Robot and Kinect – the future in patient diagnosis and treatment?

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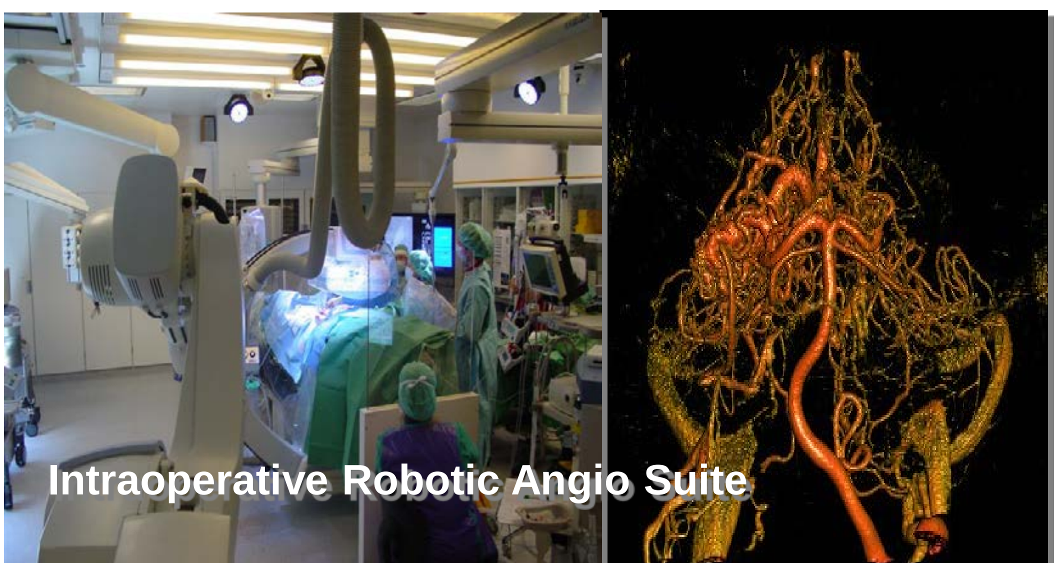
TASKS

DEVELOP NEW PROCEDURES AND METHODS

DEVELOP NEW TREATMENT STRATEGIES

COMPARE NEW AND ESTABLISHED TREATMENT STRATEGIES

STUDY SOCIAL, ECONOMIC AND ORGANIZATIONAL CONSEQUENCES OF NEW METHODS



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Research lines of interest at IVS

- MR-imaging research including functional imaging
- Image processing, image segmentation, visualisation, image registration (rigid/non-rigid), image navigation, Augmented Reality
- Robotics, sensor control, haptic feedback, simulator technology
- Biosensor development, sensor network

Robotics in surgery

- Surgical robots are still in an early stage of development.
- The number of medical applications where surgical robots are used is still limited.
- Robots are restricted to specific tasks within specific procedures.
- Humans must perform all the preparation tasks.
- Lack of haptic feedback in teleoperated systems.
- Almost no automatically performed robotic tasks

A categorization of robotic systems

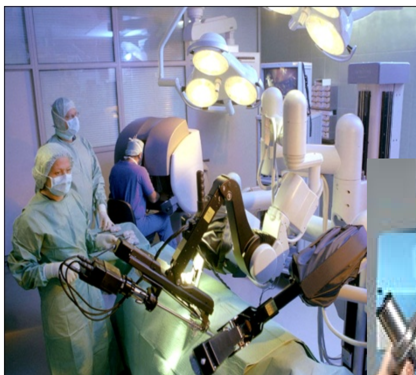
- Industrial robots
- Adaptive sensor controlled robots (Autonome robots)
- Telemanipulators
- Hybride systems (Semi-autonomous manipulators)

Surgical robots

- Surgical robotic systems
  - Image guided robots
  - Surgical telemanipulators
  - Assisting manipulators
  - Micro-/nanorobots

55. SCHURR, M. O., Kunert, W., Neck, J., Voges, U., and Buess, G. F.
Telematics and Telemanipulation in Surgery. Minimally Invasive Therapy & Allied Technologies 1998;7(2):97-103.
56. Dario, P., Guglielmelli, E., Allotta, B., and Carrozza, M. C. Robotics for Medical Applications.
IEEE Robotics & Automation Magazine 1996;3(3):44-56.
57. Davies, B. Robotic Devices in Surgery.
Min Invas Ther & Allied Technol 2003;12(1-2):5-13.

Types of Surgical Robots



Da Vinci (Intuitiv
Surgical)

Acrobot
Sculptor
(Acrobot)

AESOP
(computerMot

Pathfinder
(Prosurgics)

Auxiliary robots

Telesurgical robots

Synergetic Robots

Image-guided surgical robots

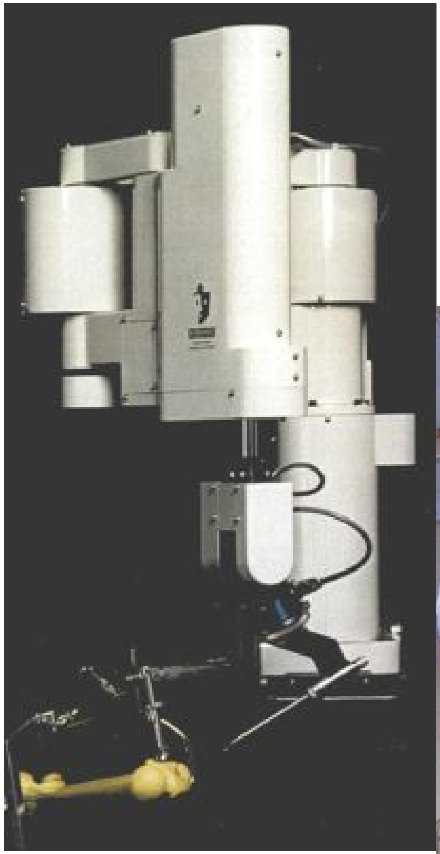
-

Degree of Autonomy

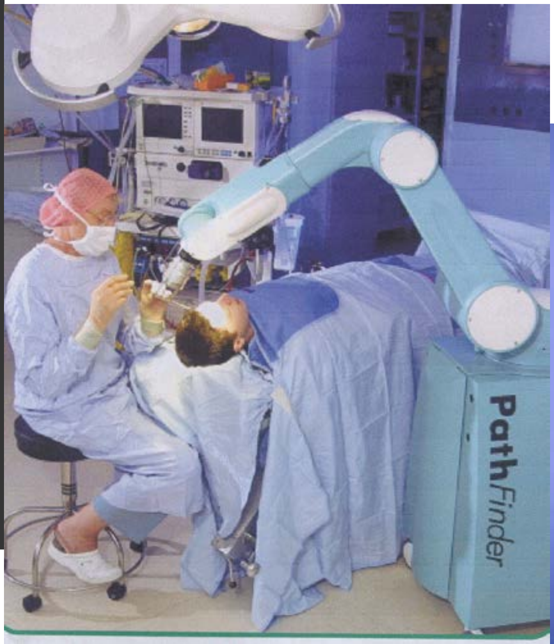
+

Image guided robots

ROBODOC –
Integrated Surgical Systems Inc.



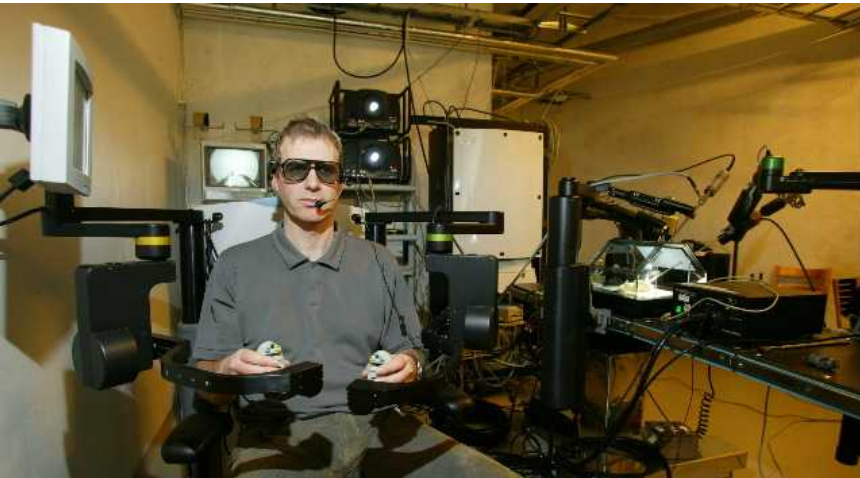
PathFinder –
Armstrong HealthCare Lmt.



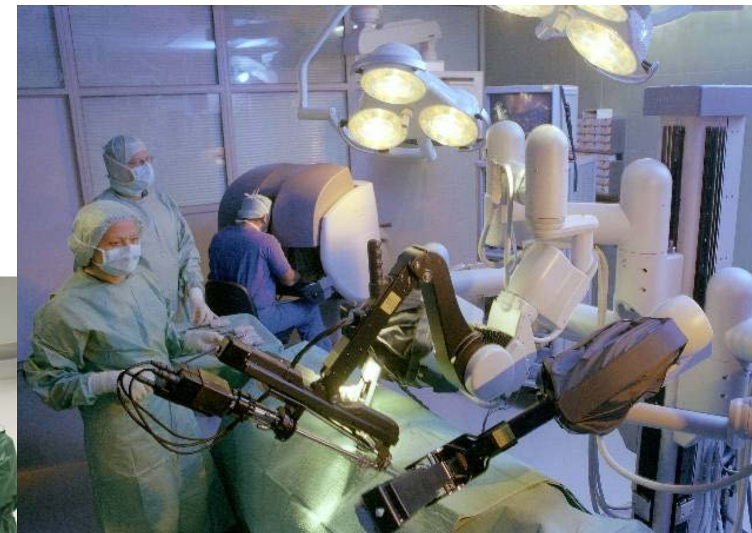
CASPAR - Maquet

Surgical telemanipulators

Zeus-
ComputerMotion Inc.



DaVinci-
Intuitive Surgical Inc.



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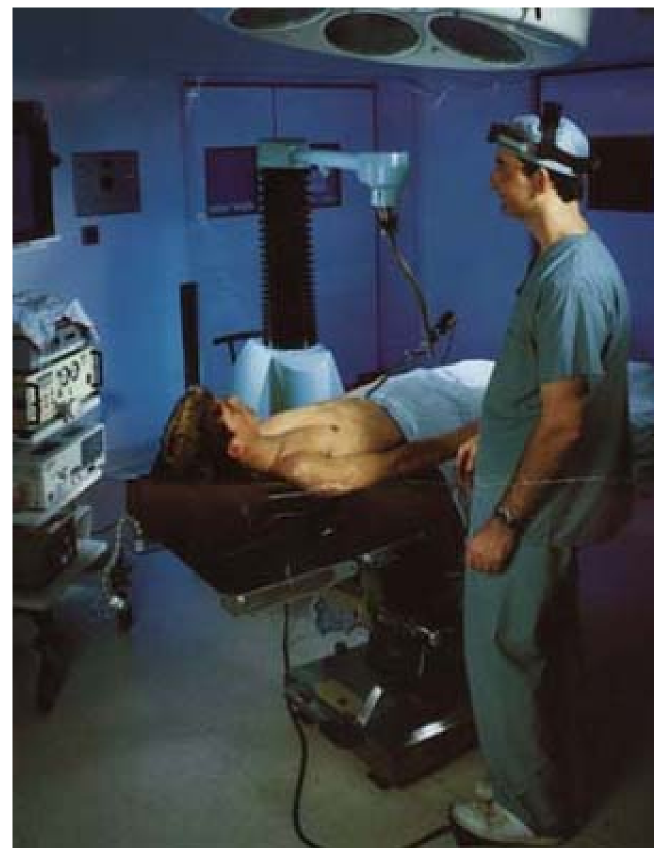
Assisting manipulators – camera holders

Aesop-
ComputerMotion Inc.

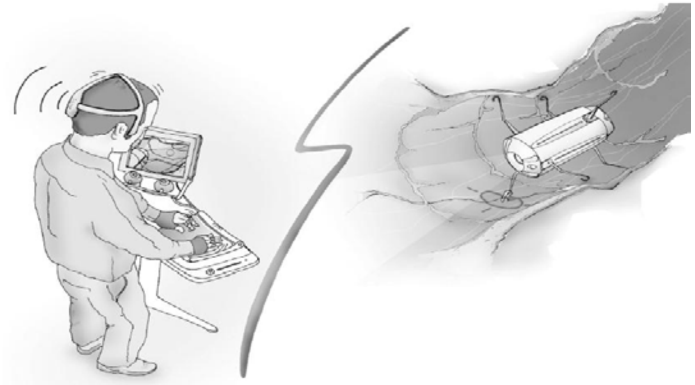
EndoAssist-
Armstrong HeathCare Lmt



Tele-operated Endoscopic Capsule with Active Locomotion

Scuola Superiore Sant'Anna, Italy (research project)

- Designed for diagnosis and therapy of the large bowel
- Patent filed in 2005
- Long-term goal: The 'all onboard philosophy", a capsule robot able to move around equipped with grippers, optics, sensors, RF modules and drug delivery system
- Focus is currently on locomotion inside the lumen
- 3 prototypes built so far
- Third prototype has eight legs, one CMOS camera and measures 40mm in length

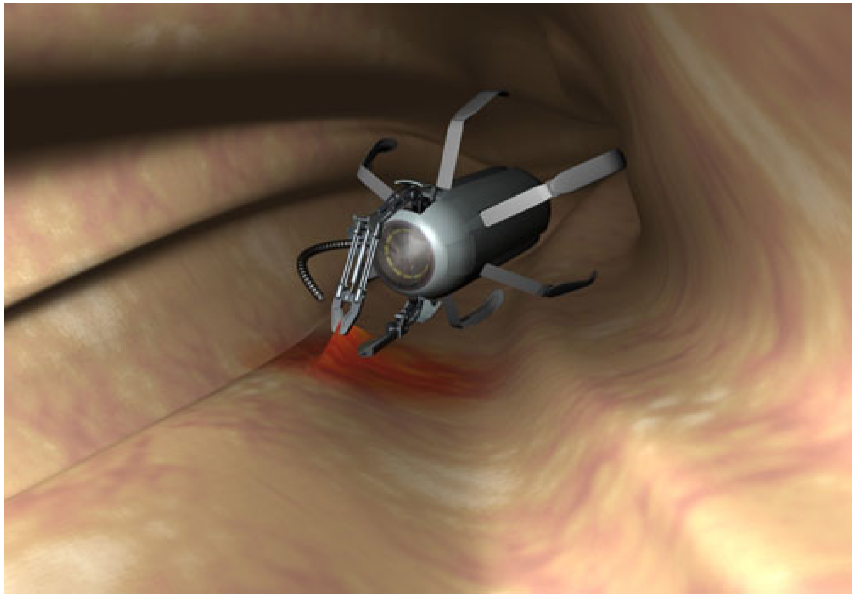


Picture: www.lirmm.fr/UEE07

Picture: iarp06.robot.jussieu.fr

VECTOR-Versatile Endoscopic Capsule for gastrointestinal TumOr Recognition and therapy Funded by the European Commission, Sixth FrameWork Programme, Information Society Technologies Priority

- Goal : The project pursues the goal of realizing smart pill technologies and applications for gastrointestinal (GI) diagnosis and therapy.



Surgical Telemanipulation

- Higher accuracy - Scaling of operator movements
- Elimination of tremor
- Improved dexterity - Computer controlled dexterity of instruments inside the body
- “Converts” keyhole surgery to open technique (instrument tip control)
- Improved Ergonomics
- Lacking haptic feedback – the sensation of touch

Autonomous Robotic surgery

- High accuracy
- Automatic task execution
- Movement compensation
- Guide for tool positioning in 3D-environment using optical navigation or image guidance
- Automatic alignment of tool based on sensor information

Visions for robotic surgery

- Tele-surgery in space or on battlefields
- Remote surgery in hostile environment (CT, brachyradiotherapy, beam therapy and iMRI)
- Automatic surgical tasks
- Real micro manipulation surgeries impossible by the human hand

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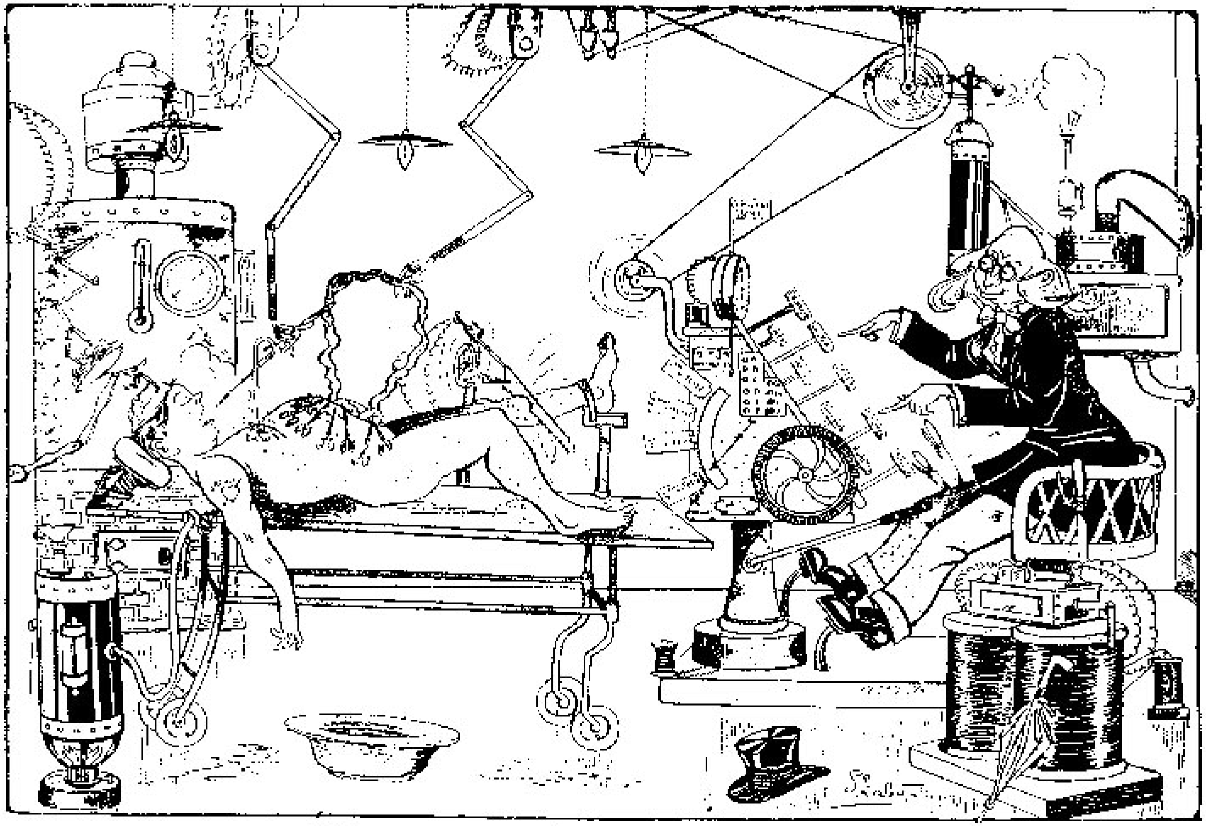
A French comic drawing from 1914 showing how the artist envisioned the operating room of year 2000



UNE SALLE D'OPÉRATIONS EN L'AN 2000

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Future of robots

- Automated systems with artificial intelligence
- Miniturization of dedicated intra-luminal robot systems
- Light-weight telemanipulators with the sensation of touch
- Robotic systems cross-linked with image information

Telesurgical Robots

In a telesurgical system the slave robot reproduces the movements of the surgeon inside the body

Possible improvements

Haptic feedback

Haptic Guidance

Autonomous functions

Haptic Guidance

Generation of virtual forces with the objective of guiding the movements of the surgeon and helping him to complete the tasks.

Advantages

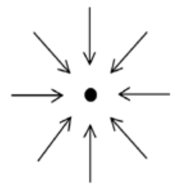
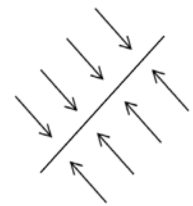
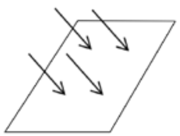
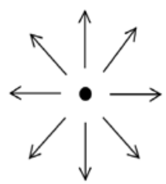
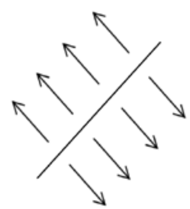
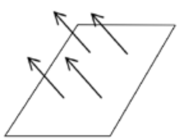
with respect to teleoperation

- Provide haptic feedback
- Increase speed and precision
- Reduce operator workload
- Reduce effects of time delays

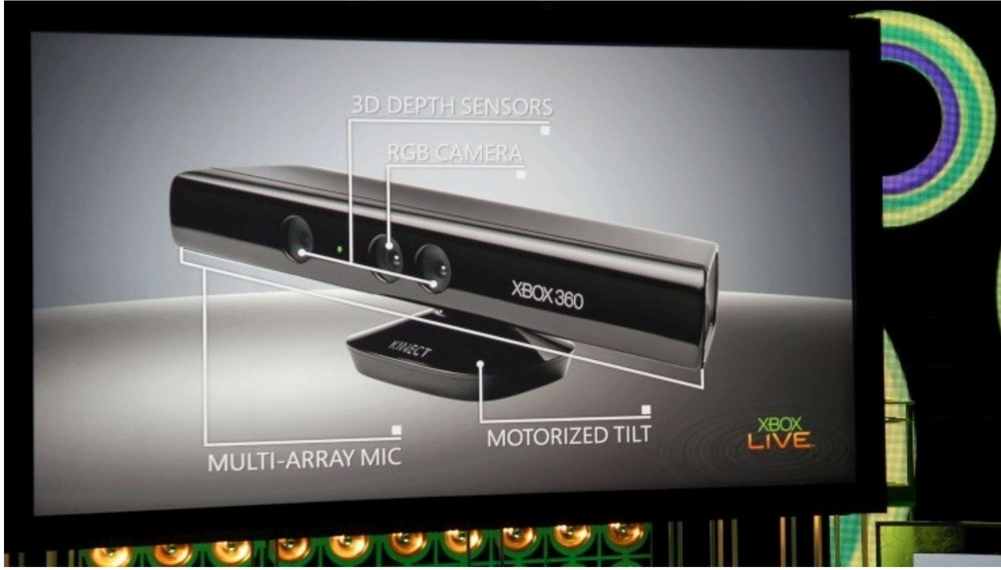
with respect to autonomous robots

- Increase the surgeon confidence
- Small registration errors can be corrected automatically

Haptic Guidance and Active Constraint

	3 motion constraints	2 motion constraints	1 motion constraint
Attractive forces (guidance)			
Repulsive forces (no-go zones or active constraint)			

Kinect



- **Kinect for Xbox 360**, (originally known by the code name *Project Natal*) is a "controller-free gaming and entertainment experience" by Microsoft for the Xbox 360 video game platform
- Kinect competes with the Wii Remote with Wii MotionPlus and PlayStation Move & PlayStation Eye motion control systems for the Wii and PlayStation 3 home consoles, respectively.
- Kinect is based on software technology developed internally by Rare, a subsidiary of Microsoft Game Studios owned by Microsoft and range camera technology by Israeli developer PrimeSense, which interprets 3D scene information from a continuously-projected infrared structured light
- The depth sensor consists of an infrared laser projector combined with a monochrome CMOS sensor, and allows the Kinect sensor to see in 3D under any ambient light conditions. The sensing range of the depth sensor is adjustable, with the Kinect software capable of automatically calibrating the sensor

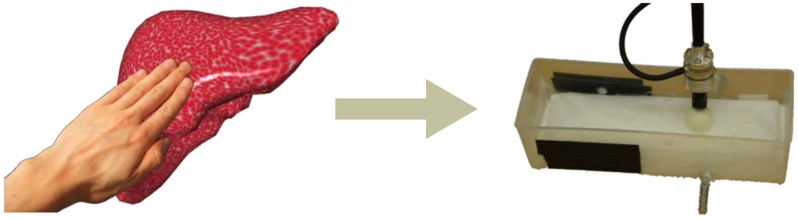
Kinect providing haptic feedback for surgical telemanipulators

- Well, you should be, because this Kinect hack is very real. A group of graduate engineering students at the University of Washington are now using Microsoft's gesture-recognizing peripheral to guide the actions of surgical robots.
- Using the Kinect to create three dimensional maps of a patient's body, the team is trying to solve the age-old problem of using surgical robots: namely, it's hard for a doctor to guide a robot hold a scalpel if he doesn't get tactile feedback as to how hard he's pressing with it. The Kinect allows these robots to integrate with force feedback technology, allowing surgeons an accurate idea of what they're doing within a patient's body.
- "It's really good for demonstration because it's so low-cost, and because it's really accessible," Ryden, who designed the system during one weekend, said. "You already have drivers, and you can just go in there and grab the data. It's really easy to do fast prototyping because Microsoft's already built everything."

Force Sensor Free Bilateral Teleoperation

Sensitivity-Optimized Controller

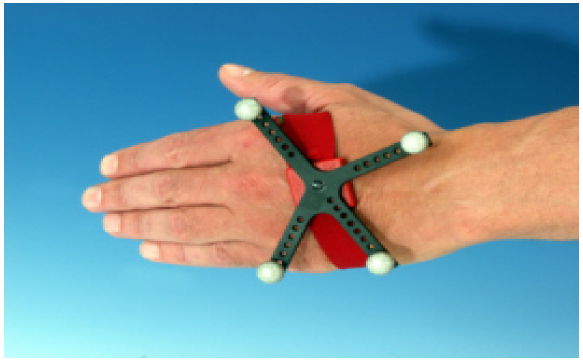
- Sensitivity-optimized teleoperation controller for surgical palpation tasks
- FSF framework applied to be independent of force sensors
- Evaluation goal: compare controllers before and after FSF transformation
- Objective evaluation: use robot as an operator to avoid all human influence
- Subjective evaluation: use a group of human operators in perception test

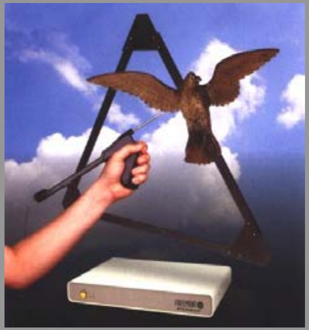


Tracking devices

The Viewing Wand by IGS

Polaris® by NDI





Freepoint 3D™ Sonic Digitizer by GTCO

Flock of Birds® by Ascension Technology Cooperation

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Image navigation systems

- Sonowand
  - Intraoperative ultrasound

Superdimension
for navigation in the lungs

Medtronic -Navigation System
for EM navigation

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Augmented Reality

- Definition:
  - Combines the real and the virtual objects in a real environment
  - Is interactive and run in real-time
  - Register virtual objects to real objects

- In other words:
  - Overlay the real world as you see it with graphics, sound and other sensoric information in real-time

*Reality-Virtuality Continuum**

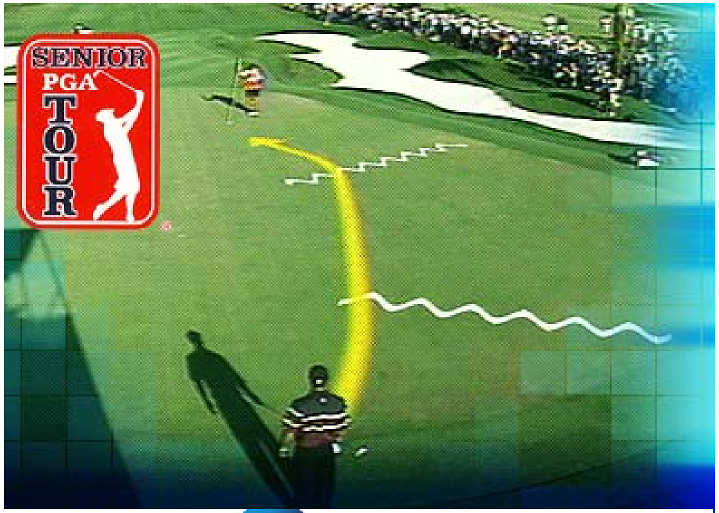
Mixed Reality

Real Environment	Augmented Reality	Augmented Virtuality	Virtual Environment

**Milgram*

Augmented Reality

- Examples



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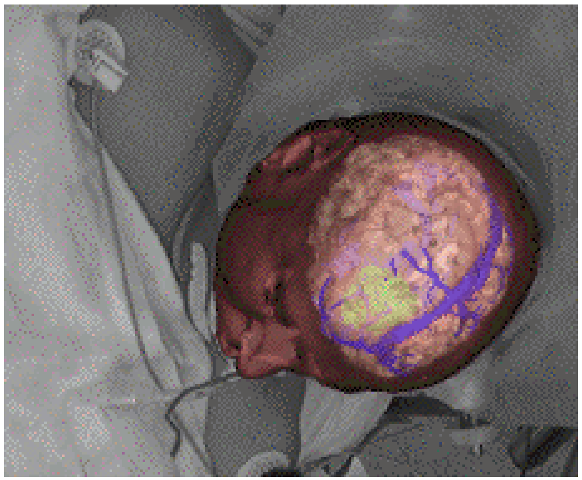
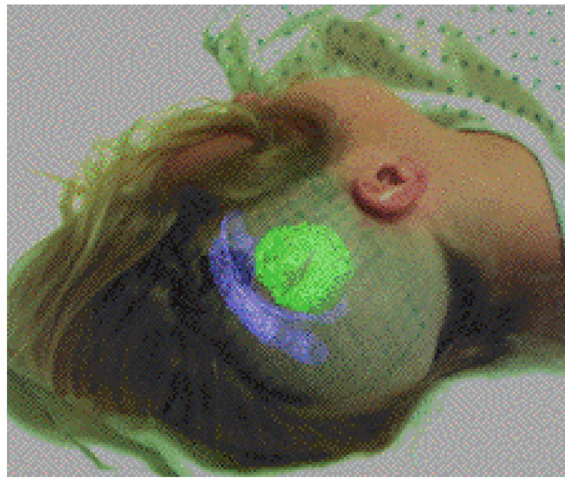
Augmented Reality

- *Medical examples*





Surgical Planning Lab, Brigham and Womens hospital,

Harvard Medical School

Artificial Intelligence Laboratory,

Massachusetts Institute of

Technology

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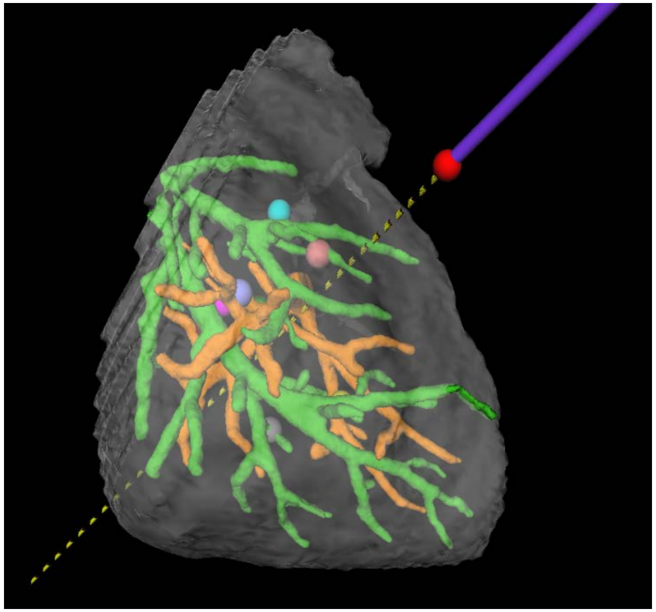
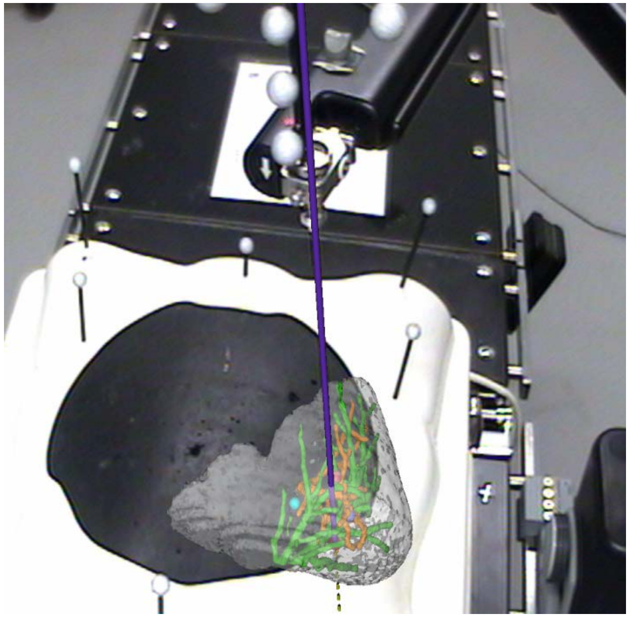
Integration with Augmented Reality

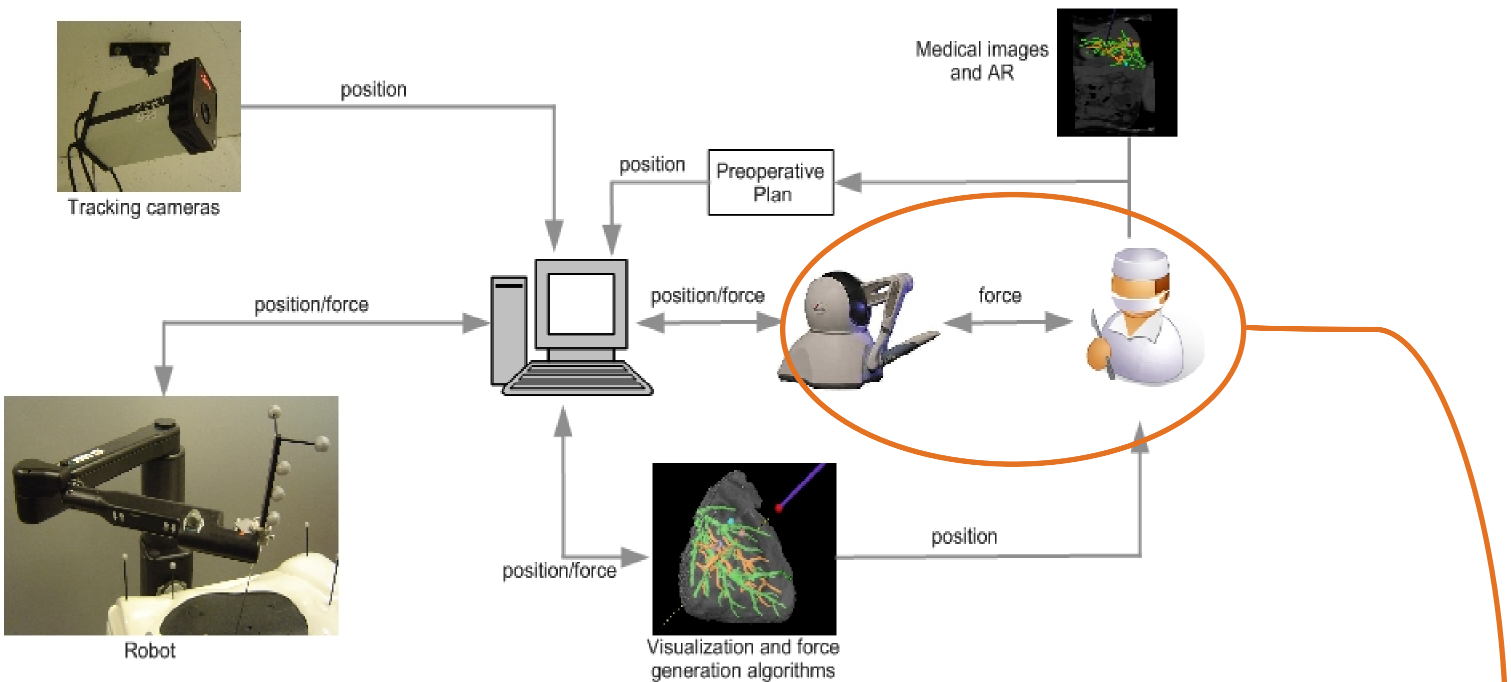
- Registration allows the use of augmented reality tools and the robot together.

- Definition of the target points that will be reached by the robot in the virtual models





Block Diagram



The surgeon feels correcting forces when deviations between the real position of the robot and the preoperative plan are detected

Development of methods for real-time surgical situation awareness

- Sensor control
- Sensor fusion algorithms
- Machine learning algorithms
- Novel resoning algorithms

- http://walyou.com/kinect-robot/
- http://www.escapistmagazine.com/news/view/107118-Kinect-Hack-Provides-Robot-Surgeon-with-New-Eyes

http://www.youtube.com/watch?v=LYVRwT2bqN8&feature=player_detailpage

Robot and Kinect

- Interfacing a 3D sensor (Kinect from Microsoft) with the robotic system (Universal robot) for diagnostics and treatment.
- It's main purpose will be to aquire 3D scene information from the patient body for compensation control to maintain a fixed relation between the robot and the patient.
- Hyphothesis: Kinect can provide 3D scene information with sufficient bandwidth and precision to be used for real-time compensation for patient motion

World's First Robotised Tele-Ultrasound Examination via Satellite (www.medgadget.com)

Robosoft, a French firm that stands behind ESTELE, a remotely operated robotic echo system profiled by us back in April 2007, has just announced the world's first robotised tele-ultrasound examination via satellite. According to the press release, the company has partnered with the European MARTE project (**M**OBILE **A**nd **R**OBOTISED **T**ELE**E**CHOGRAPHY) and **Microsoft Robotics**, which provided its Microsoft® Robotics Developer Studio software.

Autonomous Ultrasound guided robots

- “I believe the technology already exists to produce an autonomous surgical robot using current artificial intelligence programs combined with real time 3D [three dimensional] ultrasound scanners and current surgical robots,” Smith told iTnews.

  With a team of engineers at Duke University, Smith built a rudimentary tabletop robot that navigated using 3D ultrasound technology.

  The robot was controlled by an artificial intelligence program that processed real-time information and gave the robot specific commands to perform.

EU-funded project I-Sur (Intelligent Surgical Robotics)

- IVS Responsible for the work package: Intra-operative Sensing and Reasoning
  - Task 1: Analysis and representation of the sensing requirements of surgical actions
  - Task 2: Development of real-time methods for intra-operative sensing
  - Task 3: Development of methods for real-time surgical situation awareness

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Activities at IVS in collaboration with IFI

- PhD and Postdoc within August/September 2011 financed through EU-project I-Sur (Intelligent Surgical Robotics)
  - Realtime sensing
  - Automated surgical tasks
- PhD (Kim Mathiassen) financed through University of Oslo, Department of Informatics
  - Robotic Ultrasound system/Platform for Intraoperative sensing
  - System setup
    - Universal robot
    - Haptic feedback
    - Force control
    - Image interface
- Two students from Department of Informatics are working on their master with the topics:
  - Robot/Kinect interaction
  - Robot/Haptics Integration

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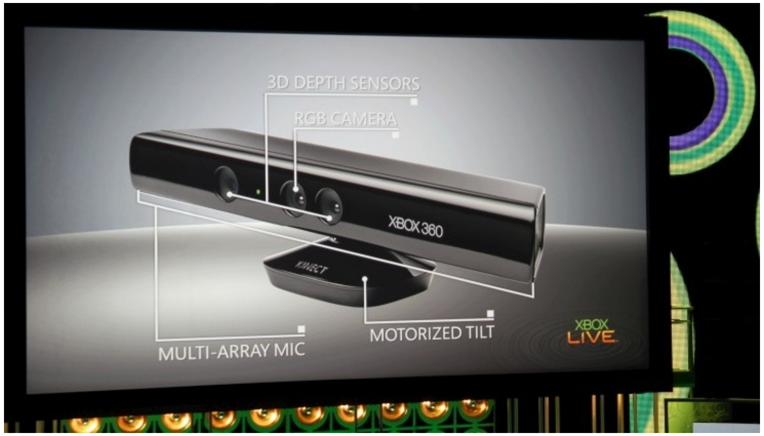
Intraoperative sensing

- Videoscopic videostream
- Ultrasound
  - External probe
  - Internal/laparoscopic US probe
- Fluoroscopy (Angio) cross-linked with robotic system
- NVIDIA CUDA hardware for real-time image processing
- Instrument contact force for force control and haptic feedback
- Range sensor
- Kinect sensor
  - w/Range sensor and
  - 3D scene information from a continuously-projected infrared structured light (3D surface registration)
- Instrument tracking (Updated tip position, registration)
  - Optical
  - Magnetic

Semi-autonomous platform

Universal robot

Kinect sensor



Phantom Premium – haptic feedback