Transferring Human Knowledge and Capabilities to Robotic Task Execution in Surgery

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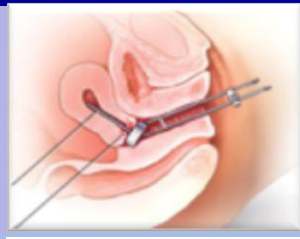
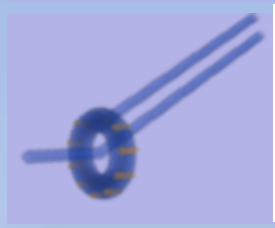
Austrian Center for Medical Innovation and Technology (ACMIT)

Shanghai Lectures
13.12.2012.

Background

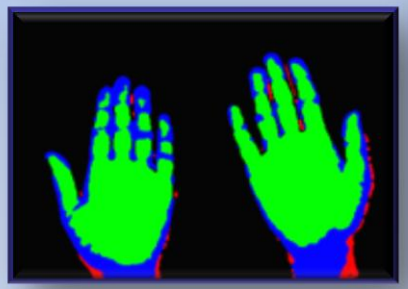
- Budapest University of Technology and Economics (BME)
  - Third biggest university in Hungary (25,000 students)
  - 8 faculties (all branches of engineering, econom., natural sci.)
  - Dept. of Control Engineering and IT
    - Laboratory of Biomedical Engineering

Introduction

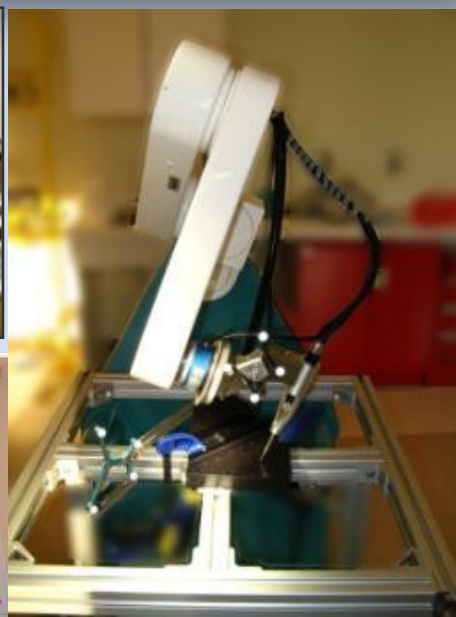

Adjunct professor at BME—in transition to Óbuda University's new iRobotics Center

- Image-guided robotic neurosurgery
- Electromagnetic tracker assessment
- Surgical skill assessment
- Classical and modern control algorithms for telesurgery



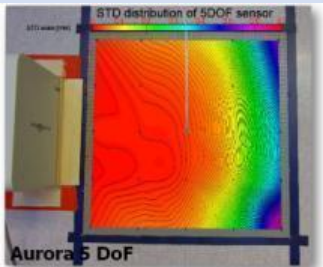

Research area manager at ACMIT

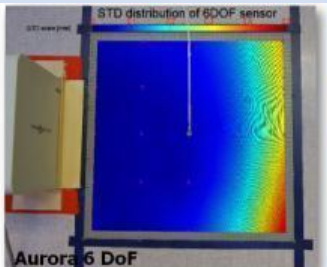
- Surgical workflow analysis
- Gyneac. robotic brachytherapy

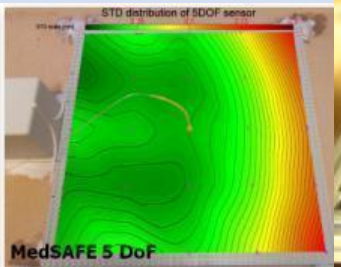



CEO/CTO at Clariton Ltd.

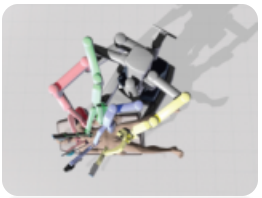
- Hand hygiene control







Categorization of robots



Robots and robot systems

- **Industrial robots**
  - Fixed base
  - Mobile
- **Service robots**
  - Personal
  - Professional
- Other applications, e.g., Military

Robotic systems in accordance with **ISO 8373**, based on **application**

Gurvinder et al. 2012

Personal service robots

Social robots — Paro

Soft robots — Aibo

Intelligent robot companions — iRobot

Medical robots

Home care servant robots, butlers — PR-2

Assistive exoskeletons — HAL

Medical service delivery robot — RP-VITA

Person carrier robot — I-FOOT

Nursing robots in hospitals — Aethon

Rehabilitation exoskeleton robots — RehaRob

Diagnostic robots — Artis zeego

Training robots (phantoms) — DARPA maneken

Surgical robots

Passive	Active
Tool holders — NeuroMate	Open surgery assist — ROBODOC
Patient positioner — RoboCouch	Minimally Invasive procedures — da Vinci
	Radiosurgery — CyberKnife

Gurvinder et al. 2012

Classical approach

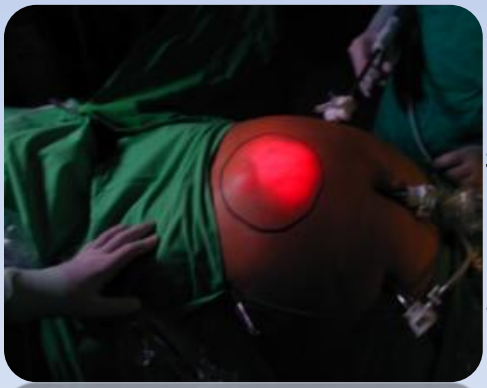
ISO 10218-12*:* The *Robot* required to maintain a minimum *separation* distance to the *human*

Objectives

Better surgery means:

- Better surgical outcome
- Faster recovery
- More precise execution
- Better decisions
- Cheaper treatment

Credit: BrainLAB



Credit: Gy. Wéber

The beginning

- 1985 first brain biopsy
  - Memorial Medical Center – Long Beach, CA
- 1988 PROBOT - prostatectomy
  - Imperial College – London, UK
  - Unimate PUMA 560
- 1989 NeuroMate (Neuromate Sarl Inc.)
  - Grenoble University Hospital
  - Stereotaxis with a modified AID robot
- 1992 ROBODOC (Curexo Inc.)
  - Integrated Surgical Systems Inc.
  - First orthopaedic robot (~IBM Scara)
- 1993 RAMS (NASA)
  - Opthalmology
  - Teleoperation paradigm

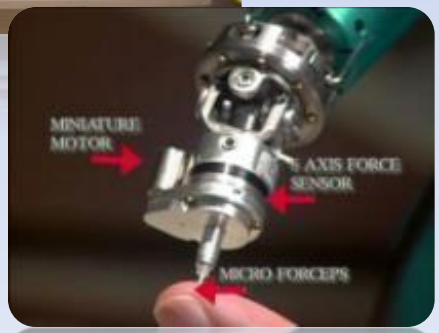
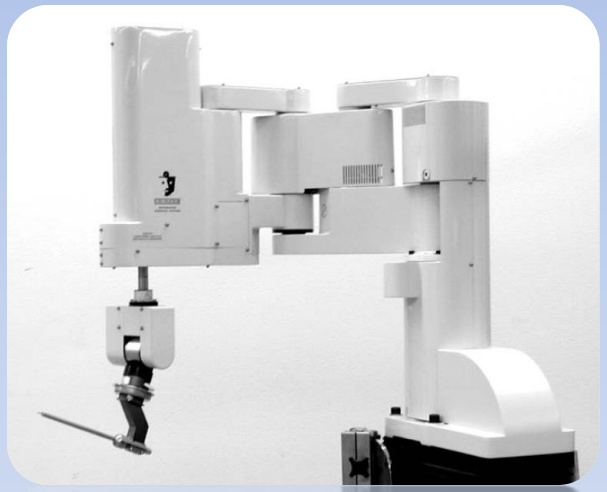


Photo: Integrated Surgical Systems Inc.

Robotic approaches

- **Registration (image) based**
  - Human oversight

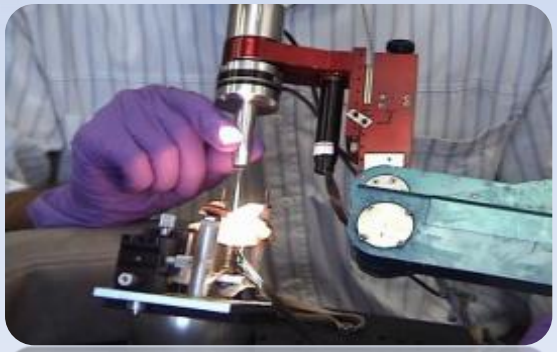


Credit: ISS Inc.

- **Human-in-the-loop control**
  - Leave the mapping to the surgeon

Credit: White House

- **Cooperative control**



Credit: JHU

Surgical robotic sales

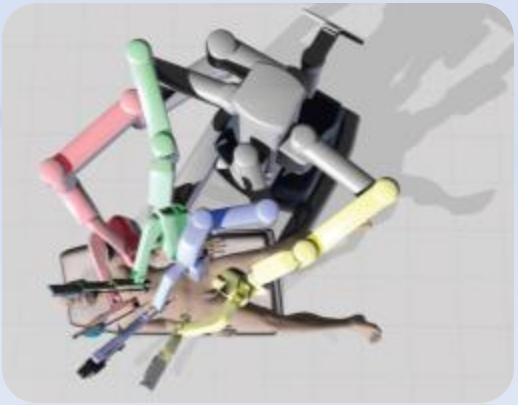
- Zeus: 50 (2002, discontinued 2003)
- NeuroMate: ~30 (16 by ISS)
- ROBODOC: ~50 (37 before 2000)
- CASPAR: ~93 (discontinued in 2003)
- MAKO RIO: 113 systems sold (12.2011)
- SpineAssist: 3 in the USA (07.2010)
  - Renaissance: 2 in the USA (12.2011.)
- CyberKnife: 220 (2010)
- Hansen Sensei: 130 (Q3 2012)
- da Vinci: ~2500 robots (Q3 2012)











Cooperative control

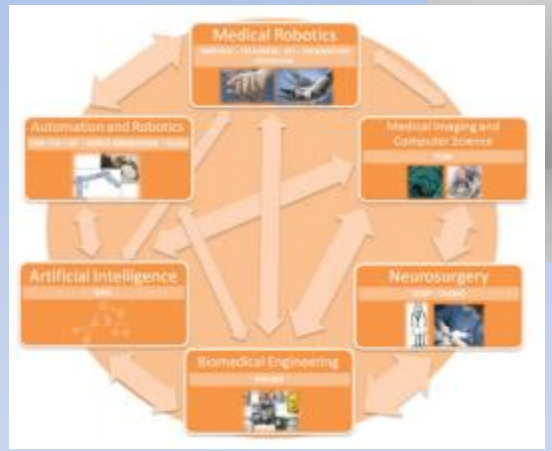
- **“Hands-on” technique**
  - The master and the slave devices are identical
  - Real-time force/torque measurement
  - Provides haptic feedback

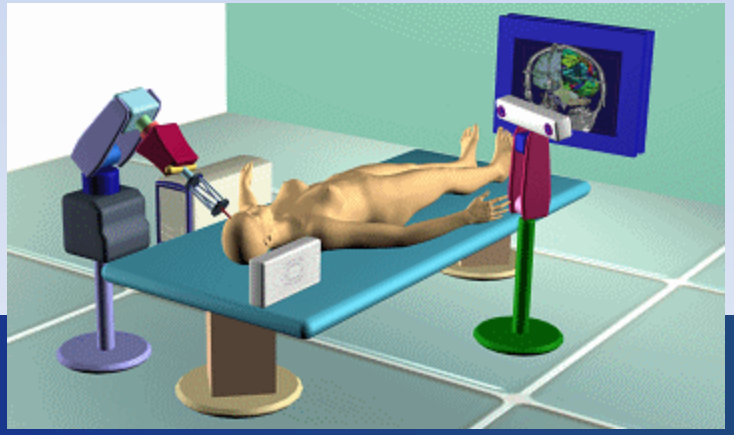
Application examples

- Acrobot (Imperial College, London)
  - Total knee replacement [Jakopec 2003]
- PathFinder (Armstrong HealthCare, UK)
  - IG neurosurgery [Finlay 2006]
- Steady-Hand Robot (JHU, USA)
  - Sinus surgery [Li 2007]
  - Skull base surgery [Matinfar 2007]
  - Eye robot: retinal vein cannulation [Balicki 2009]

EU FP6–7 projects

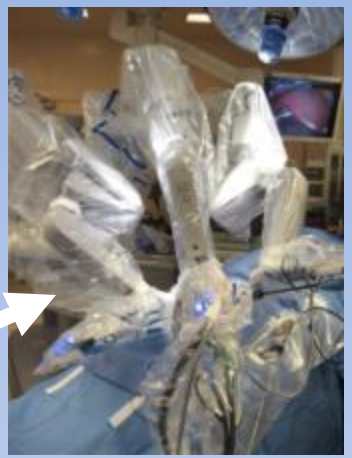
- ACTIVE
  - Awake epilepsy surgery with soft robots and motion compensation
  - *www.active-fp7.eu*
- ROBOCAST
  - Keyhole neurosurgery with micro-macro robot
  - *www.robocast.eu*



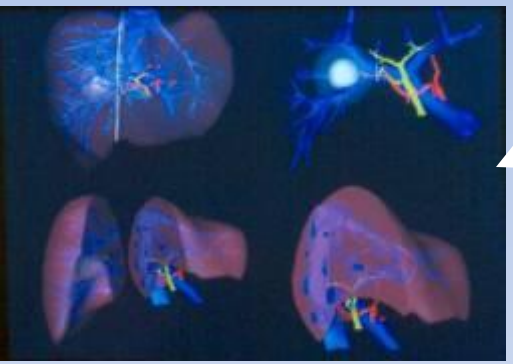


INFORMATION

Telesurgery



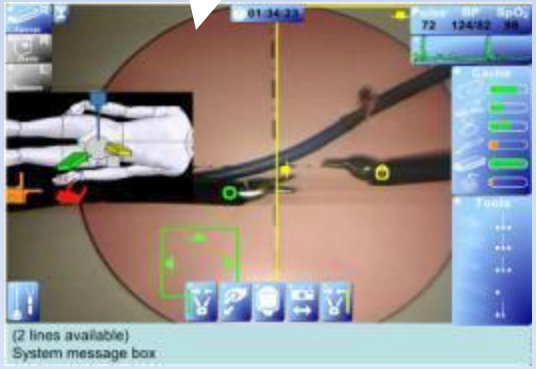
MIS/open surgery



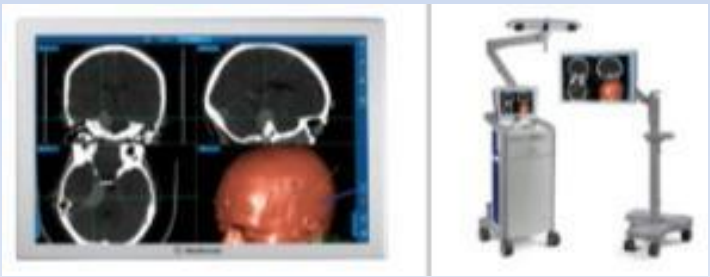
Pre-op planning

Augmented reality

Simulation, practice and warm-up



Sensor fusion



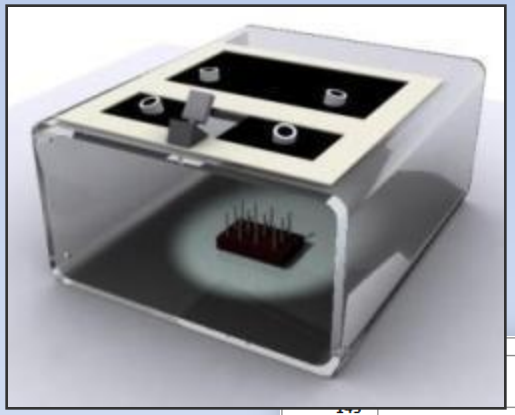
Intra-operative navigation

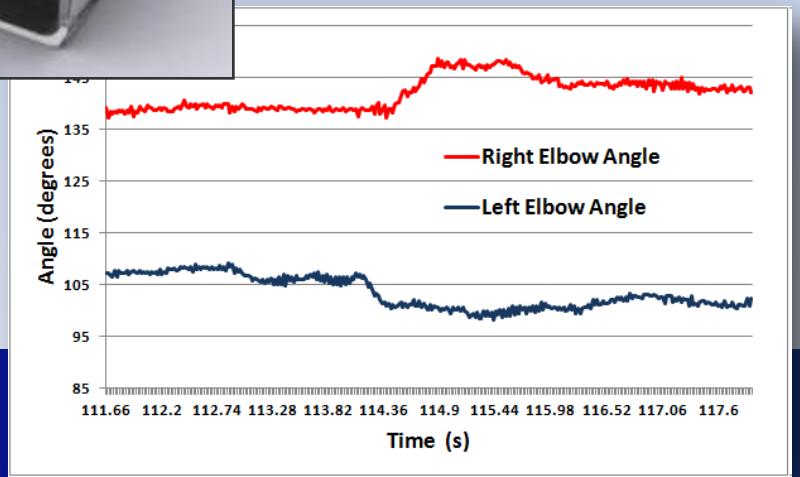
Source: Joel Jensen, SRI International, Menlo Park, CA

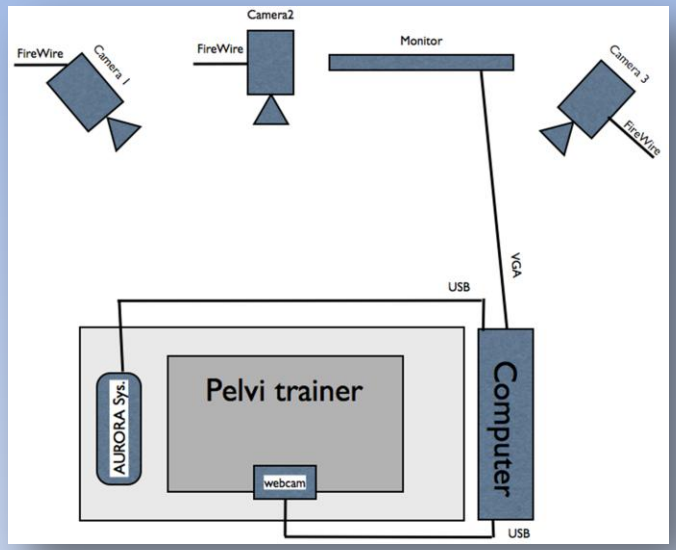
Step I: recording surgery

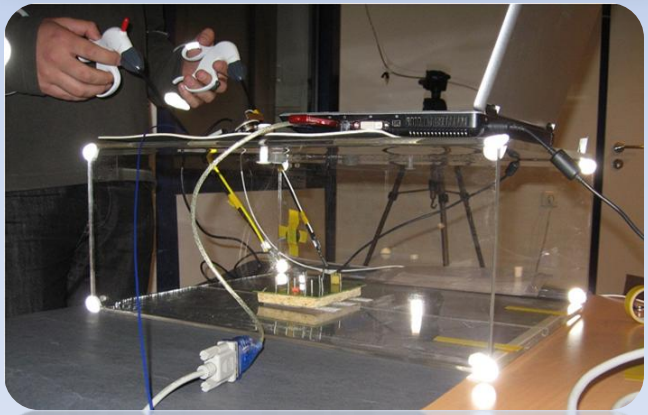
Understand key performance indicators

- Time
- Path
- Forces
- Surgical outcome



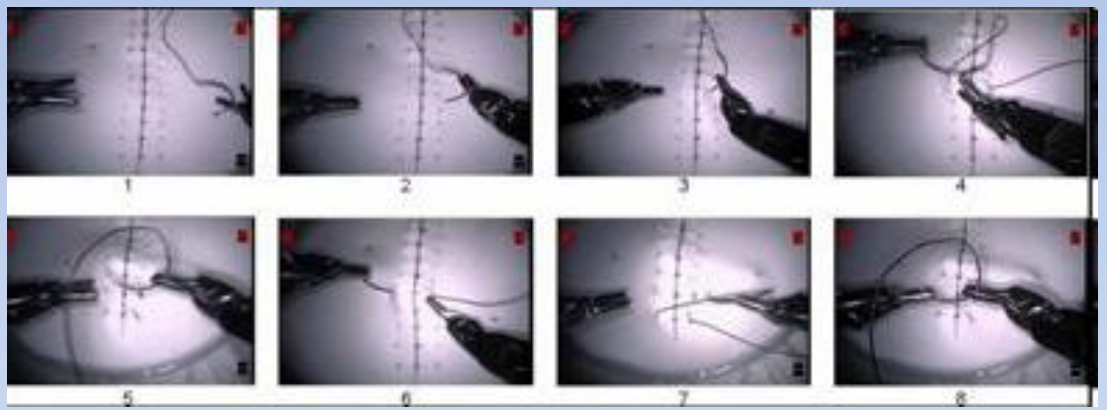


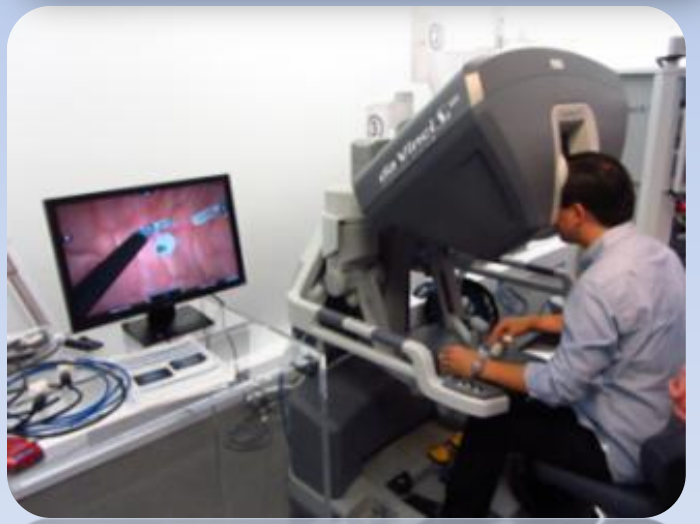


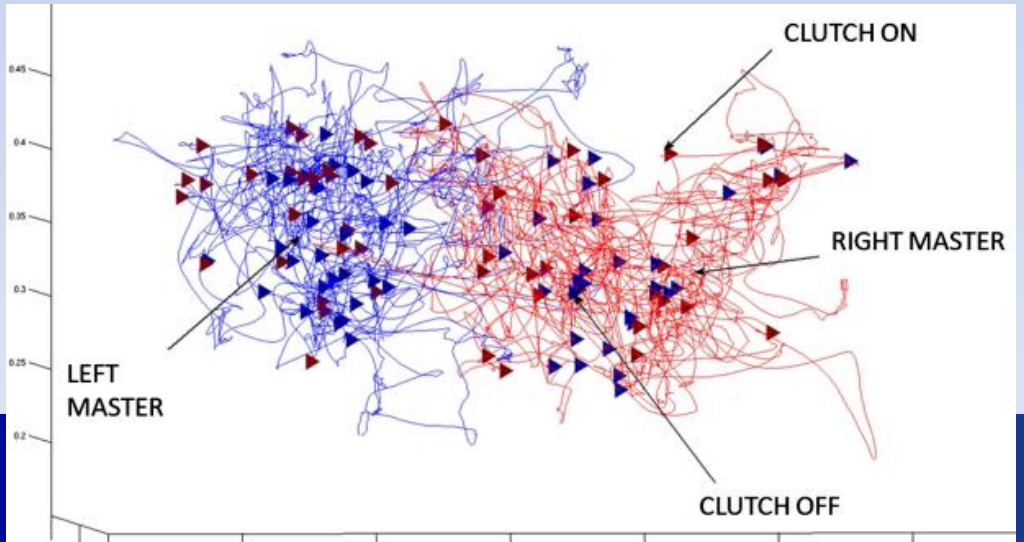


Step II: analyze surgery

- Da Vinci Skill Simulator
  - Extended training opportunity
  - “Language of surgery” project



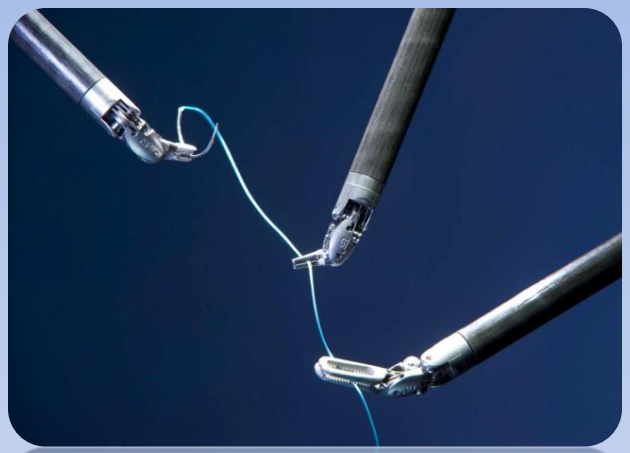


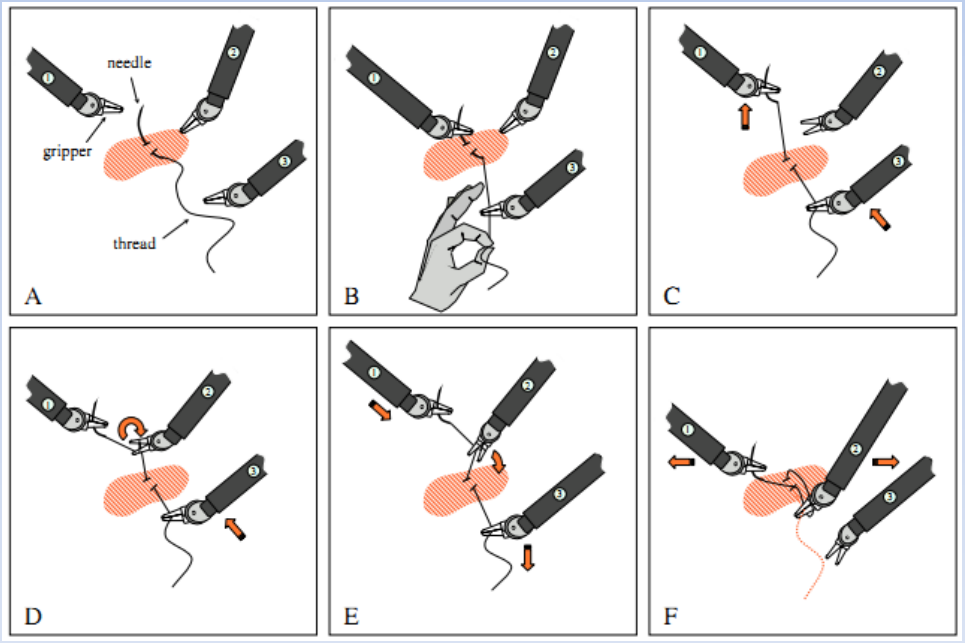


Step III: repeat surgery

TUM knot tying setup

- Learning the “perfect knot”
  - Artificial intelligence methods





Step IV: automate surgery

First cardiac ablation

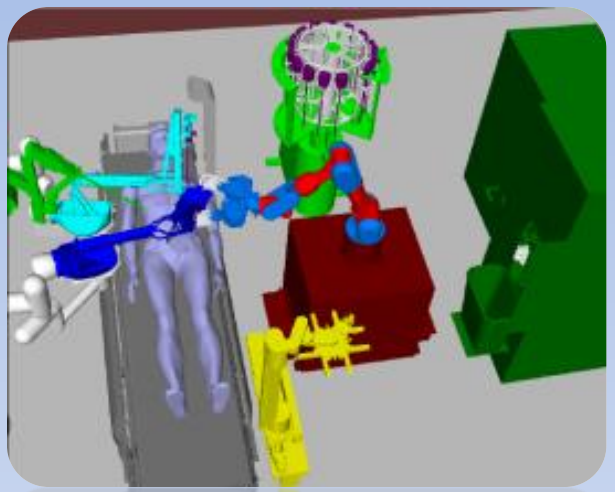
- A remotely-controlled catheter guiding robot used in 2006;
- Teleproctoring to Milan form Boston *[Pappone et al., 2006]*

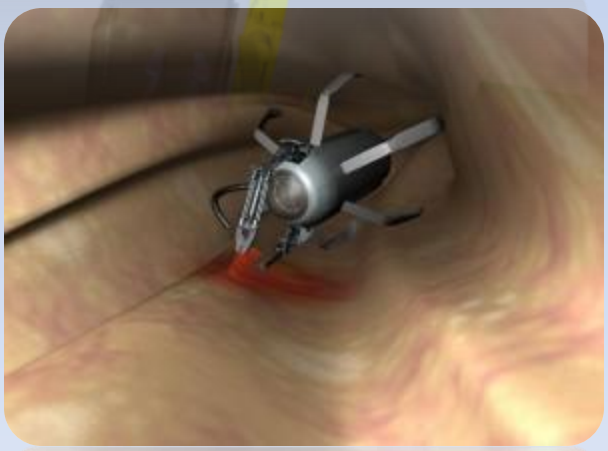
Robotic anesthesia

- 2008- McGill University hospital

Suturing

- Getting there at various groups



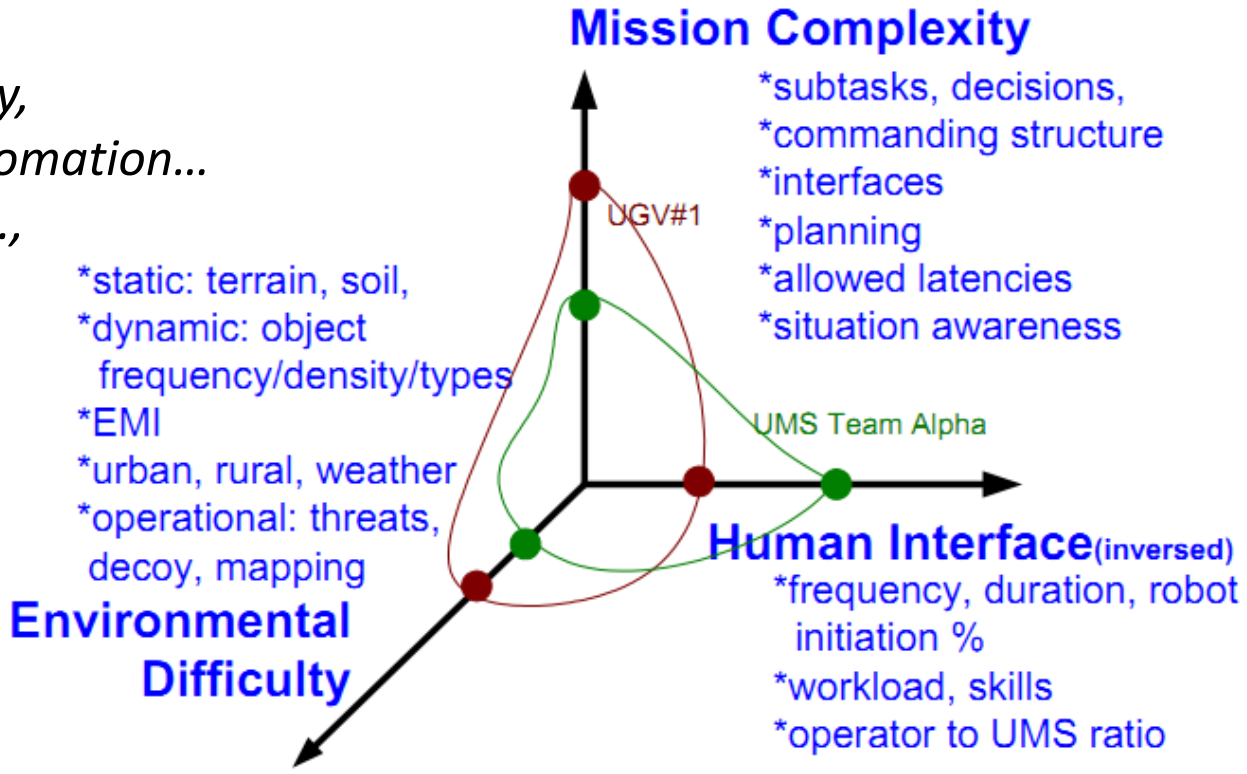


Standards following

Degree of Autonomy (DoA) the missing piece

- Risks and hazards originating from DoA
  - In current and future medical electronic equipment
- ALFUS approach
  - IEEE workgroup for Autonomy Levels for Unmanned Systems
- DoA levels identified
  - *D.B. Kaber, M.R. Endsley,*

The effects of level of automation…
Theor. Issues in Ergon. Sci.,
5(2), pp. 113-153, 2004



Nesting the legal background

International Organization for Standardization

ISO/TC 184/SC 2/JWG 9

- TC 184: Technical Comm. on Automation Systems & Integration
- SC 2: Sub-Committee on Robots and Robotic Devices
- **JWG 9: Joint Work Group on Standard for Medical Robot Safety**
- Delegate of the Hungarian Standards Institution (MSZT)
- Governor: Gurvinder S. Virk (UK)
- National POC: Dr. Seungbin Moon <sbmoon@sejong.ac.kr>

IEEE RAS standing committee for standardization

- Member of the ORA workgroup—Ontologies for Robots
- Leaders: Craig I. Schlenoff (USA), Edson Prestes (BR)

Rational for standards

- Following the mainstream development
- Facilitating interoperation
- Clarifying legal issues
- Ensuring user safety

Thank you for your attention!

Post script

For more information:

SurgRob

a blog on CIS and medical robotics

http://surgrob.blogspot.com

Takeaway

“Get smarter people than you are, and make them excited about your problem!”

/R.H. Taylor/

”If you enjoy your job, you will never have to work for your entire life.”

/ Teik Seng Tan/