Introduction to Surgical Robotics

Etienne Dombre
LIRMM, Montpellier
dombre@lirmm.fr
http://www.lirmm.fr/~w3rob/comics/comics_base.htm

Medical Robotics

Assistive technologies

Robots and machines which improve the quality of life of disabled and elderly people, mainly through increased personal independence

Surgical robotics

Rehabilitation robotics

Robots and mechatronic tools for clinical therapy in neuro-motor rehabilitation

Non-surgical robotics

Robots for diagnosis

Outline

- A short overview on assistive technologies & rehabilitation robotics
- Analysis of some surgical functions and limitations of manual procedures
- How can robotics help surgery?
- State of the art
- Safety issues
- Future directions of R&D and technical challenges
- Conclusion
- Biography

A short overview on assistive technologies and rehabilitation robotics

Assistive technologies

Robots and machines which improve the quality of life of disabled and elderly people, mainly through increased personal independence

→

- **Prosthetic devices**
- **Orthotic devices**
- **FES**
- **Robotic aids**
- **Smart living space**
- **Personal assistants**

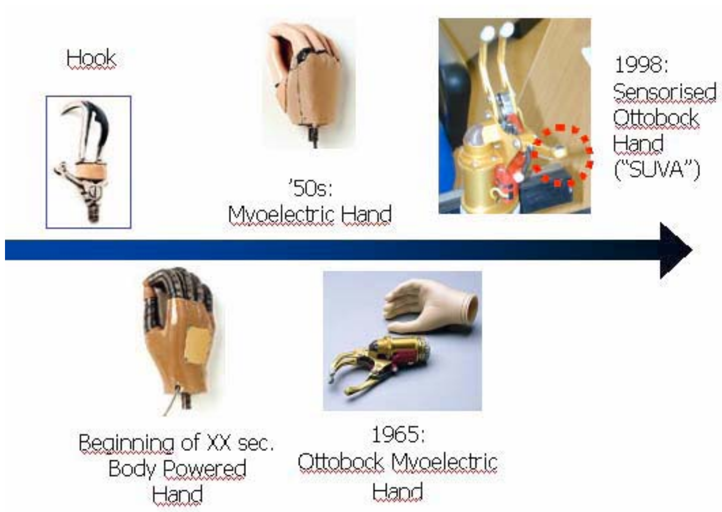
Rehabilitation robotics

Robots and mechatronic tools for clinical therapy in neuro-motor rehabilitation

→

- **Robots for physical & occupational therapy**

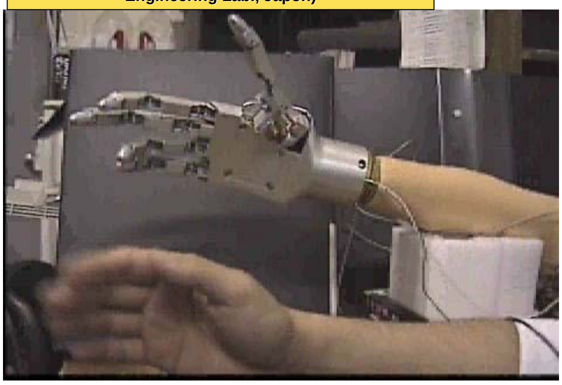
Assistive technologies: prosthetic devices



Evolution of the active hand prostheses (from EURON Roadmap, 2004)

Assistive technologies: prosthetic devices (1/2)

EMG Prosthetic Hand (Autonomous System Engineering Lab., Japon)

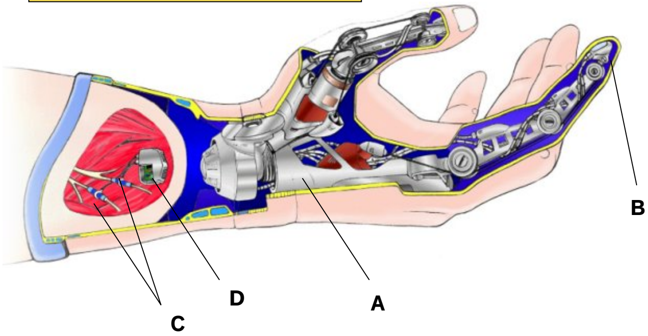


Utah Arm 2 Utah Hand (Motion Control, Inc., USA)

C-Leg (Otto Bock HealthCare, Inc., USA)

Assistive technologies prosthetic devices (2/2)

Cyberhand Advanced Prosthetic Hand
(EU Project coordinated by SSSA, Pisa)



(A) advanced underactuated multi-degree of freedom hand for below elbow amputees
(B) finger tip pressure built-in sensors
(C) neuroprosthetic electrodes implanted in or around the nerve stump to detect the user's volitional commands and to feedback sensations from the pressure sensors (and others)
(D) implanted custom stimulator/amplifier

Courtesy of Ken Yoshida, ROBEA, March 30,2005

Assistive technologies & Robionics

- Robionics : interfaces between an assistive device and the human nervous system such that the user's brain functions become part of the system control loop
  - Biomechatronic prostheses
  - Implantable micro-sensors and micro-actuators for sensory and motor augmentation
- R&D issues
  - biocompatible implantable electrodes, actuators
  - energy
  - Neurophysiology: which neurons to interface?
  - Data processing (volitional command and artificial sensory feedback)…

Assistive technologies: orthotic / wearable devices

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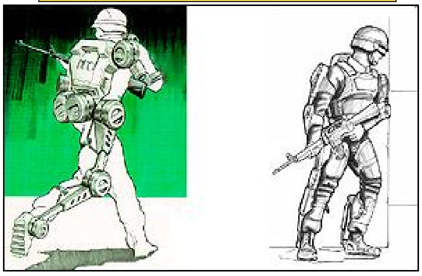
Exoskeletons for Human Performance Augmentation (DARPA, USA)



Rancho arm (Rancho Los Amigos Hosp., Downey), 1970

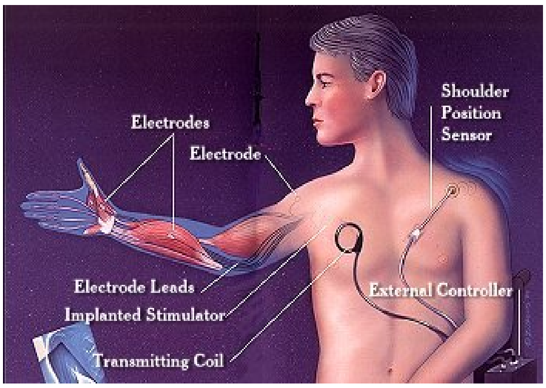
- R&D issues
  - Miniaturization of actuators and batteries
  - Force control
  - Safety…

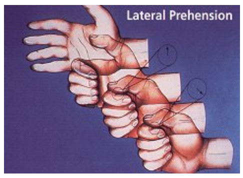
The Berkeley Lower Extremity Exoskeleton (BLEEX) (Univ.of Berkeley, USA)

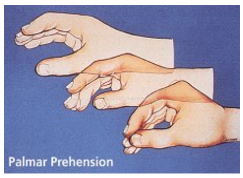
Assistive technologies: Functional Electro-Stimulation (FES) (1/4)

LIRMM

Freehand system (NeuroControl Corp., Cleveland, Ohio, USA)

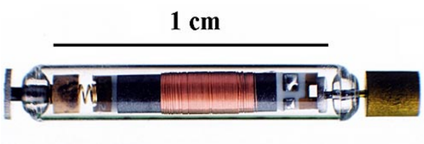




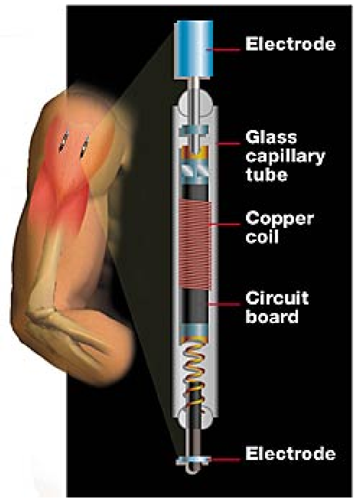


Assistive technologies: Functional Electro-Stimulation (FES) (2/4)

BION (Alfred E. Mann Institute, USC, Los Angeles)

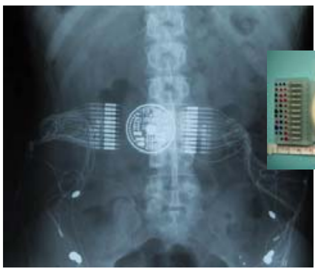


- BION for BIOnic Neurons
- Glass-encapsulated
- implanted by injection
- To prevent disuse atrophy and restore functional movement of paralyzed muscles
- Power and digital command data transmitted by a RF coil



Assistive technologies: Functional Electro-Stimulation (FES) (3/4)

SUAW, EU-Project, (Coordinated by Prof. Rabischong, Montpellier), 1996-2000



Partial restoration of the locomotion function in certain paraplegic patients

Assistive technologies: Functional Electro-Stimulation (FES) (4/4)

DEMAR project, LIRMM/INRIA, Montpellier (2002-2010)

- Continuation of the SUAW project to close the loop: control the muscle contraction to minimize fatigue while guarantying stability; improve coordination of muscles to better mimic natural locomotion
- Modelling and controlling the human sensori-motor system
  - Multi-scale modelling from micro to macro behavior
  - Synthesis and simulation: find the stimulation patterns for a given movement
  - Robust control strategies and high level coordination of muscles for walking
- Interfacing artificial and natural parts through neuroprosthetic devices
  - Implanted stimulator and electrodes (microelectronics & neurophysiology)
  - Implanted sensors for closed-loop control (physical and natural sensors)
  - Patient interface
  - Supervision and networking of the multiple components

Assistive technologies: Robotic mobility/manipulation aids

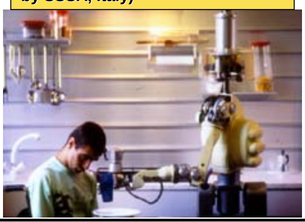
Robot MANUS (Exact Dynamics BV, The Netherlands)

Smart walker GUIDO (Haptica, Dublin, + Univ. Polytech. Madrid)

Physical weight support, steered by the user, with assistance to avoid obstacles

Care-O-Bot, IPA, Stuttgart

MOVAID EU project (Coordinated by SSSA, Italy)



- R&D issues
  - robust indoor navigation system
  - natural language interfaces
  - Cost, adaptation to patient
  - Acceptability…

Assistant to elderly

Assistive technologies: Smart living spaces

- Also referred to as ubiquitous robotics: intelligence built into appliances and living spaces
- To improve quality of life of persons with chronic physical / cognitive disabilities, namely for the elderly and disabled
- Number of sensors embedded in the environment or worn by the person:
  - To anticipate the person needs and intentions
  - For monitoring and diagnosis by off-site persons (cardiac and respiratory cycles, arterial pressure, temperature, motion detectors…)
- Issues
  - Miniature and wearable devices to measure physiological parameters
  - Human movement / behavior interpretation (speech, facial expression, gestures…)

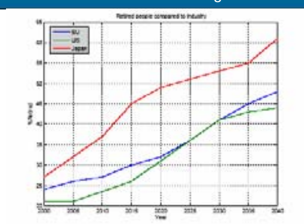
D.H. Stefanov, Z. Bien, W.C. Bang, Smart house for older persons and persons with physical disabilities: structure, technology, arrangments, and perspectives, IEEE Trans. On Neural Systems and Rehabilitation Engng., Vol. 12(2), June 2004, pp. 228-250.

Assistive technologies: Personal assistants

Companion (InTouch Health, Goleta, CA, USA)

Healthcare through a “Remote Presence” Robot, RP-6: the doctor is projected to another location where the patient is located

… or healthcare through companion/humanoids…



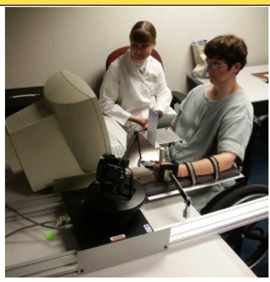
[World Bank, 2004]

HRP2, Kawada Industries, Inc. & AIST, Japan

- R&D issues: all the research topics of Robotics + Cognitive sciences

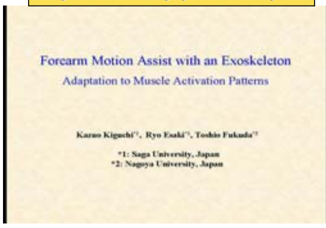
Rehabilitation robotics

Robotic therapy (Neurobotics Lab, Rob. Institute, Carnegie Mellon, USA)



Virtual environment with a robotic device to extend the strength and mobility of people recovering from strokes

Saga Univ. & Nagoya Univ., Japan



Robotic exerciser: the robot guides the patient through a pre-programmed path. The movement may be performed against a resistance provided by the robot

•**Rehabilitation robotics:** robots and mechatronic tools for clinical therapy in neuro-motor rehabilitation

- R&D issues
  - Better human-robots interfaces

6-dof Rehabilitation Robot Osaka Univ., Japan), 2005

Walking Rehabilitation Robot (Hitachi, Japan)

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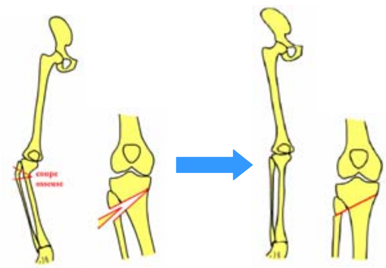
IARP Workshop on Medical Robotics, Hidden Valley, May 2004:
http://www.nsf.gov/eng/roboticsorg/IARPMedicalRoboticsWorkshopReport.htm

Outline

- A short overview on assistive technologies & rehabilitation robotics
- Analysis of some surgical functions and limitations of manual procedures
  “Machining”, insertion, MIS, suturing
- How can robotics help surgery?
- State of the art
- Safety issues
- Future directions of R&D and technical challenges
- Conclusion
- Biography

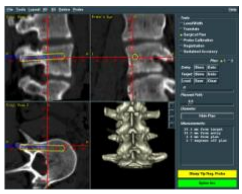
Function: "Machining" rigid surfaces (1/2)

High tibial osteotomy for genu varus (bow-leggedness)

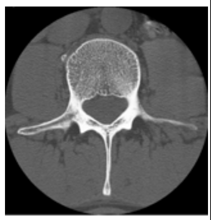


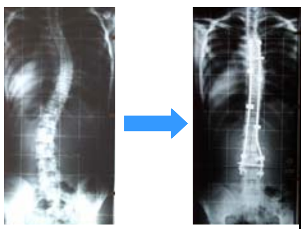
http://www.genou.com/arthrose/osteotomies.htm

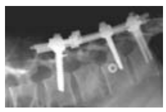
cutting



Pedicular screw placement







drilling

10% to 40% ill-placed screws

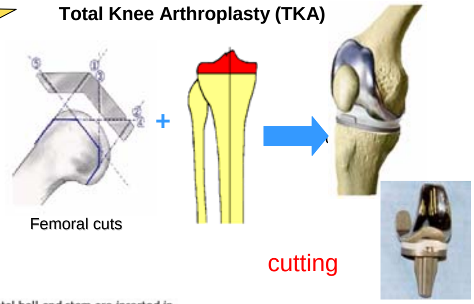
(Source J. Troccaz, 1st Summer School in Medical Robotics 2003)

Function: "Machining" rigid surfaces (2/2)

Lecture of E.Stindel

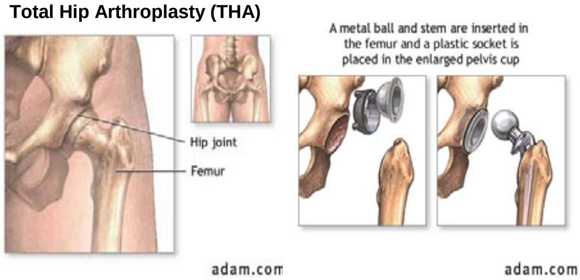
- **Some difficulties:**
  - complex geometry,
  - localization of the cutting planes, drilling axes…,
  - accuracy,
  - force control
  - …

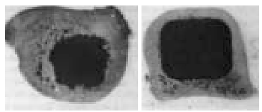
Total Knee Arthroplasty (TKA)



cutting

Total Hip Arthroplasty (THA)



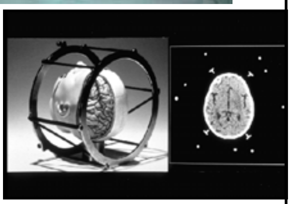


Milling/drilling

Function: Insertion of instrument in soft tissue

- insertion of instruments / needles: biopsy, radio frequency ablation of tumors, cryotherapy; delivery of optimized patterns of local treatments (radiation seeds, injections…)
- Wide use in neurosurgery, cardiac surgery, urology, abdominal surgery…
- Image-guided (CT-scan, MRI) alignment and insertion
- Manually driven: the surgeon is exposed to radiation

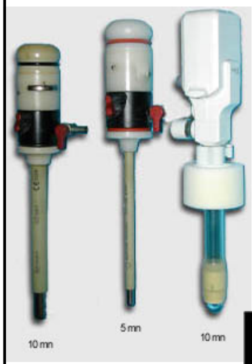
- **Some difficulties:**
  - requires mental registration of the patient's anatomy to the image in targeting,
  - requires precise hand-eye coordination in inserting the Instrument / needle
  - force control during insertion while penetrating tissues with heterogeneous stiffness
  - compensation for physiological motions
  - avoiding vital areas
  - …



Function: Minimally-invasive surgery (MIS) (1/2)

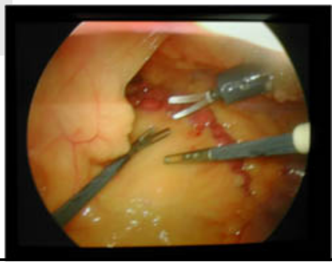
LIRMM

Introduction to Surgical Robotics (23)



Trocars

Endoscope + cold light fountain



Control LCD

Instruments

Function: Minimally-invasive surgery (MIS) (2/2)

LIRMM

Introduction to Surgical Robotics (24)

(Source : US Surgical Corporation)

- Widely used in abdominal surgery, more and more in cardiac surgery
- **Some difficulties:**
  - 3 hands are mandatory
  - monocular vision
  - comfort of the surgeon
  - eye-hand coordination (fulcrum effect)
  - no force feedback (friction in the trocar)
  - loss of internal mobility due to kinematics constraints induced by the trocar
  - restricted workspace
  - Occlusion of the field of view
  - compensate for physiological motions
  - avoid critical areas
  - …

Lecture of O. Chavanon

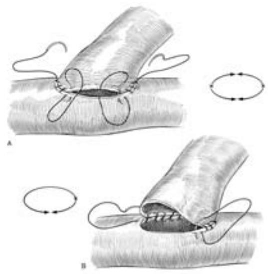
Lecture of N. Bonnet

Function: Suturing

- Example: anastomosis for coronary artery bypass grafting (CABG)
- Ø 2 mm, 10 to 20 penetrations
- Ø of the thread: few tens of µm
- Penetration force: up to 1N
- Resolution: better than 0.1 mm
- suturing (stitching + knot tying),

- **Difficulties:**
  - very accurate force-controlled motion
  - soft tissue interaction
  - complex geometry
  - …
  - + the difficulties of MIS if it is done this way

Suturing of the graft to the aorta and the coronary artery



Outline

- A short overview on assistive technologies & rehabilitation robotics
- Analysis of some surgical functions and limitations of manual procedures
- How can robotics help surgery?
  Functions and limitations of robots
- State of the art
- Safety issues
- Future directions of R&D and technical challenges
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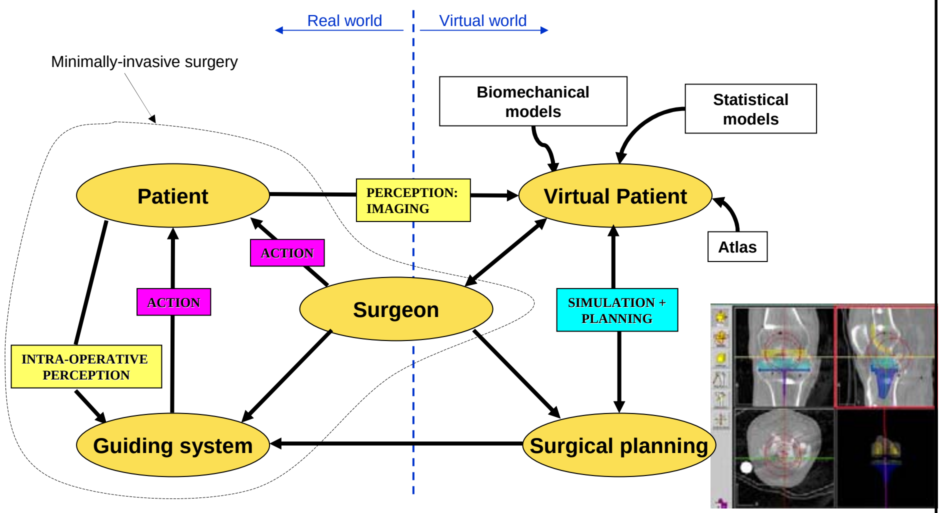
How can robotics help surgery?

LIRMM — Introduction to Surgical Robotics (27)

General structure of a Computer-Aided Surgical system: the perception-planning-action loop (revisited from S. Lavallée, PhD thesis 1989)



How can robotics help surgery?

LIRMM — Introduction to Surgical Robotics (28)

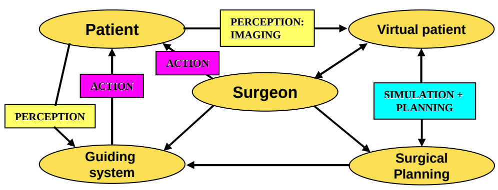
- Medical imaging : image segmentation and registration
- Modelling

Lectures of H. Delingette

Lecture of C. Barillot

- Design and safety

Lecture of F. Pierrot



- Brain imaging & registration

Lecture of P. Poignet

- Registration
- Control

Lecture of L. Soler

Lecture of M. De Mathelin

Lecture of G. Morel

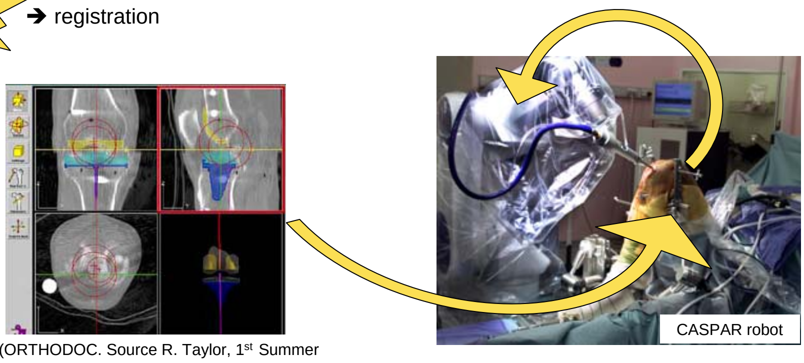
Lecture of J. Troccaz

- Simulation

How can robotics help surgery?

- **Several difficulties of manual surgical procedures that a robotic system can help to solve:**
  - Precise localization (position and orientation) of instruments wrt to patient with reference to pre-operative planning or intra-operative imaging:
    ➔ registration

Lecture of J. Troccaz



(ORTHODOC. Source R. Taylor, 1st Summer School in Medical Robotics 2003)

How can robotics help surgery?

- **Several difficulties that a robotic system can help to solve:**
  - Precise localization (position and orientation) of instruments with reference to pre-operative or intra-operative imaging
  - Complex and accurate path following (e.g. milling a bone, targeting a tumor from multiple radiation ports…)
  - Cancel the hand-eye coordination problem (e.g. in MIS)
  - Real time integration of intra-operative data: image-guided motion (e.g. needle insertion); visual-servoing (e.g. to compensate for physiological motions and patient's motions); force-controlled motion (e.g. machining, skin harvesting), …
  - Limitation of risks: possible to constrain the instrument to move into safe regions
  - Heavy loads (e.g. linac, microscope…)
  - 3rd hand
  - …
- **… and improvments that can be expected wrt manual procedures:**
  - Compensation for surgeon's hand tremor
  - Motion and force augmentation or scaling (e.g. for microsurgery)
  - Better comfort for the surgeon

How can robotics help surgery?

- **Some expected "added-values" of surgical robotics…**
  - In neurosurgery, percutaneous therapy, radiosurgery : limits collateral effects due to lesions of instruments or radiations while accessing smaller and smaller targets closer and closer to vital areas; minimizes the radiation for the patient; removes the operator from hazardous environment such as X-ray
  - In orthopedic: less revision surgeries; longer life expectancy of protheses; less risk (e.g. pedicular screw placement)
  - In MIS: control of additional mobilities at the distal part of instrument; haptic feedback; performing surgeries that cannot be executed manually (e.g. beating heart surgery) still minimizing invasiveness; less pain and trauma and shorter recovery time
  - Tele-surgery
  - Training / mentoring of young surgeons

Lecture of M. T. Ortmaier

Lecture of J. Rosen

Lecture of L. Soler

How can robotics help surgery?

- **… but some constraints related to the use of a robotic system in the OR:**
  - Cost effectiveness (source B. Armstrong, CARS Berlin, 2005): **not yet proved**
    - Benefits need to justify cost/complexity
    - No technical team in the OR
    - Simple to train surgeons
    - Skin-to-skin times similar to conventional
    - Reduce OR cost, not just overall costs (lack of joined-up accounting)
  - Clinical added value: **not yet clear:** *"it is difficult to prove their effectiveness since there are no established methods to relate conventional (nonrobotic) techniques that would serve as benchmarks* …"
  - Easy to use and setup: **currently longer**
  - Compatible with the environment of the OR (cluttered, other electrical devices…): **yet too bulky**
  - User-friendly interfaces
  - Safety

Lecture of J. Rosen

➔ **Still a lot of technical and clinical (change the procedures) research work**

See also http://www.nsf.gov/eng/roboticsorg/IARPMedicalRoboticsWorkshopReport.htm

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Robotics for surgery and diagnosis: state of the art

- Today main robotically assisted surgical specialities
  - Neurosurgery
  - Orthopedics
  - Minimally-invasive surgery (MIS) / laparoscopy
  - Percutaneous therapy
  - Radiosurgery, maxillofacial surgery, prostatectomy, microsurgery…
- Other non surgical specialities
  - Tele-echography

Robotics for surgery and diagnosis: state of the art

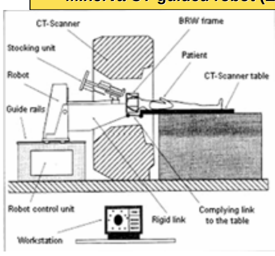
- Some milestones

- 1985 – Neurosurgery, Puma 260, Kwoh et al., 22 patients
- 1989 – Neurosurgery, Speedy (AID robot), Lavallée, Benhabid et al., Hundreds of patients
- 1989 – TransUrethral Res. of Prostate, Puma 560 (Imperial College)
- 1992 – Orthopedic surgery, ROBODOC (ISS), Still in use: >70 robots, over 10000 patients
- 1994 – MIS, AESOP (Computer Motion), > 400
- 1998 – MIS, Zeus (Computer Motion)
- 1998 – MIS Da Vinci (Intuitive Surgical), Still in use: > 200
- 2001 – Tele-echography, SYTECH (LVR), Bourges-Kathmandu
- 2001 – MIS + Tele-surgery (IRCAD), "Operation Lindbergh", New York-Strasbourg

(revisited from J. Troccaz, UEE 2003)

State of the art: Neurosurgery

Minerva CT-guided robot (EPFL, Lausane), 1993

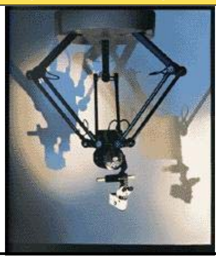


NEUROMATE (IMMI/ISS), 1996

StealthStation (Medtronik SD)

NEUROBOT (Imperial College)

Surgiscope (Elekta-IGS, now ISIS), 1997: microscope-holder



MKM (Zeiss): microscope-holder

- Microscope holders
- Robots
- Navigation systems

Lecture of Y. Patou

State of the art: Orthopedics

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ROBODOC (ISS), 1992


CRIGOS (Helmholtz-Institute/TIMC), 1997

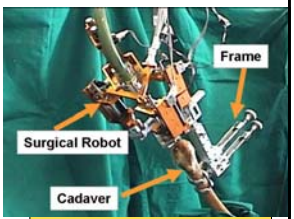

ACROBOT (Imperial College/Acrobot Ltd), 2001


MARS, Technion/Mazor Surg. Haifa, 2002

- Robots
- Navigation systems


CASPAR (OrtoMaquet / URS Ortho), 1997


BRIGIT (MedTech, LIRMM), 2005



ARTHROBOT, KAIST, 2002

State of the art: Minimally Invasive Surgery (MIS)

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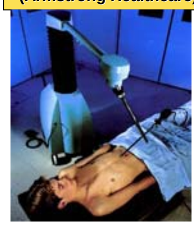
EndoAssist (Armstrong Healthcare)


AESOP (Computer Motion), 1992



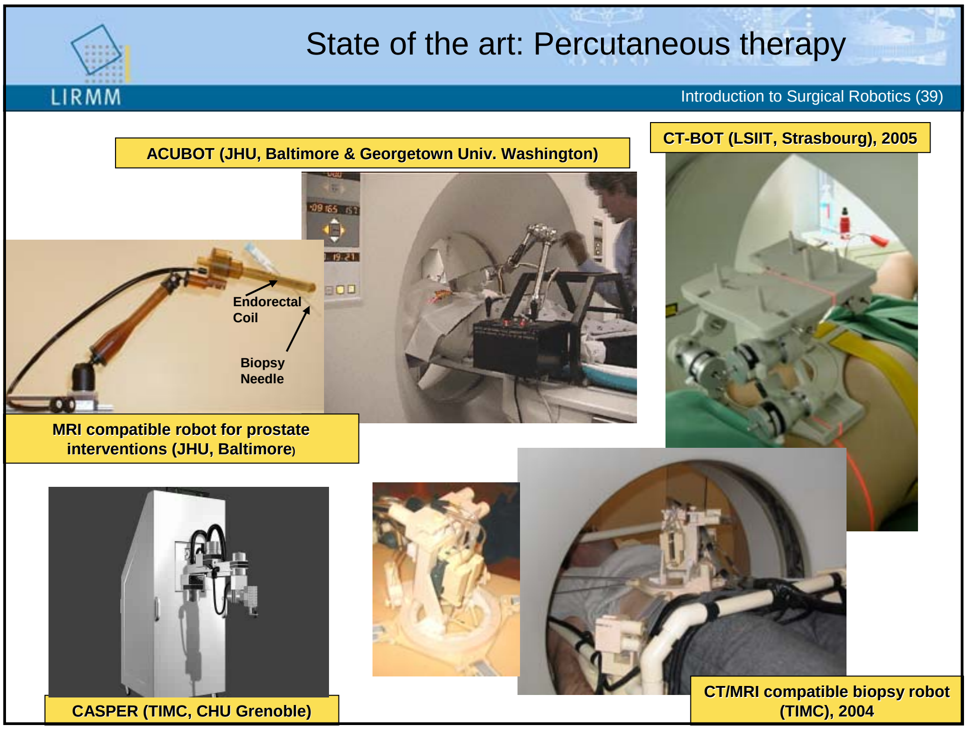
Da Vinci (Intuitive Surgical), 1999

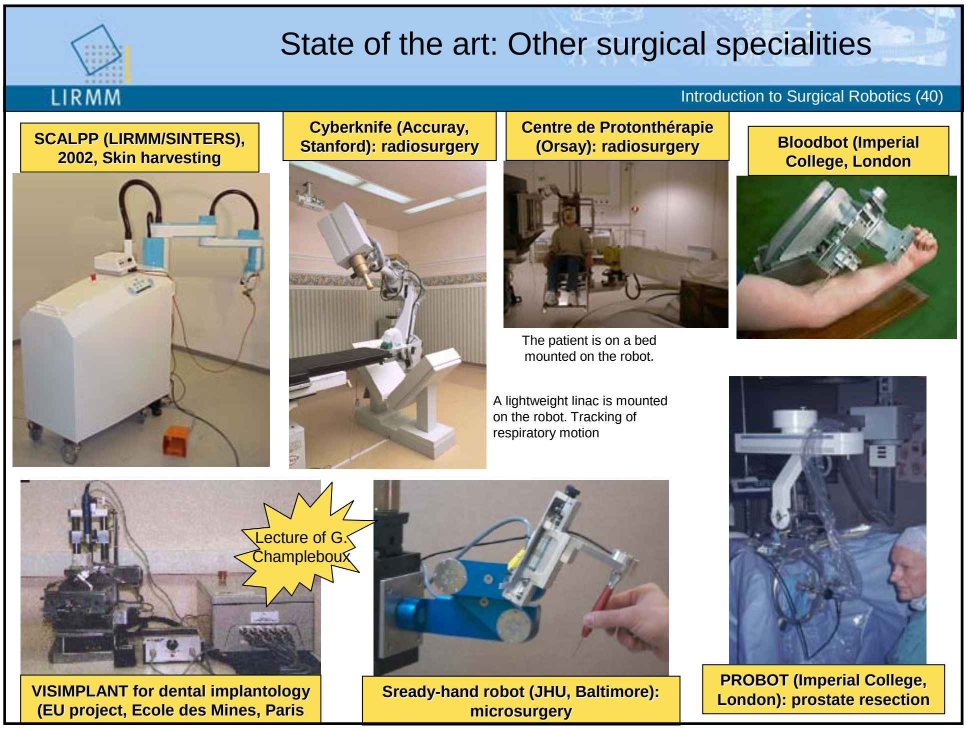
Artemis (FZK, Karlsruhe)


EndoXiroB, Sinters), 2004


RTW (UC Berkeley), 1999


ZEUS (Computer Motion), 1998



LIRMM
State of the art: Percutaneous therapy
Introduction to Surgical Robotics (39)
ACUBOT (JHU, Baltimore & Georgetown Univ. Washington)
CT-BOT (LSIIT, Strasbourg), 2005
Endorectal Coil
Biopsy Needle
MRI compatible robot for prostate interventions (JHU, Baltimore)
CASPER (TIMC, CHU Grenoble)
CT/MRI compatible biopsy robot (TIMC), 2004


LIRMM
State of the art: Other surgical specialities
Introduction to Surgical Robotics (40)
SCALPP (LIRMM/SINTERS), 2002, Skin harvesting
Cyberknife (Accuray, Stanford): radiosurgery
Centre de Protonthérapie (Orsay): radiosurgery
Bloodbot (Imperial College, London
The patient is on a bed mounted on the robot.
A lightweight linac is mounted on the robot. Tracking of respiratory motion
Lecture of G. Champleboux
VISIMPLANT for dental implantology (EU project, Ecole des Mines, Paris
Sready-hand robot (JHU, Baltimore): microsurgery
PROBOT (Imperial College, London): prostate resection

State of the art: Tele-echography

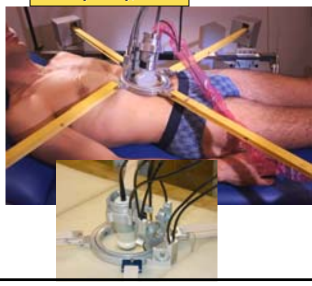
HIPPOCRATE (LIRMM/SINTERS), 1999

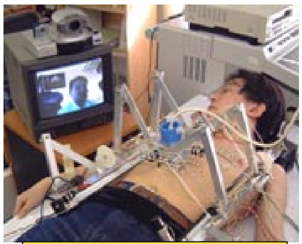
The Ultrasound robot (UBC), 1999

TERESA (LVR-Bourges/ SINTERS), 2003

SYRTECH (LVR-Bourges), 2001

TER (TIMC), 2001





Masuda Lab. Tokyo Univ. A&T, 1999

State of the art: classification

- Classification 1 (J. Troccaz, B. Davies)
  - *Passive* systems: give information to the surgeon
  - *Active* systems: realize the intervention with human supervision
  - *Interactive* systems: mechanical guides
    - Semi-active devices
    - Synergistic devices (constrain the instrument to move into safe regions)
  - *Teleoperated* devices
- Classification 2 (J. Taylor, 6th Conf. on AIME, 1997)
  - Internal replacements
  - Telesurgical systems
  - Navigational aids
  - Precise positioning systems
  - Precise path systems
- Classification 3 (L. Joskowicz, CARS 2005)
  - Navigation systems
  - Passive systems
  - Floor/table-mounted robots
  - Patient-mounted robots

Type of Interaction	Type of Access: Traditional Access	Type of Access: Minimally Invasive Access	Type of Access: Endocavitary/ endoluminal access
Autonomous systems	ROBODOC CASPAR	Stereotaxis Inc	MUSYC/EMIL
Interactive systems	Eye scalpel RinC	AESOP MIAS	Active Catheters
Teleoperated systems	Mammotome PAKY	da Vinci ZEUS	MiNOSC
Passive systems	PinPoint	HALS (not robotic)	Given Imaging (not robotic)

- Classification 4 (P. Dario, EURON Roadmap, 2004)

State-of-the-art: commercial systems

- **Today commercial systems**
  - Navigation systems for neurosurgery, orthopedics & maxillofacial surgery: StealthStation (Medtronik), VectorVision (BrainLab), Surgetics (Praxim), Navigation System (Stryker), OrthoPilot (Aesculap), Galileo (PI Systems), InstaTrack (GEMS), Acustar (Z-Cat)…
  - Neurosurgery / Microscope holder: Surgiscope (ISIS), ~~MKM (Zeiss~~*)
  - Neurosurgery / Robot: ~~Neuromate (ISS*~~)
  - Orthopedics: ~~ROBODOC (ISS*~~), ACROBOT (Acrobot Ltd), MARS/Smart Assist (Mazor Surgical Technologies)
  - MIS: Da Vinci (Intuitive Surgical), ~~AESOP & ZEUS (Computer Motion**~~) Radiosurgery: Cyberknife (Accuray)

Lecture of Y. Patou

* out of business
** merged with Intuitive Surgical since 2003

- **… and tomorrow?**
  - *Medical robotics suffers from a “chicken and egg” phenomenon in the sense that systems need to be developed before they can be tested clinically, but only through the latter will their true effectiveness and utility be proven […]*
  - *To date, much of medical robotics research has been performed on a “technology push” rather than a “market demand” basis […]*
  - *Strategic investment in research and development is needed: we estimate several $US billion are required over the next decade. Because medical robotics has yet to show its ultimate value, it is unlikely that industry will provide much of the needed funding, hence government will have to be the main source […]*

In http://www.nsf.gov/eng/roboticsorg/IARPMedicalRoboticsWorkshopReport.htm

Outline

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- State of the art
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- Future directions of R&D and technical challenges
- Conclusion
- Biography

Safety issues

Safety issues

- **Problems:**
  - the robot shares its working space with surgical staff and patient
  - “trail & error” or “doing again” motions are not allowed
  - sterilizability constraints
- **Some solutions:**
  - At the design level: redundancy in control and sensing; intrinsically safe design to decrease the level of risk by construction (e.g. limit the actuator power to give the instrument just the energy required by the task); use of reliable components
  - At the operation level: dedicated man-machine interfaces and adequate rules for use

Lecture of F. Pierrot

Safety: examples of solutions

Proximity sensors to reduce robot speed

KR3 SI (Safety Integrated) (Kuka) for medical applications

Collision prevention: safe switches to stop robot in case of contact and protective foam covering the arm to absorb kinetic energy

Comply or stop when necessary…

Overview

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Lecture of M Mitsuishi

Lecture of G. Hager

Lecture of P. Dario

Lecture of P. Cinquin

Future directions of R&D and technical challenges

- **Some technical challenges for new clinical procedures:**
  - Neuroendoscopy (endoscopy of the spinal cord) for back pain treatment (EU Project MINOSC coordinated by SSSA)
  - Gastrointestinal diagnosis and therapy
  - Microsurgery
  - …
- **Some technical challenges for improving existing procedures:**
  - Lightweight, smaller, simpler, cheaper robots
  - More integrated systems: plug-and-play robots
  - MMI: real cooperation between Surgeon and Robot (“Hands-on” concept: the surgeon operate the device)
  - …
- **Some solutions currently explored:**
  - Portable (patient-mounted) robot
  - “Smart” instruments for simple dedicated tasks rather than multi-functions
  - Intra-body robots: active catheters, “pills” and endoscopes, mobile robots…
  - Microtechnologies

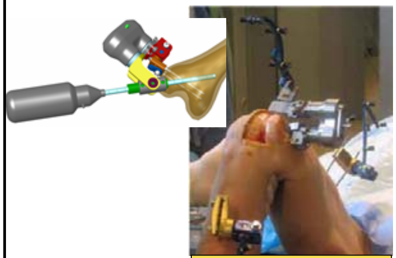
Future directions of R&D and technical challenges: portable robots

LIRMM

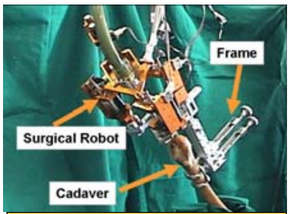
Introduction to Surgical Robotics (51)

- **Advantages of patient-mounted robots**
  (L. Joskowicz, CARS, Berlin 2005)
  - Small size/footprint –minimal obstruction
  - Close proximity to surgical site
  - No patient/anatomy immobilization
  - No tracking/real-time repositioning
  - Small workspace –fine positioning device
  - Potentially higher accuracy
  - Intrinsic safety due to small size/low power

MARS (Technion/Mazor Surg. Haifa), 2002: spine surgery



Praxiteles (TIMC): TKA



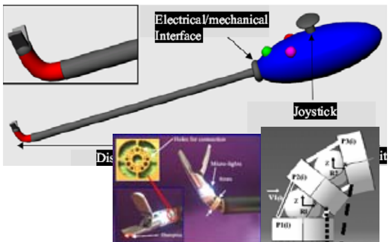
ARTHROBOT (KAIST), 2002: TKA

MBARS (CMU, Pittsburg): TKA

Future directions of R&D and technical challenges: smart instruments

LIRMM

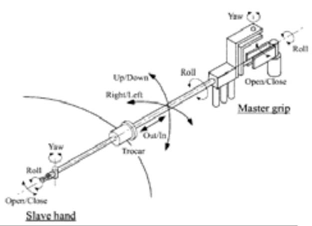
Introduction to Surgical Robotics (52)



Disposable plastic compact wrist (LAAS, Sinters 2004): plastic vertebra+balls and NiTi super-elastic wires

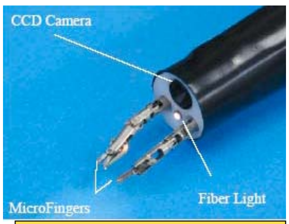
Bending forceps based on rigid linkage mechanism (Univ. Tokyo), 2003

Bending forceps (Hitachi, Japan), 2000



Master-slave combined manipulator (Toshiba, Japan), 2004

Bending US coagulator/cutter (Women's Medical Univ. Tokyo), 2004

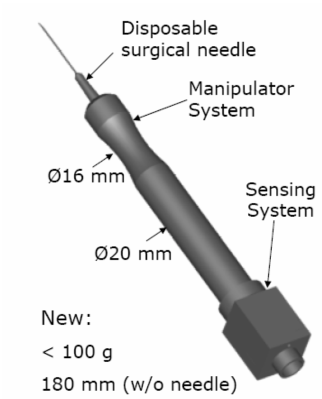


Endoscopy surgery system (Nagoya Univ.), 2004

Future directions of R&D and technical challenges: smart instruments

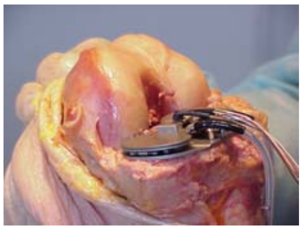
LIRMM

MICRON tremor cancelling instrument (CMU, Pittsburgh): eye surgery



Lecture of W.T. Ang

Robotized spacer for ligament balance in TKA (TIMC, Grenoble)



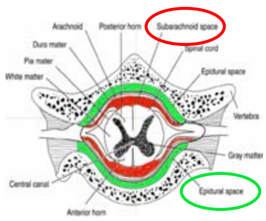
Future directions of R&D and technical challenges: active catheters

LIRMM

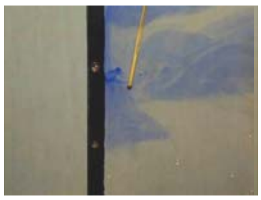
MALICA (LIIA, Paris XII): aneurysm repair

- Guidance of catheter to fix endoprothesis inside the artery (aortic aneurysm repair)
- Hydraulic « Snake like » robot: 2 ddl, Ø 5mm x 20mm

MINOSC (5th FP EU project coordinated by SSSA, Pisa): precise and early diagnosis of spinal cord lesions



Endoscopy of the spinal cord: navigation in the cerebro-spinal fluid with micro-jets to avoid touching tissues

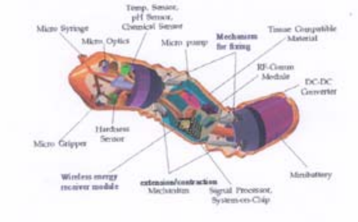


Future directions of R&D and technical challenges: "pills" and endoscopes

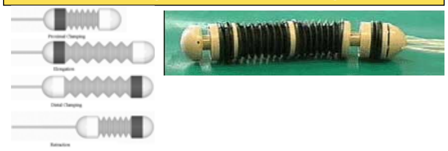
LIRMM — Introduction to Surgical Robotics (55)

"Intelligent" capsules with a high level of autonomy to localize target, deliver drugs, cut polyps …

Microcapsule for gastrointestinal diagnosis and therapy (IMC, Korea)



EMIL (SSSA, ARTS Lab., Pise)



Smart capsule endoscope (Olympus Co., Japan)

The Endoscopy « Pill » M2A (Given Imaging), 2001

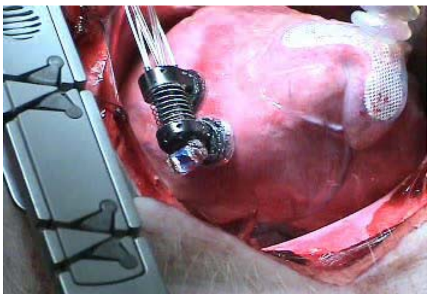
Norika3 (RFSystem Lab., Japan)

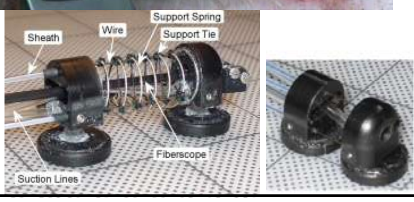
Future directions of R&D and technical challenges: intra-body mobile robots

LIRMM — Introduction to Surgical Robotics (56)

HeartLander (The Robotics Institute, CMU, Pittsburgh)

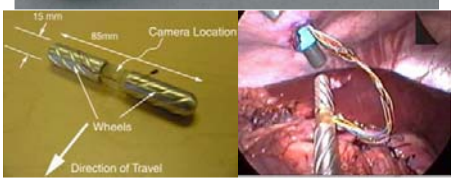
… an inchworm-like mobile robot for minimally invasive beating- heart cardiac surgery





(Robotics & Mechatronics Lab., Univ. Nebraska)

… a wheeled-driven mobile robot to be placed in the abdominal cavity



Future directions of R&D and technical challenges

Micro-robots, micro-sensors, MEMS…

Lecture of P. Dario

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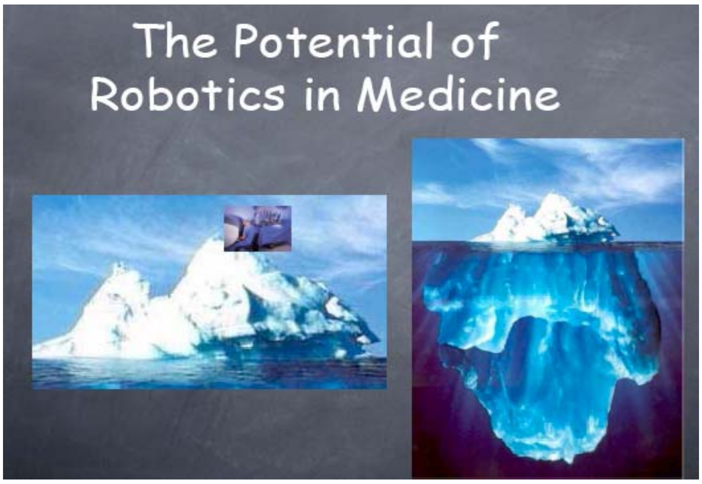

(Source: Vance Watson, ISIS, Georgetown Univ. Hosp., Washington (CARS 2005)

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- **Suggested readings and websites:**
  - IEEE Trans. on Robotics & Automation, Special issue on Medical Robotics, Vol. 19(5), October 2003
  - IARP Workshop on Medical Robotics, Hidden Valley,May 2004: http://www.nsf.gov/eng/roboticsorg/IARPMedicalRoboticsWorkshopReport.htm
  - CARS Workshop on medical Robotics, Berlin, June 2005: http://www.caimr.georgetown.edu/Medical%20Robotics%20Workshop/main.htm
  - 1st Summer School in Medical Robotics, September 2003, Montpellier: http://www.lirmm.fr/manifs/UEE/accueil.htm
  - EURON Research Roadmap (April 2004): http://www.cas.kth.se/euron/euron-deliverables/ka1-3-Roadmap.pdf
  - MICCAI, Tutorials “From mini-invasive surgery to endocavitary / endoluminal interventions”, St Malo 2004: http://miccai.irisa.fr/index2.php?menu=Exhibits_and_Workshops&page=Tutorials
  - Journals: general Robotics and Biomedical J. (IEEE RO, BME, Mechatronics,…) and more “Image processing” oriented (MedIA, JCAS, IEEE PAMI…)
  - Conferences: general Robotics conf. (ICRA, IROS, ISER…) and more dedicated: MICCAI, CARS, CA0S…