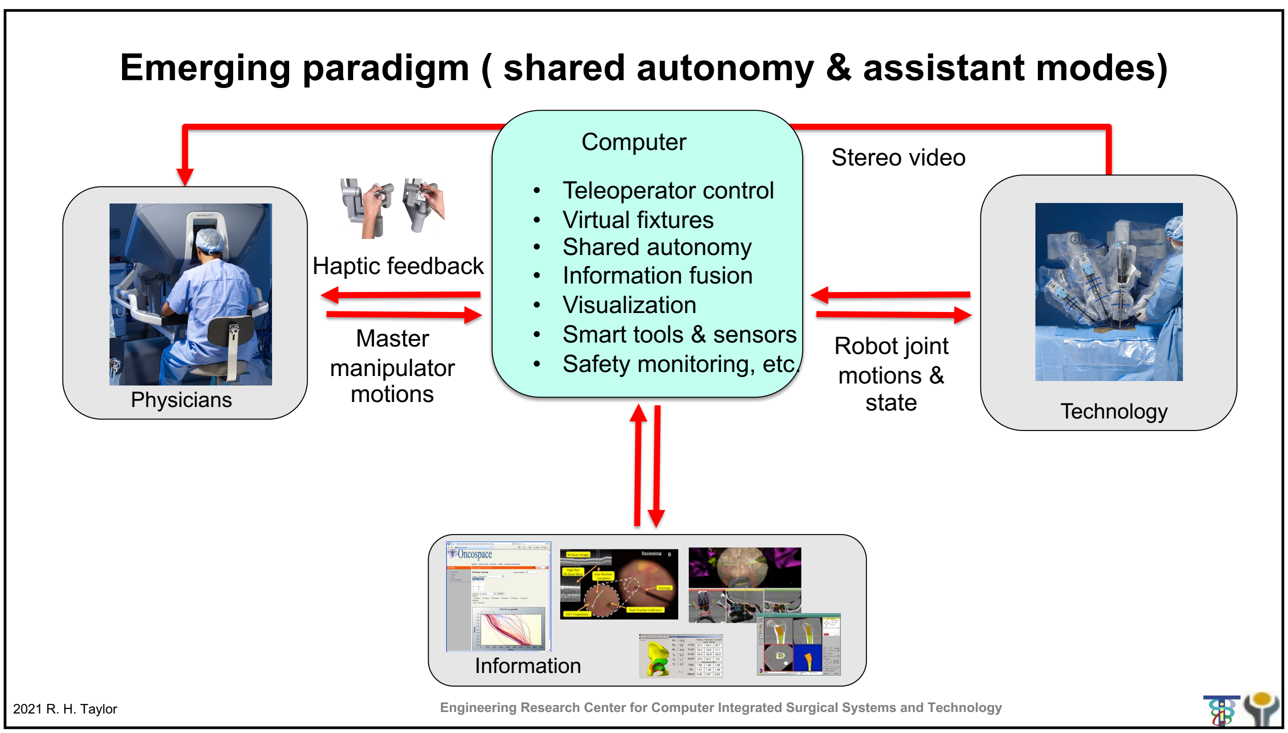
Emerging paradigm (shared autonomy & assistant modes)
Computer
• Teleoperator control
• Virtual fixtures
• Shared autonomy
• Information fusion
• Visualization
• Smart tools & sensors
• Safety monitoring, etc.
Stereo video
Physicians
Haptic feedback
Master manipulator motions
Robot joint motions & state
Technology
Information
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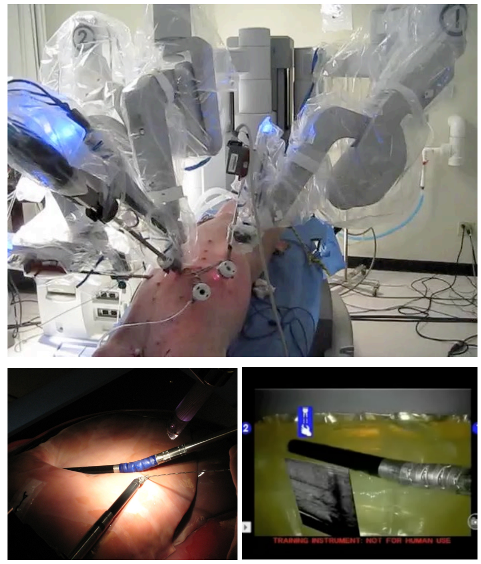
Robotically Assisted Laparoscopic Ultrasound

C. Schneider, P. Peng, R. Taylor, G. Dachs, C. Hasser, S. Dimaio, and M. Choti, "Robot-assisted laparoscopic ultrasonography for hepatic surgery", *Surgery*, Oct 5. (Epub), 2011.

- NIH STTR between CISST ERC and Intuitive Surgical
- Goals
  - Develop dexterous laparoscopic ultrasound instrumentation and software interfaces for DaVinci surgical robot
  - Produce integrated system for LUS-enhanced robotic surgery
  - Evaluate effectiveness of prototype system for liver surgery
- Approach
  - Custom DaVinci-S LUS tool
  - Software built on JHU/ISI "SAW" interface
- Status
  - Evaluation of prototype by surgeons



Research DaVinci Application – Not for Human Use

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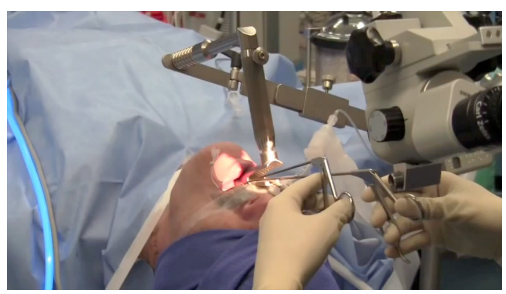
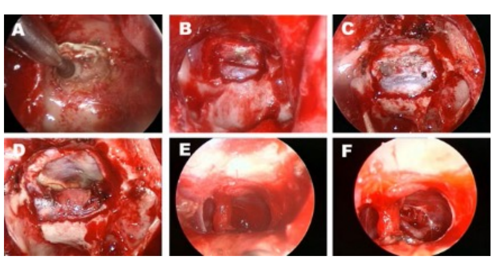
Example: Challenges in Precise Minimally Invasive Head-and Neck Surgery

- Long (25cm) instruments
  - amplify hand tremor
  - reduce precision
- Tight spaces near sensitive anatomy
- Limited working area





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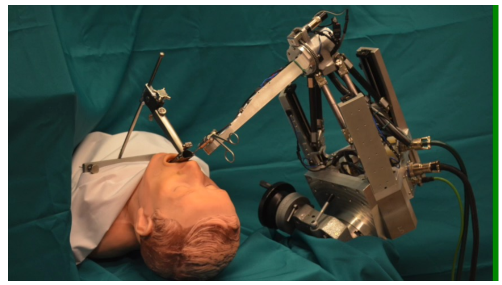
The Robotic ENT Microsurgery System (REMS)



User interface:

- Hands-on control, surgeon “in the game”
- Foot pedal-controlled gain

Technical specs:

- Up to 0.025 mm precision on-demand
- 6 degrees of freedom
- 125x125x125mm work volume
- Calibrated accuracy ~50-150µm

Control modes:

- Free hand
- Remote center of motion
- Virtual fixture avoidance
- Teleoperation

K. Olds, *Robotic Assistant Systems for Otolaryngology-Head and Neck Surgery,* PhD thesis in Biomedical Engineering, Johns Hopkins University, Baltimore, March 2015.

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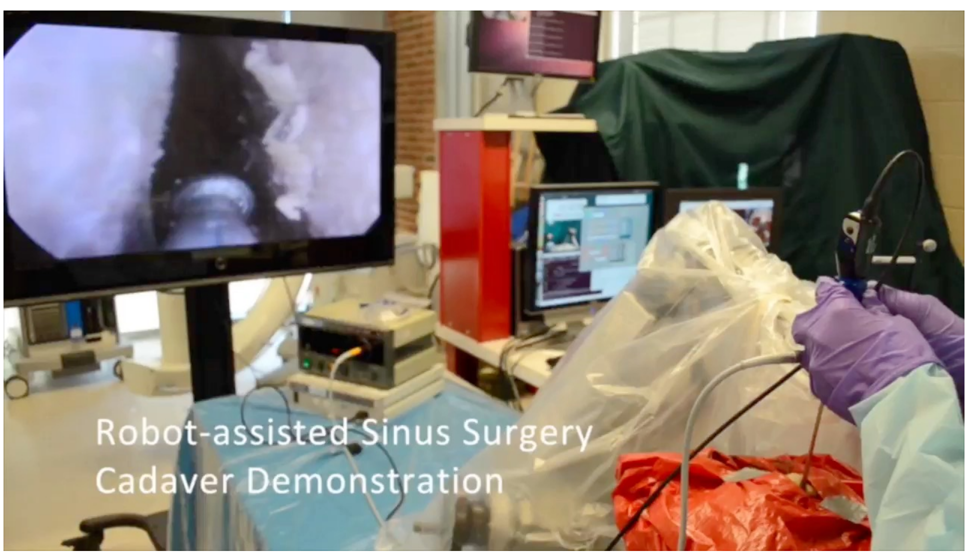
Cadaver Study: Sinus Surgery with Virtual Fixtures



K. Olds, M. Balicki, M. Ishii, R. Taylor

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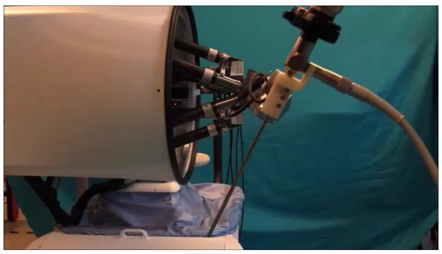
GALEN ROBOTICS

The Galen Platform

Technology:
- Custom 5-DOF architecture
- “Steady Hand” cooperative control
- Hand tremor cancellation
- Virtual fixtures



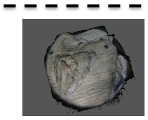
Ease of Use:
- Same footprint as a person
- Accommodates standard instruments
- Minimal change to existing surgical workflow

Broad Applications:
- ENT, spine, brain, trauma, ….

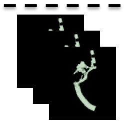
Disclosure: Under a license agreement between Galen Robotics, Inc. and the Johns Hopkins University, Dr. Taylor and the University are entitled to royalty distributions on technology related to technology described in the study discussed in this publication. Dr. Taylor also is a paid consultant to and owns equity in Galen Robotics, Inc. This arrangement has been reviewed and approved by the Johns Hopkins University in accordance with its conflict-of-interest policies.

A “smart” skull base surgical assistant

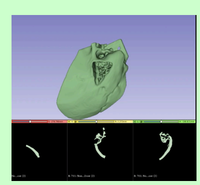
Stereo Video



3D Point Cloud



Patient CT



Registered and updated real time model

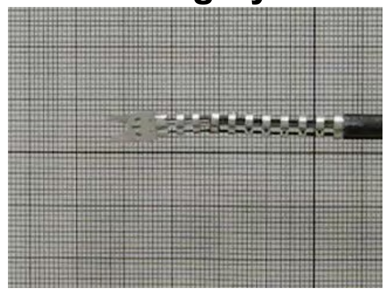
Tool tracking

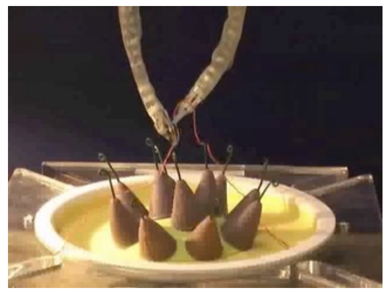
Assistance Modes & Virtual fixtures
Navigation
Advanced Visualization
Learning & Training

Max Li, Russ Taylor, Mathias Unberath, Francis Creighton,

Snake-like robot for minimally invasive surgery

- **Goals**
  - Develop scalable robotic devices for high dexterity manipulation in confined spaces
  - Demonstrate in system for surgery in throat and upper airway
- **Approach**
  - "Snake-like" end effectors with flexible backbones and parallel actuation
  - Integrate into 2-handed teleoperator system with optimization controller
- **Status**
  - Licensed to industry partner
  - Significant research at Vanderbilt
- **Funding**
  - NIH R21, CISST ERC, JHU, Columbia
  - NIH proposals pending





R. Taylor, N. Simaan, *et al.*

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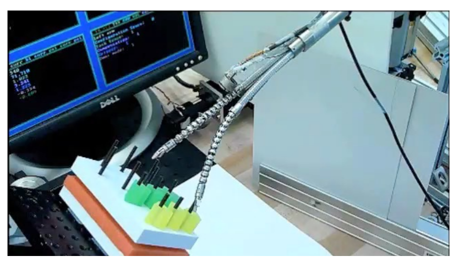
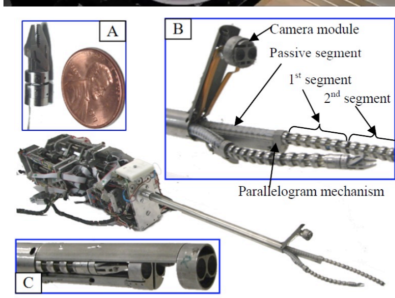
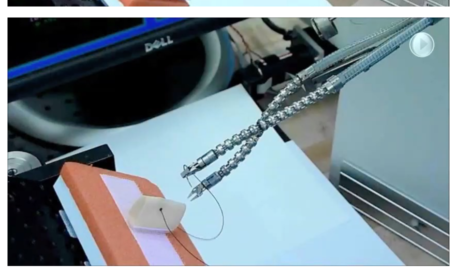
Single Port Access Surgery

Nabil Simaan (Vanderbilt, Columbia), with P. Allen (Columbia), D. Fowler (Columbia)







New technology finally allows true evaluation of the potential of single port access surgery. Systems raise new questions about control and telemanipulation infrastructure/cooperative control.

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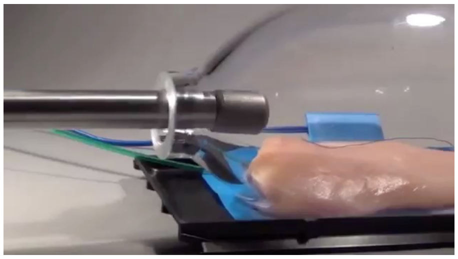
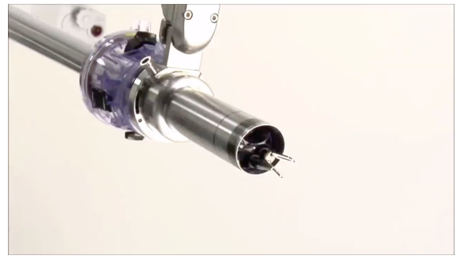
Single Port Access Robotic Surgery



Titan Medical Sport

https://www.youtube.com/watch?v=jIvjvcKA6xQ



Intuitive Surgical Sp

https://www.youtube.com/watch?v=-jm63JdTrp4

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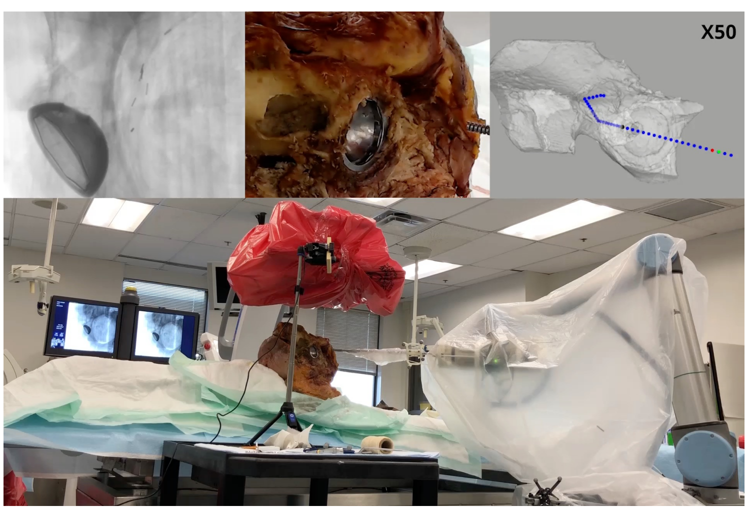
Treatment of Osteolysis Through the Acetabular Implant Screw Holes



Sefati et al, *IEEE TRO*, 2021

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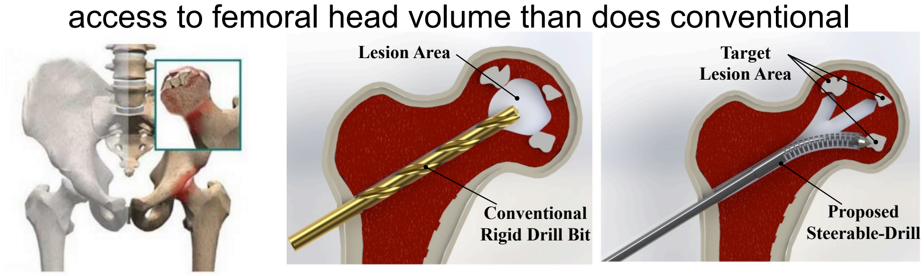
Curved Drilling of the Femoral Head

- Osteonecrosis of the femoral head
  - More than 20,000 patients per year
  - To reduce the pressure in the femoral head, core decompression was developed more than three decades ago.
- Steerable “snake” with flexible drill provides better access to femoral head volume than does conventional



Farshid Alambeigi, Yu Wang, Shahriar Sefati, Ryan. J. Murphy, Iulian Iordachita, Russell H. Taylor, Harpal Khanuja, and Mehran Armand, “Curved-Drilling Approach in Core Decompression of the Femoral Head Osteonecrosis Using a Continuum Manipulator”, *Proc. ICRA 2017*

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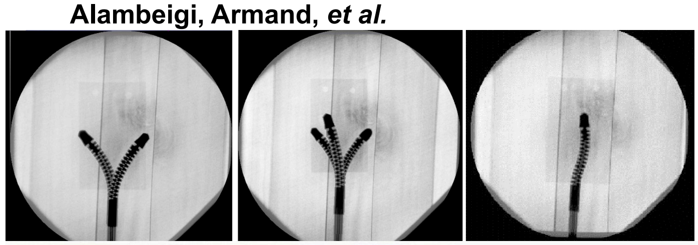
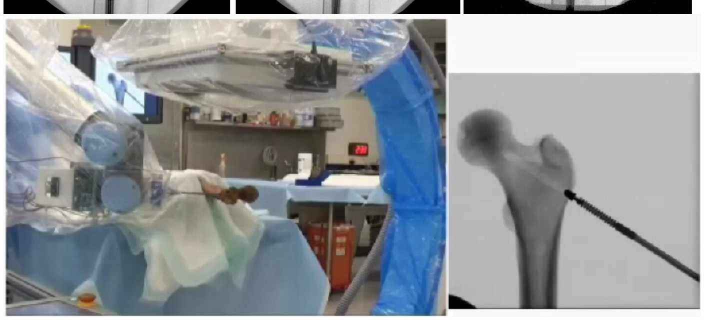
Curved Drilling of the Femoral Head

Alambeigi, Armand, *et al.*

S-Shape and multiple branch curved-drilling



Curved-Drilling Experiments on human cadaver specimens



Farshid Alambeigi, Yu Wang, Shahriar Sefati, Ryan. J. Murphy, Iulian Iordachita, Russell H. Taylor, Harpal Khanuja, and Mehran Armand, “Curved-Drilling Approach in Core Decompression of the Femoral Head Osteonecrosis Using a Continuum Manipulator”, *Proc. ICRA 2017*

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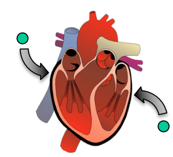
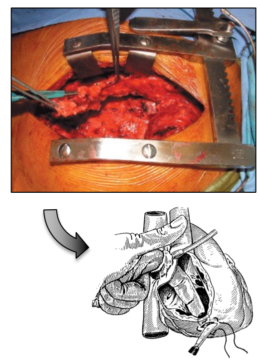
Foreign Bodies in the Heart

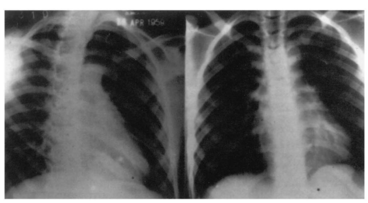
Causes
Thrombi, Shrapnel
Iatrogenic



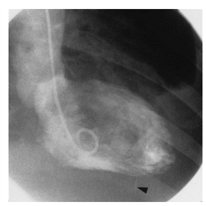
Symptoms
Cardiac Tamponade
Hemorrhage
Arrhythmia
Infection
Shock
Embolism
Valve Dysfunction

Conventional Treatment
Median Sternotomy
Cardiopulmonary Bypass





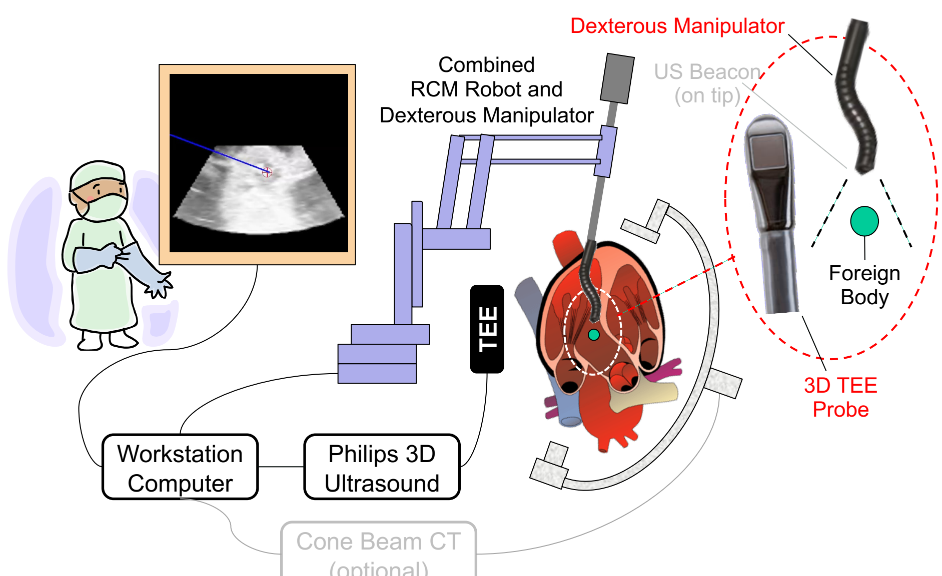
(Actis Dato, 2003)



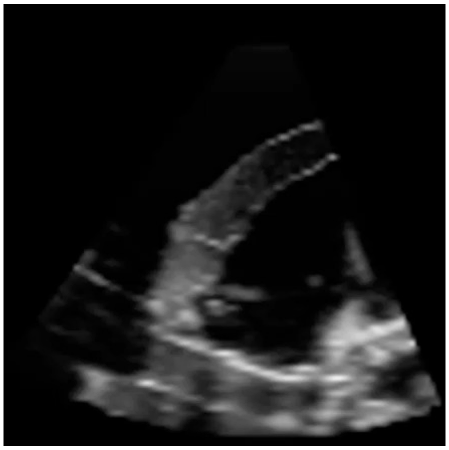
(LeMaire, 1999)

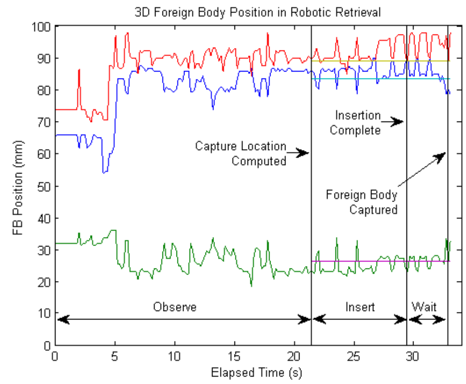
Beating Heart MIS with 3D US Guidance

Paul Thienphrapa, Aleksandra Popovic, Russell Taylor



Retrieval Experiment Results



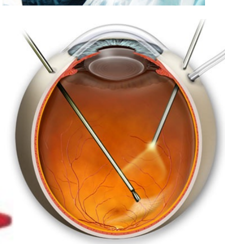


PHILIPS

Thienphrapa *et al. 2013*

Vitreoretinal Microsurgery

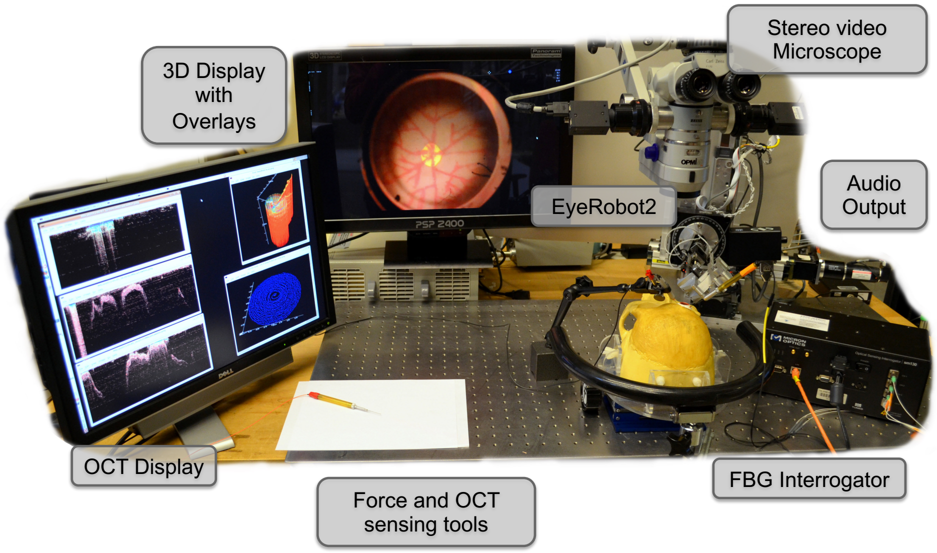
British Journal of Ophthalmology 2004 - Akifumi Ueno et al



www.eyemdlink.com

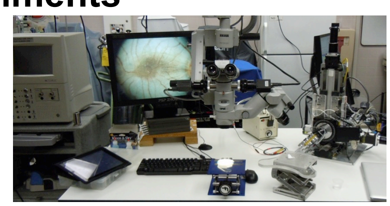
Alcon Vitreosurgery Instrument

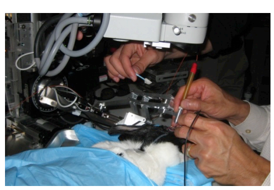
Microsurgery Assistant Workstation

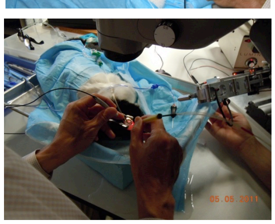


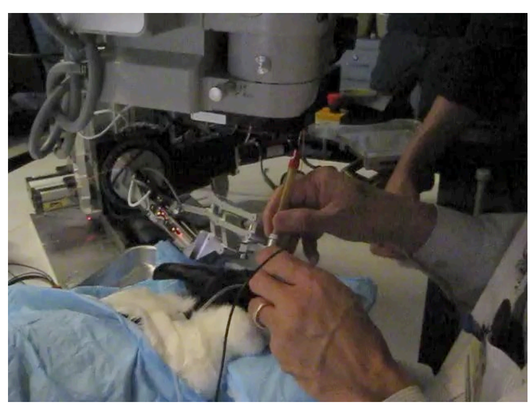
In-Vivo Experiments

- Overall System Performance
- System Ergonomics
- Collect Data
  - Robot / Force / OCT
  - Video / Audio

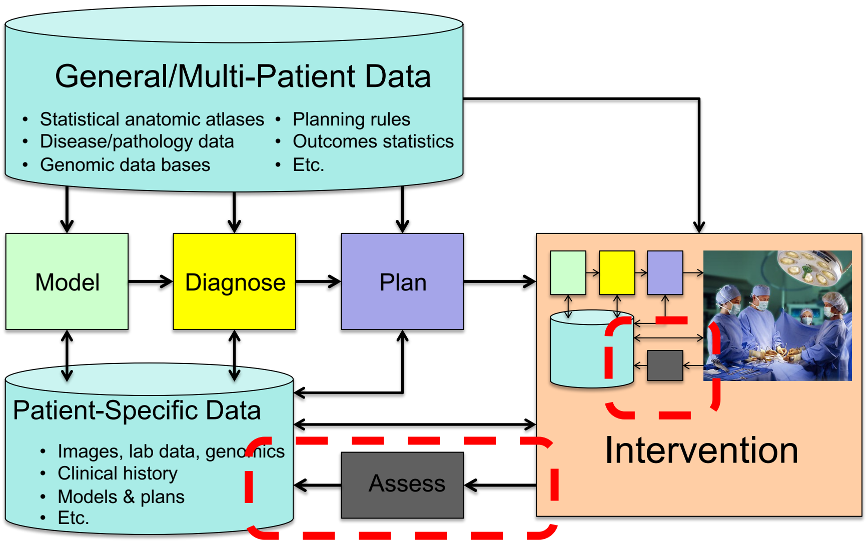








Patient-specific assessment and feedback



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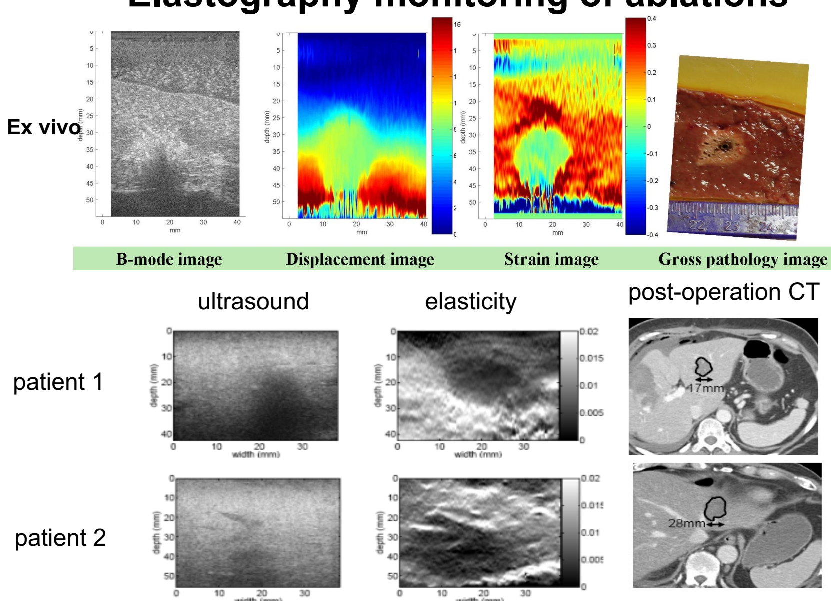
Elastography monitoring of ablations



Credit: Boctor, Rivaz, Choti, Hager, *et al.*

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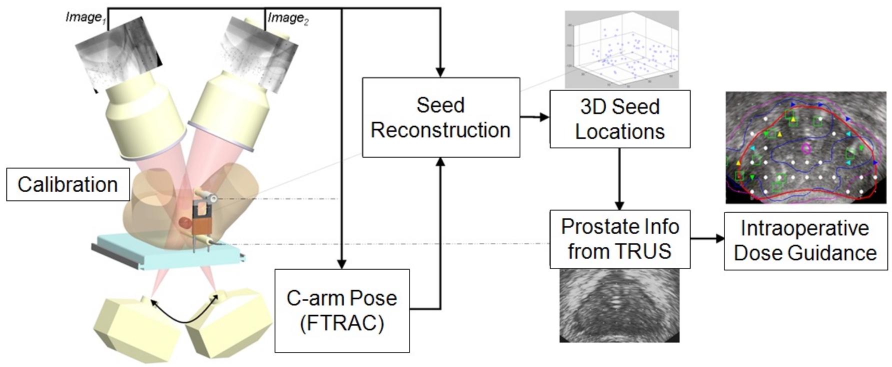
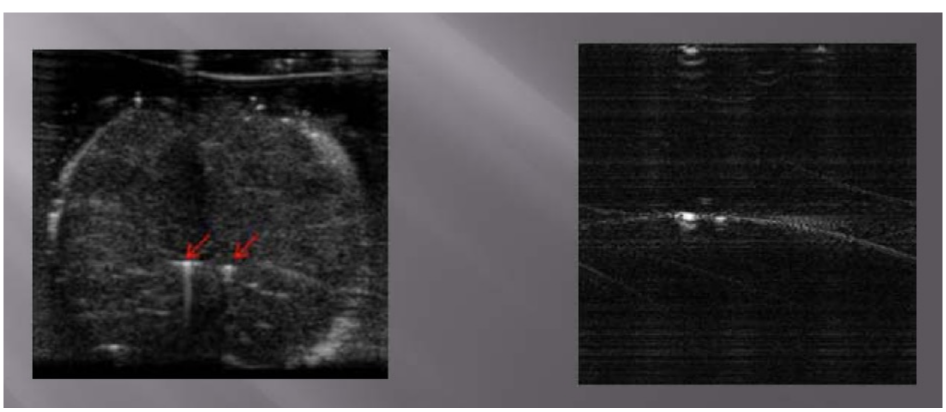
Image-Guided Radiation Therapy - Prostate Brachytherapy

- **Goals:** Provide immediate feedback for use in executing and monitoring implant procedure and for intra-operative treatment optimization.
- **Issues / Themes:** Online imaging, real-time implant reconstruction and multi-modal image registration, visualization/feedback, and dosimetry optimization.



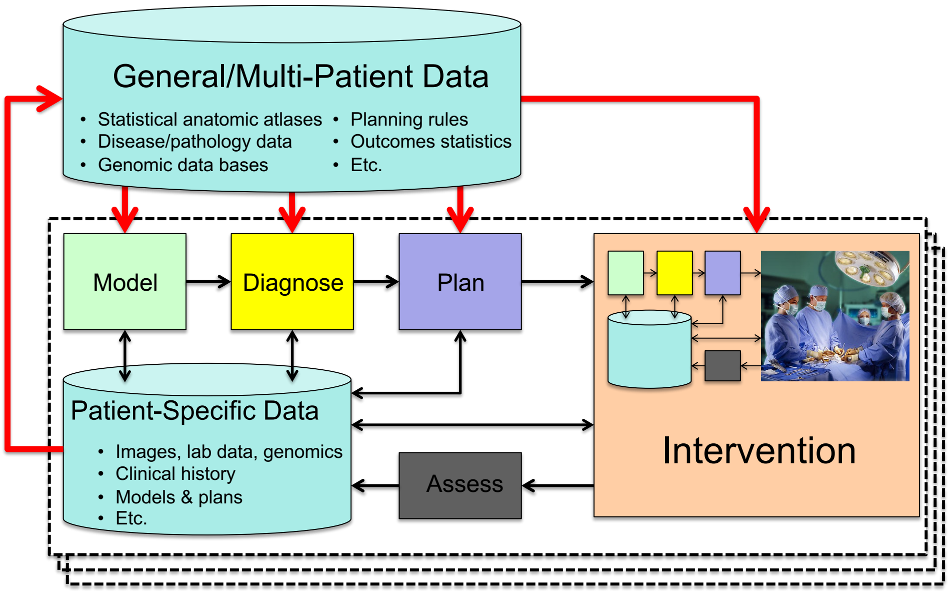
J. Lee, A. Jain, A. Deguet, N. Kuo, M. Ayad, C. Labat, G. Fichtinger, J. Prince, *et al*.

Prostate brachytherapy seed localization using combined photoacoustic and ultrasound imaging Boctor/Kang/Prince (JHU), Burdette (AMS)



B-mode PA-mode

Statistical Analysis and Decision Support



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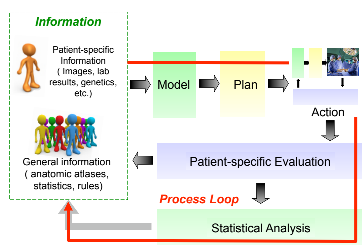
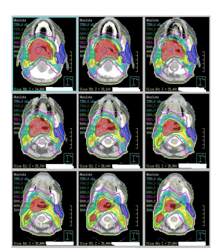
Information-Integrated Process Learning

- **Key idea**
  - Medical robots and CAI systems inherently generate data and promote consistency
  - Eventually, outcomes are known
  - Combine this information over many patients to improve treatment plans / processes
- **Issues / Themes**
  - Very large data bases combining heterogeneous data
  - Statistical modeling of patients, procedures, and outcomes
  - Online tracking of procedures





Credit: Todd McNutt

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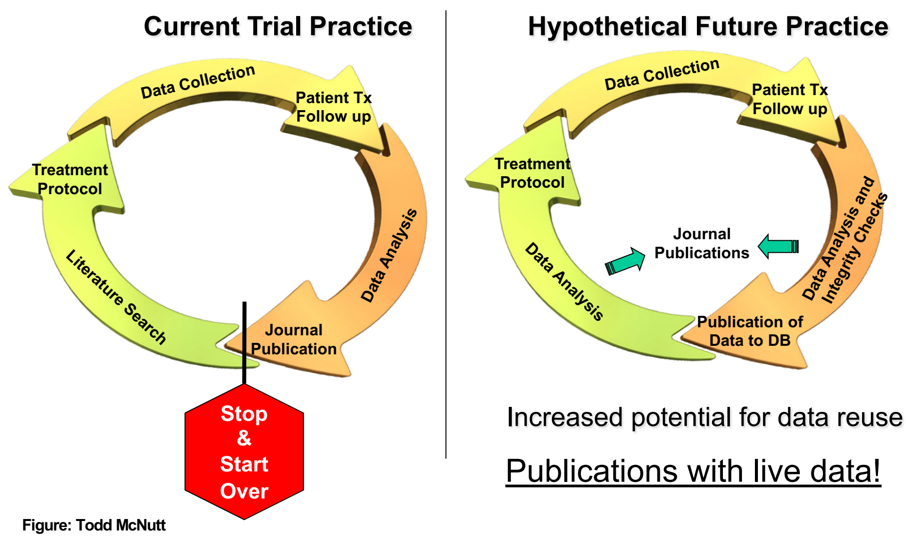
Outer/Population Loop

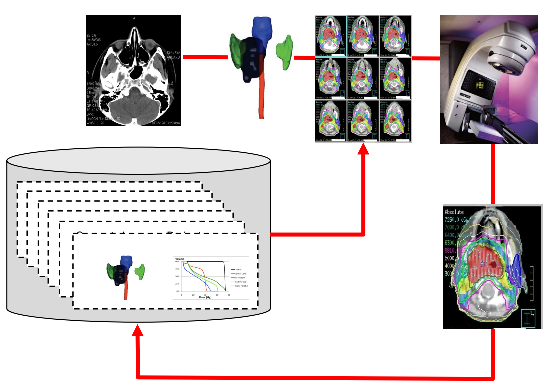


Increased potential for data reuse

Publications with live data!

Figure: Todd McNutt

Statistical process control for radiation therapy

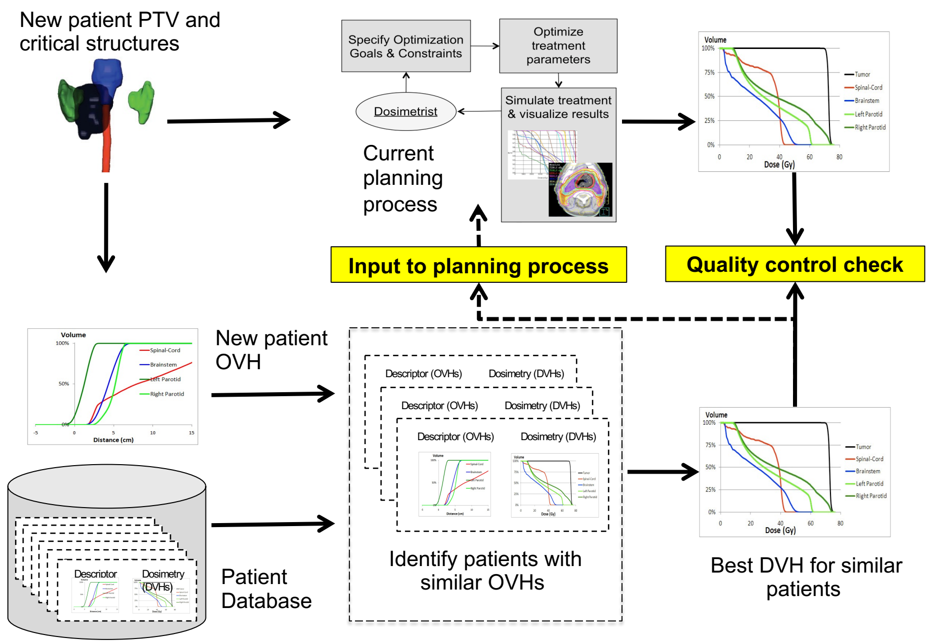


Overall Goal: Use a database of previously treated patients to improve radiation therapy planning for new patients

Team:

- **CS:** R. Taylor, M. Kazhdan, P. Simari, A. King
- **BME:** R. Jacques
- **Rad. Oncology:** T. McNutt, J. Wong, B. Wu, G. Sanguinetti (MD)

Support: Paul Maritz, Philips, JHU internal funds



T. McNutt, B. Wu, M. Kazhdan, P. Simari, A. King, R. Jacques, J. Wong, R. Taylor

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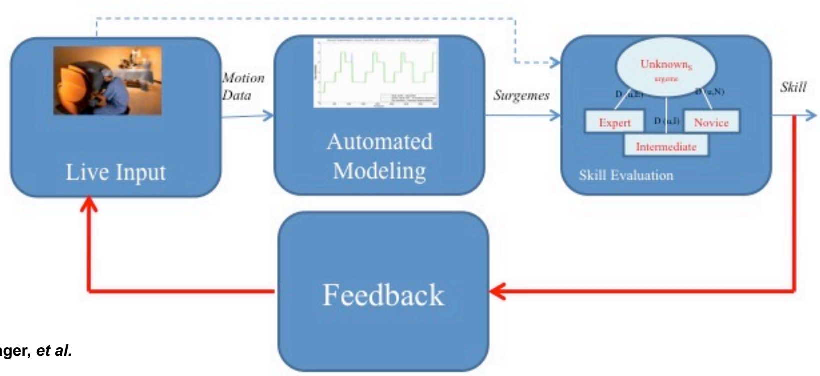
Applications Of Surgical Motion Models

Underlying hypothesis: Learned motion models of experts can be used for teaching, training, and automation of surgical actions.



G. Hager, *et al.*

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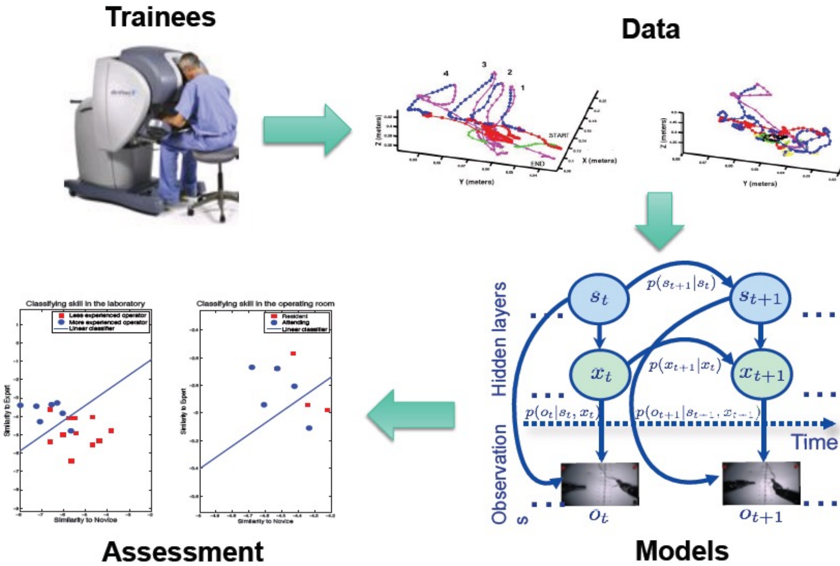
The Language of Surgery

Hager, Khudanpur, Vidal + Chen, Lee, Ishii



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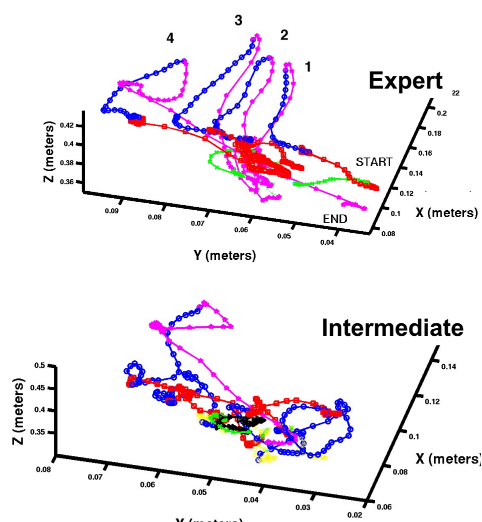
Example: Automatic Detection and Segmentation of Robot-Assisted Surgical Motions

- Goals:
  - Automatic recognition of different surgical motions
  - Comparison of skill level differences between surgeons
- Method
  - Extract features from position and velocity traces
  - Linear discriminant analysis with probabilistic Bayesian classifier



H. Lin, I. Shafran, T. Murphy, D. Yuh, A. Okamura, G. Hager (MICCAI 2005)

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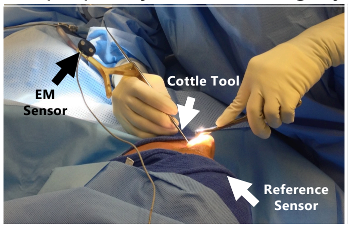
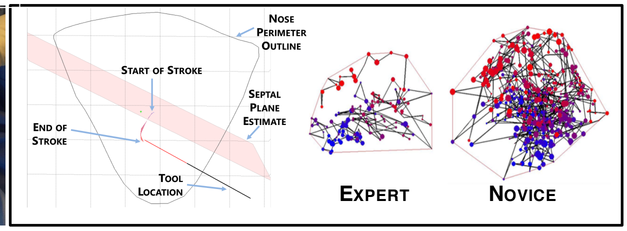
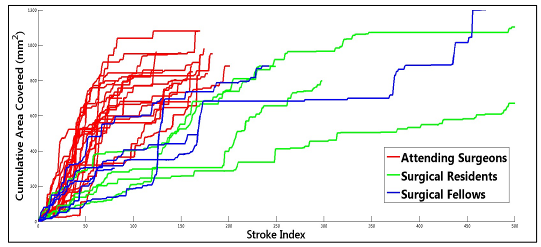
Unstructured surgeries: Discovering “teachable” tactics

Septoplasty: “index” surgery





Automatic Segmentation of Strokes in Nasal Septoplasty

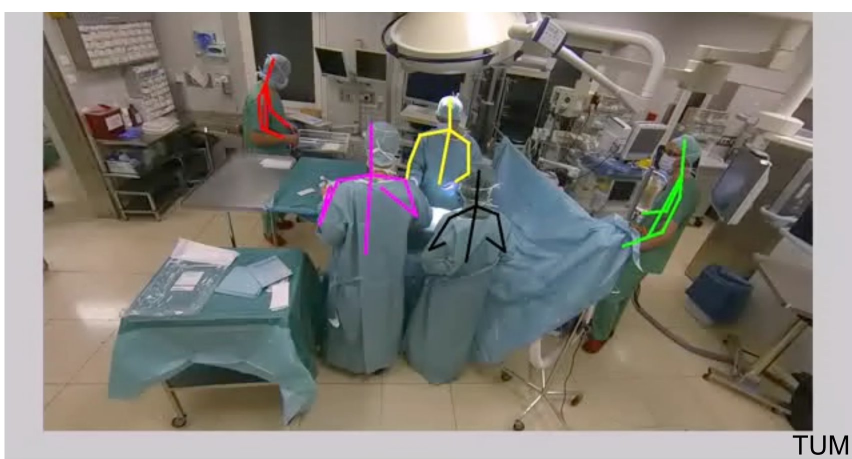


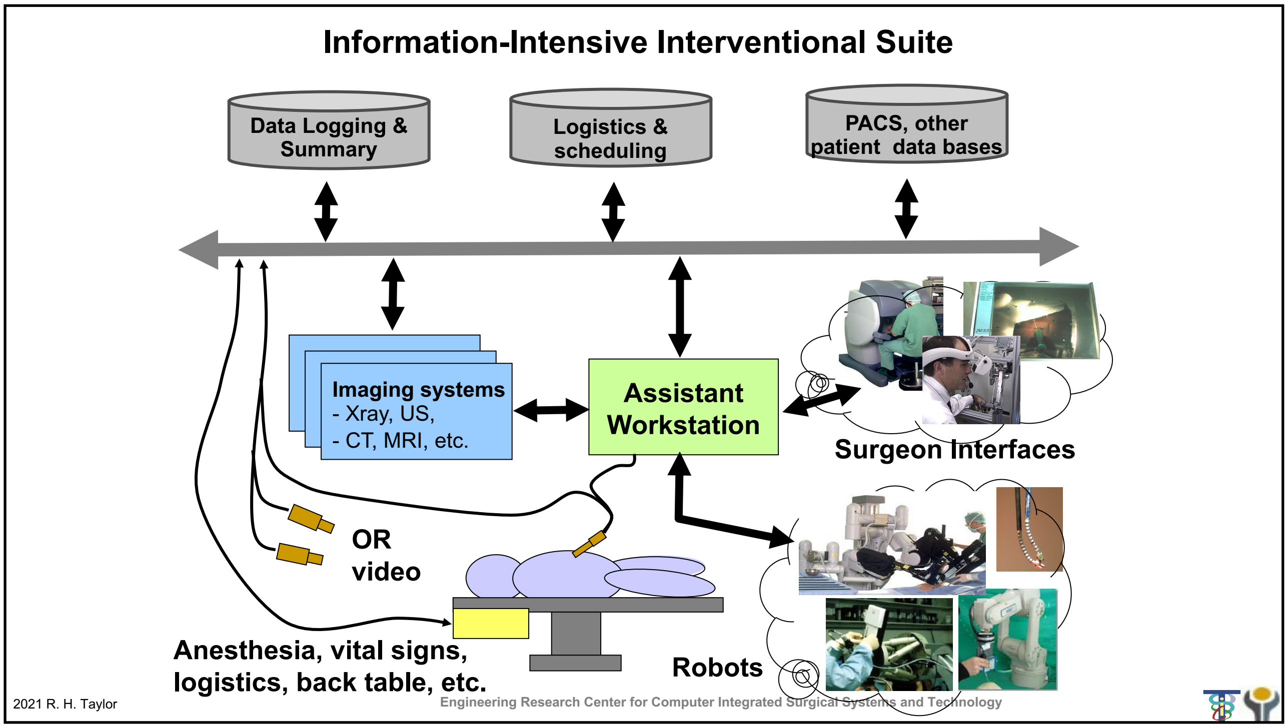
Feedback: Stroke Curvature Consistency: Draw similar-shape curves (instead of straight lines) sequentially
Stroke Duration Consistency: Spend the same amount of time drawing the curves
Coverage Rate: Practice strong enough brushing motions to elevate mucosa

Poddar P., Ahmidi N., Vedula S.S., Ishii, L., Hager G.D., Ishii M.: Automated Objective Surgical Skill Assessment in the Operating Room Using Unstructured Tool Motion. M2CAI 2014.

OR Workflow Observation and Analysis

N. Navab *et al.*




Information-Intensive Interventional Suite
Data Logging & Summary
Logistics & scheduling
PACS, other patient data bases
Imaging systems
- Xray, US,
- CT, MRI, etc.
Assistant Workstation
Surgeon Interfaces
OR video
Anesthesia, vital signs, logistics, back table, etc.
Robots
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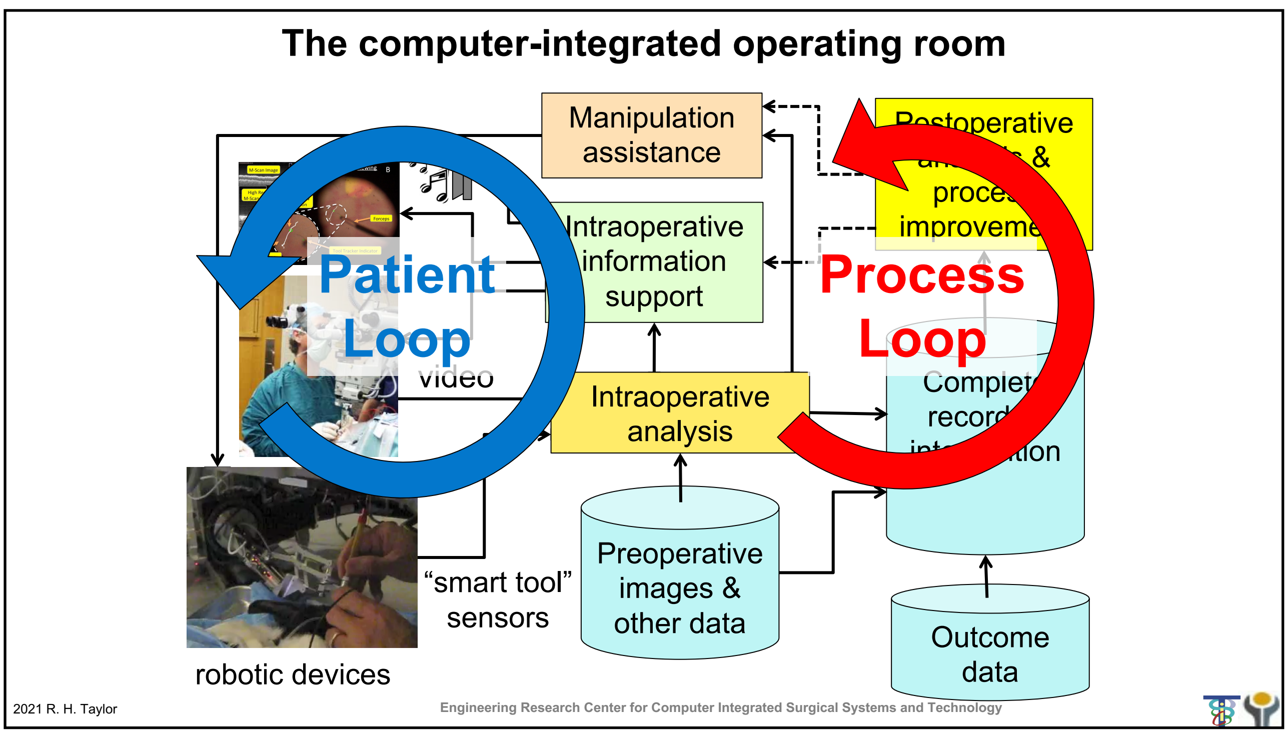
The computer-integrated operating room
Manipulation assistance
Intraoperative information support
Intraoperative analysis
Preoperative images & other data
Outcome data
Patient Loop
Process Loop
video
"smart tool" sensors
robotic devices
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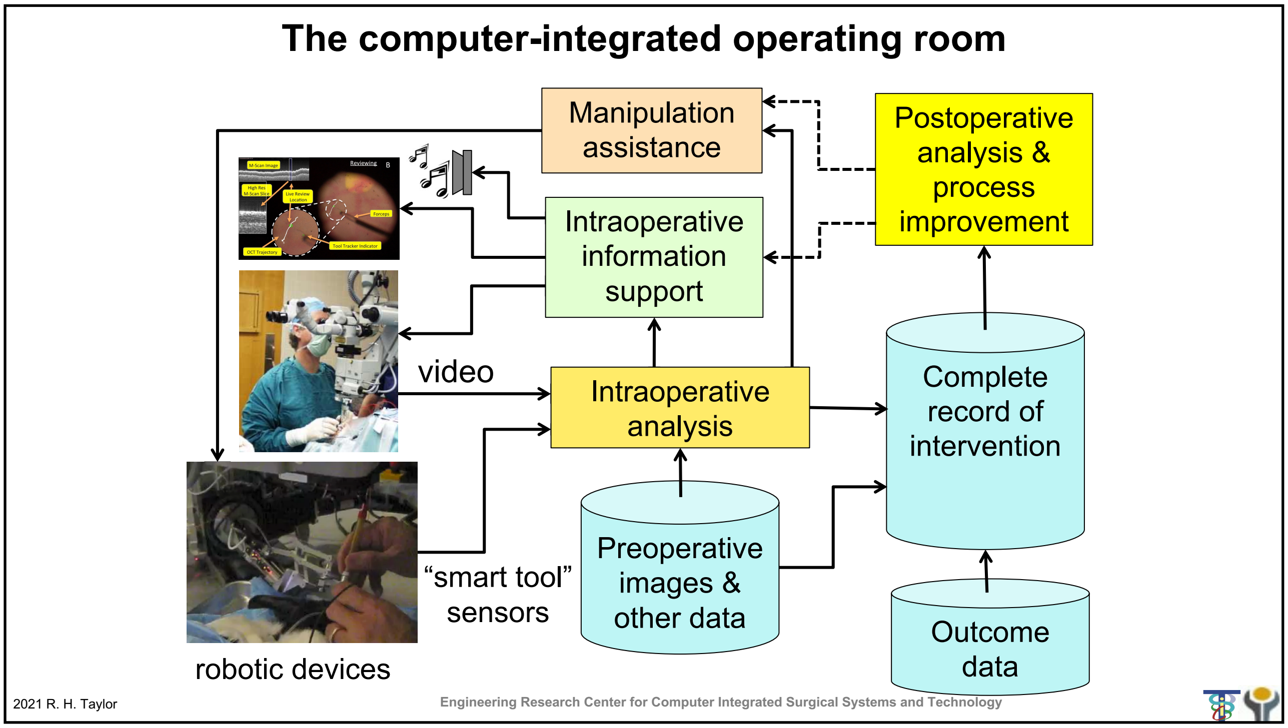
The computer-integrated operating room
Manipulation assistance
Postoperative analysis & process improvement
Intraoperative information support
video
Intraoperative analysis
Complete record of intervention
"smart tool" sensors
Preoperative images & other data
Outcome data
robotic devices
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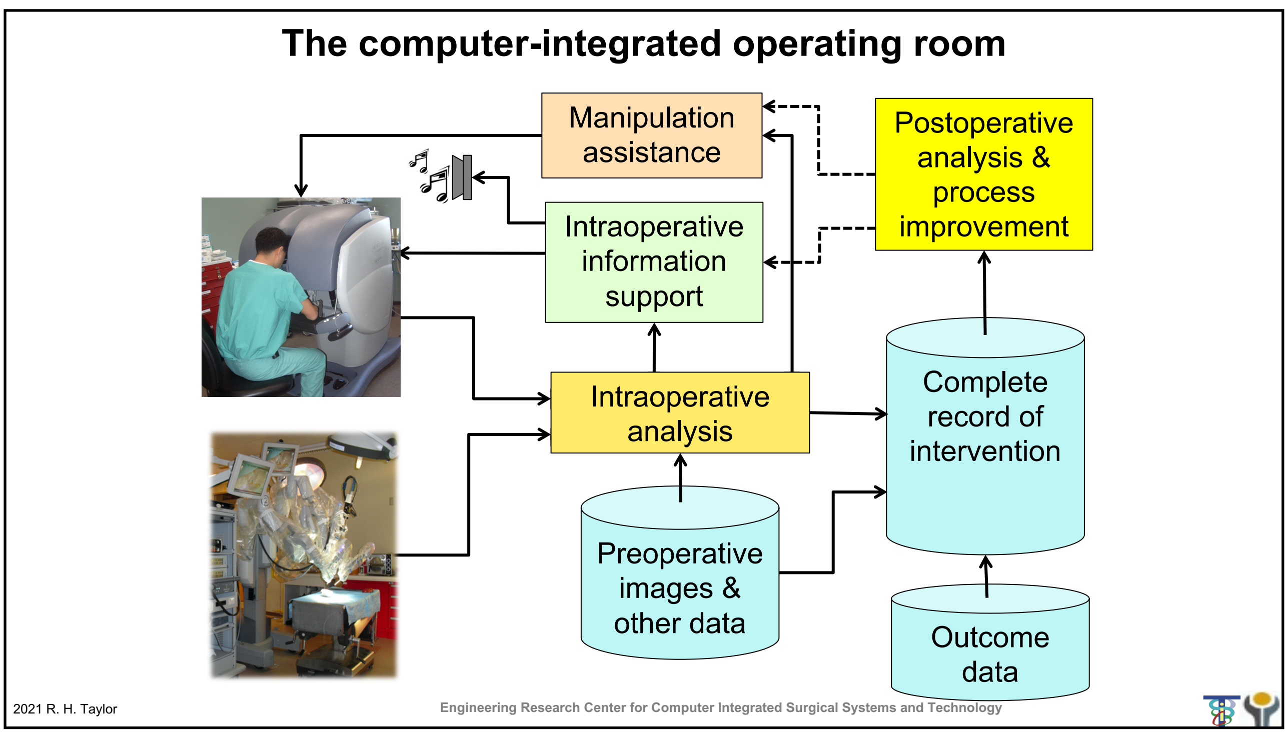
The computer-integrated operating room
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Complete record of intervention
Preoperative images & other data
Outcome data
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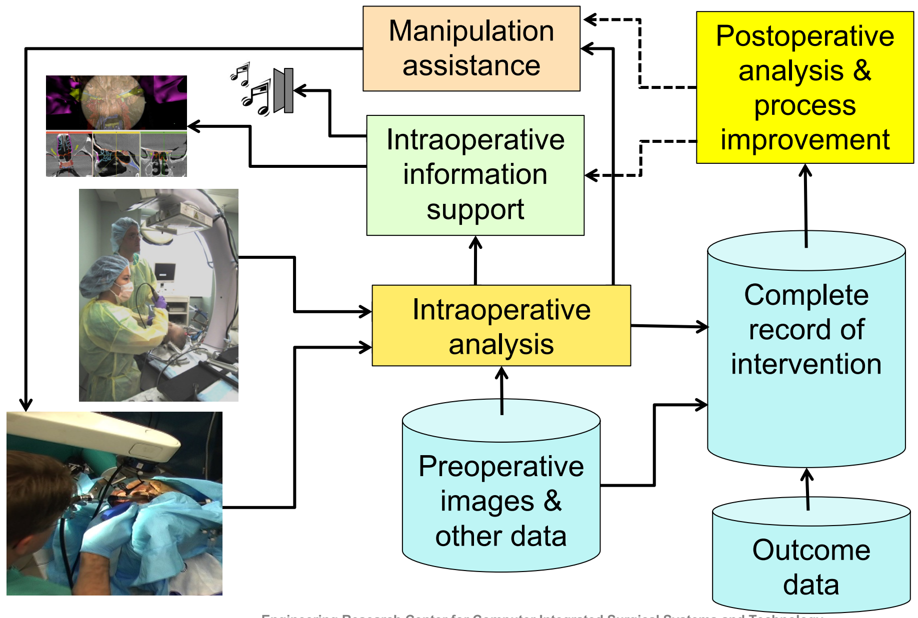
The computer-integrated operating room



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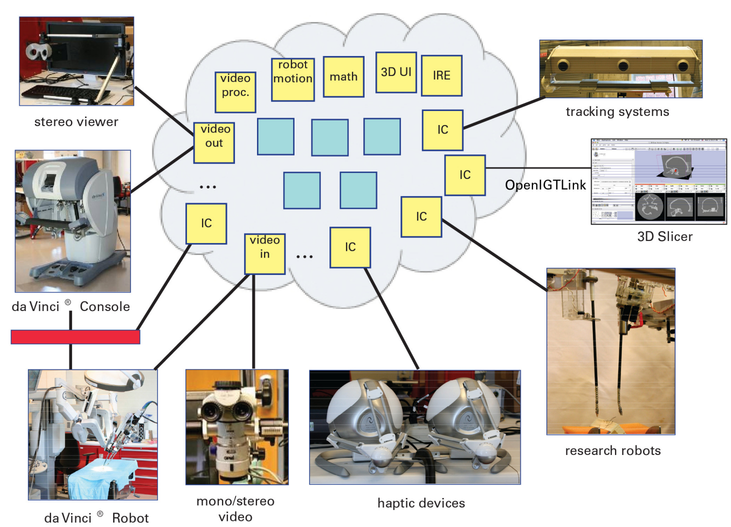
cisst libraries and Surgical Assistant Workstation

https://trac.lcsr.jhu.edu/cisst



Peter Kazanzides, Simon P. DiMaio, Anton Deguet, and many more

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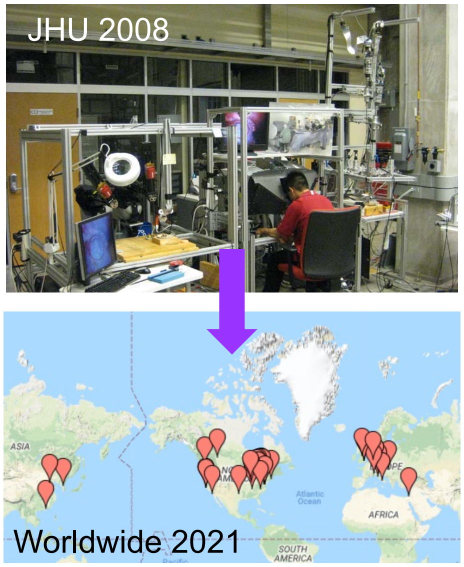
Use Case: da Vinci Research Kit



- Mechanical components from da Vinci “classic” systems
- Donated by Intuitive Surgical to selected academic labs
- Consortium to provide “open source” engineering and support
  - Software – JHU (CISST/SAW)
  - Controller electronics –JHU
  - Interface electronics – ISI
  - Controller power/packaging – WPI
- Controllers and software also adapted for use with complete recycled da Vinci “classic” systems
- 42 systems now deployed around the world
- **http://research.intusurg.com/dvrkwiki/**

General working model

Use clinical applications to provide focus & key problems

- Emphasis on surgery and interventional procedures
- Directly involve clinicians in all stages of research
- Emphasize integration into complete systems
- Point toward clinical deployment

Some current areas include

- Skull base and head-and-neck
- Spine and orthopaedic surgery
- Thoracic surgery
- Abdominal and solid organ procedures (kidney, liver, prostate)
- Vascular & endoluminal
- Microsurgery

Funding models

- NIH, other Government grants
- Collaboration with NIH intramural programs
- Industry partnerships (use master research agreements to facilitate)

The real bottom line: patient care

- Provide new capabilities that **transcend human limitations** in surgery
- Increase **consistency and quality** of surgical treatments
- Promote **better outcomes** and more **cost-effective** processes in surgical practice

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Discussion

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