

# Transferring Human Knowledge and Capabilities to Robotic Task Execution in Surgery



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# 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**

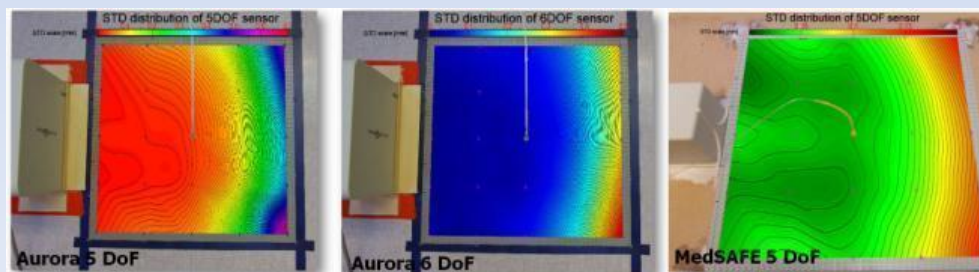
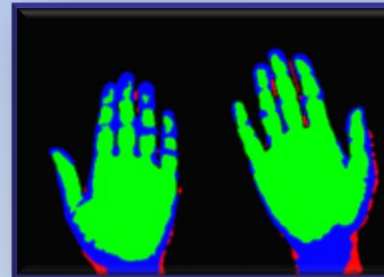
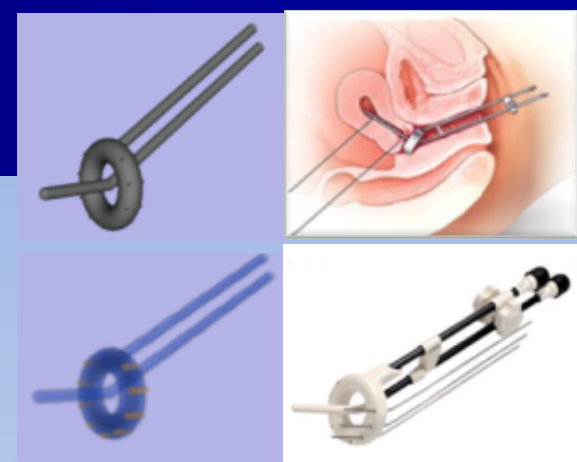
- Image-guided robotic neurosurgery
- Electromagnetic tracker assessment
- Surgical skill assessment
- Classical and modern control algorithms for telesurgery

**Research area manager at ACMIT**

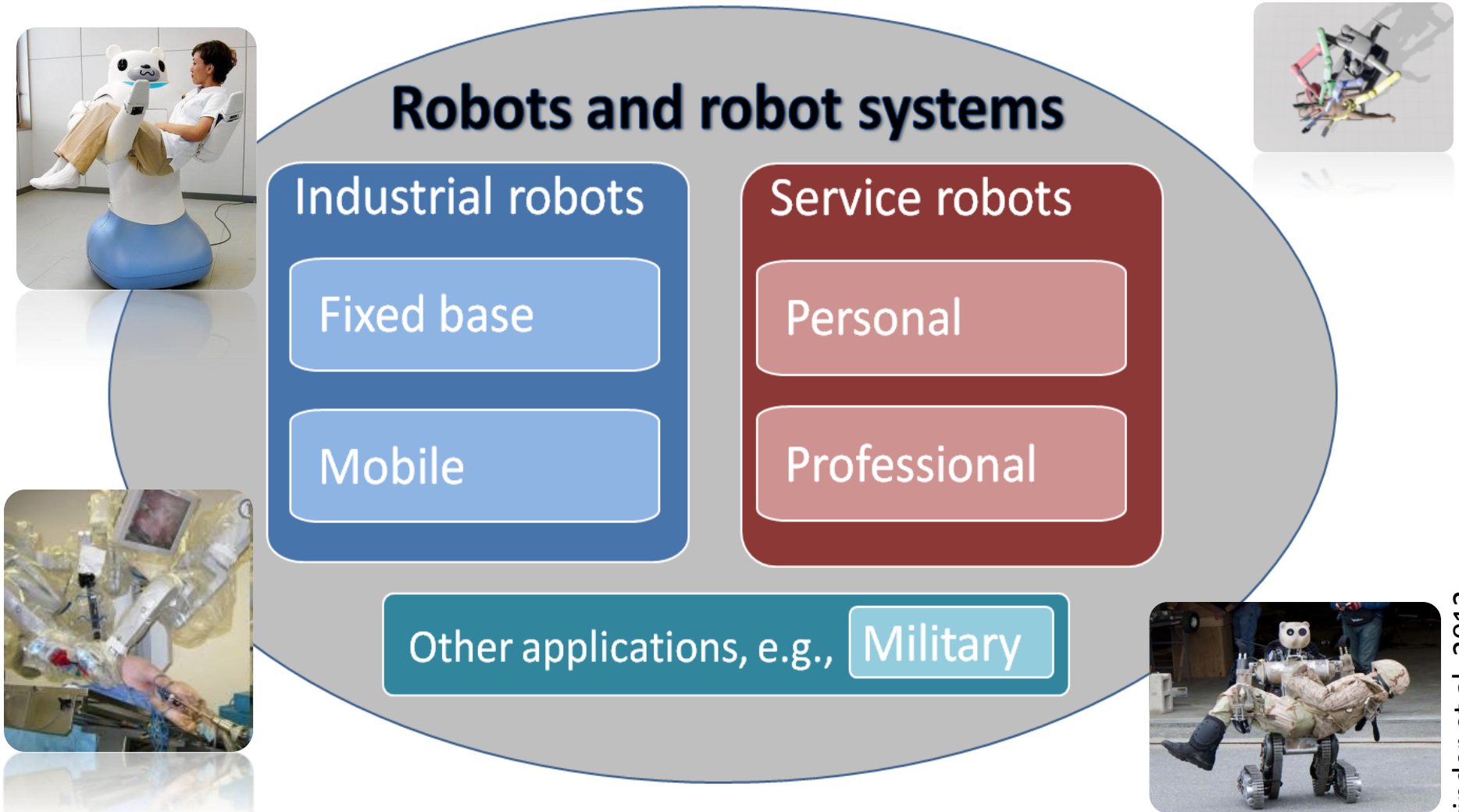
- Surgical workflow analysis
- Gyneac. robotic brachytherapy

**CEO/CTO at Clariton Ltd.**

- Hand hygiene control



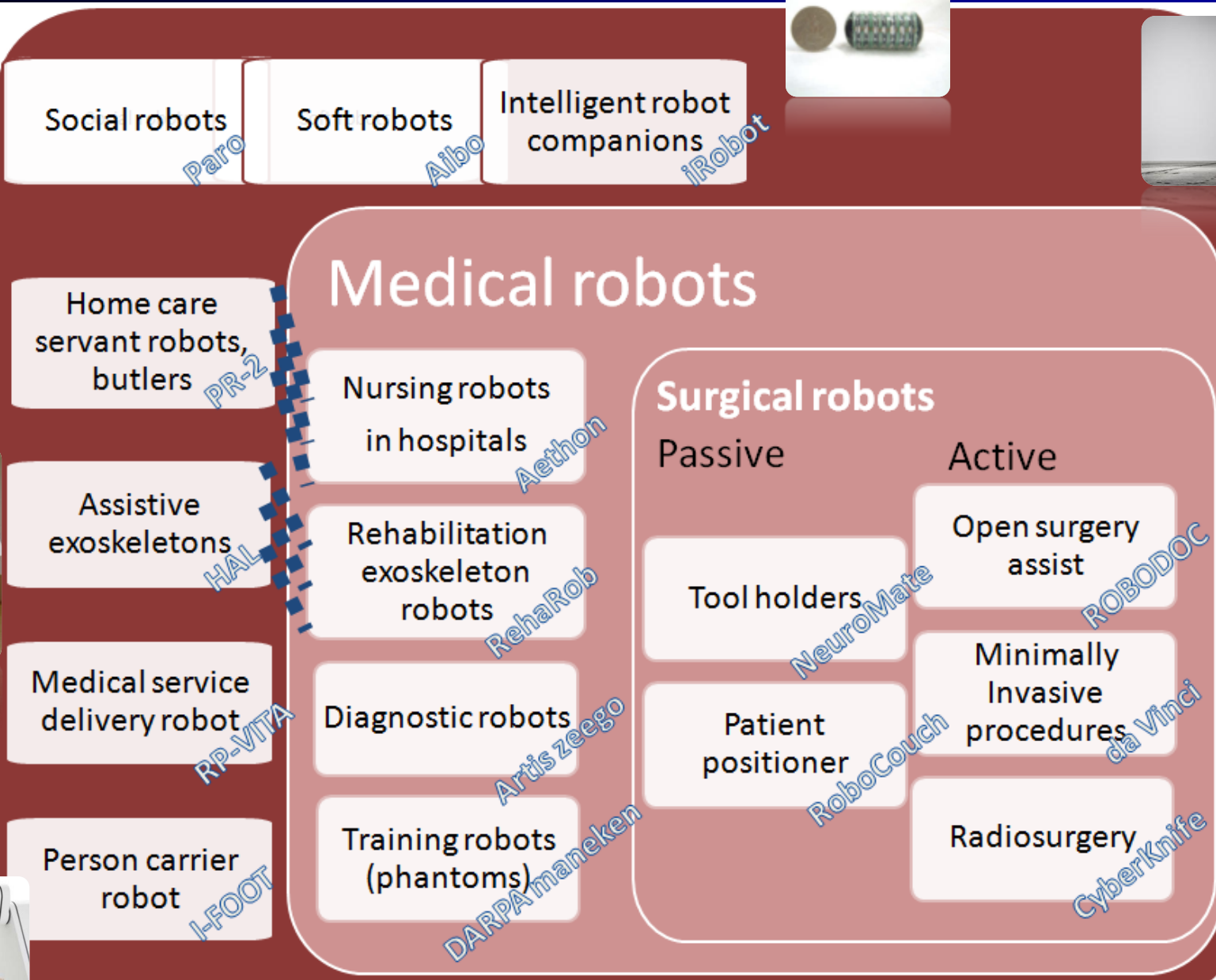
# Categorization of robots



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



# Personal service robots



# Classical approach



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

## Better surgery means:

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



Credit: BrainLAB



Credit: Gy. Wéber

# The beginning

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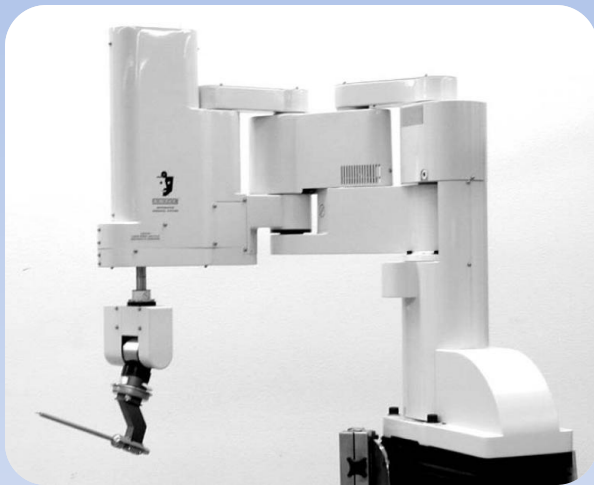
- 1985 first brain biopsy
  - Memorial Medical Center – Long Beach, CA
- 1988 PROBOT - prostatectomy
  - Imperial College – London, UK
  - Unimate PUMA 560
- 1989 NeuroMate (Neuromate Sarl Inc.)
  - Grenoble University Hospital
  - Stereotaxis with a modified AID robot
- 1992 ROBODOC (Curexo Inc.)
 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





- **Registration (image) based**

- Human oversight



Credit: ISS Inc.

- **Human-in-the-loop control**

- Leave the mapping to the surgeon



Credit: White House

- **Cooperative control**



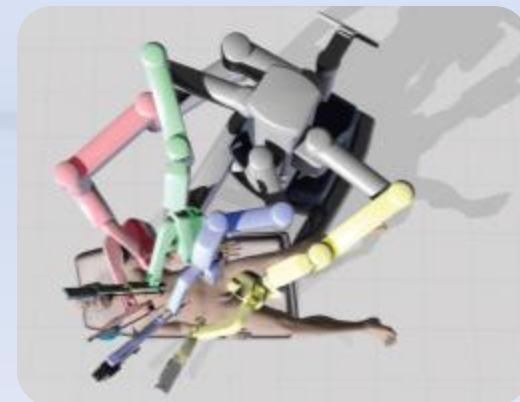
Credit: JHU

# Surgical robotic sales

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- 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

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- **“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]



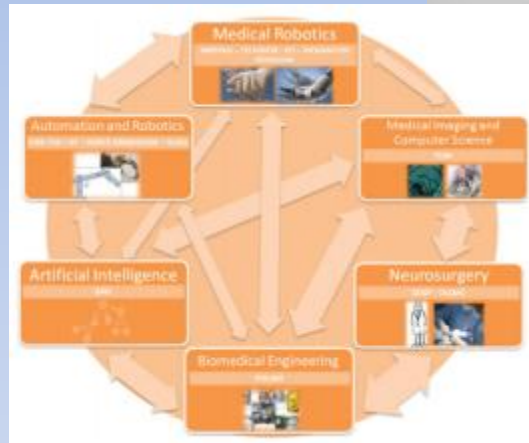


- ACTIVE

- Awake epilepsy surgery with soft robots and motion compensation
- [www.active-fp7.eu](http://www.active-fp7.eu)

- ROBOCAST

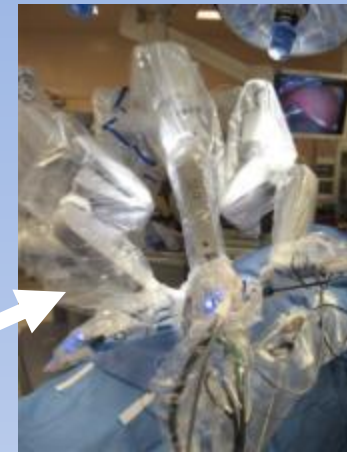
- Keyhole neurosurgery with micro-macro robot
- [www.robocast.eu](http://www.robocast.eu)



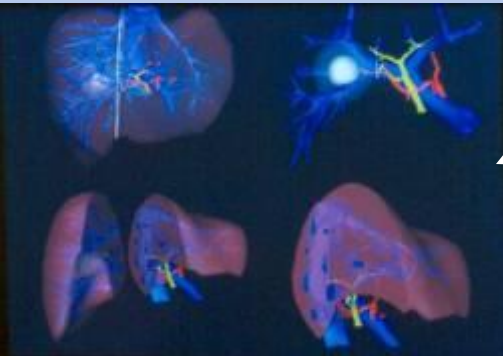
# INFORMATION



Telesurgery



MIS/open surgery



Pre-op planning



Augmented reality



Sensor fusion



Intra-operative navigation

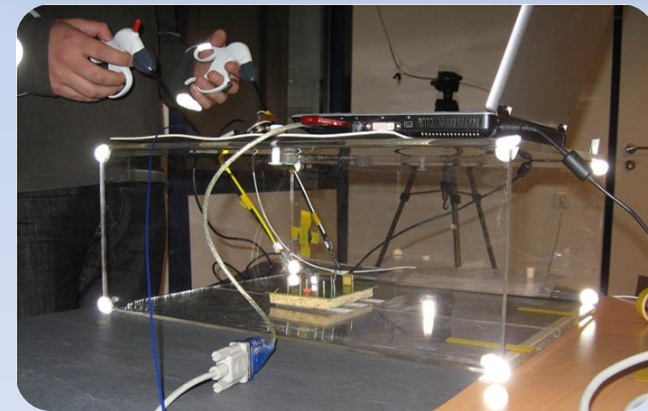
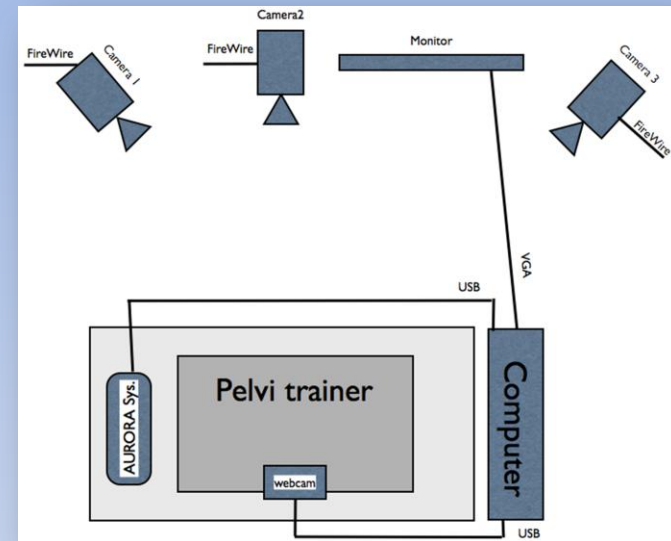
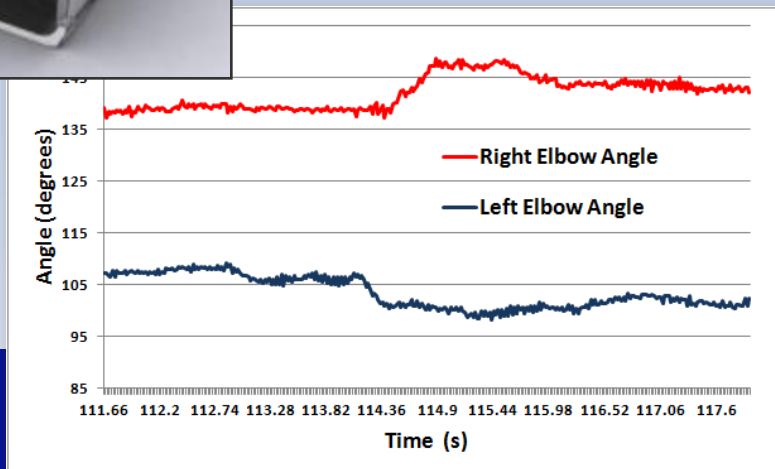
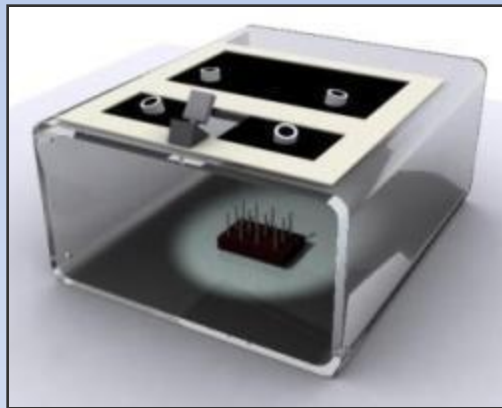


Simulation, practice and warm-up

# Step I: recording surgery

## Understand key performance indicators

- Time
- Path
- Forces
- Surgical outcome

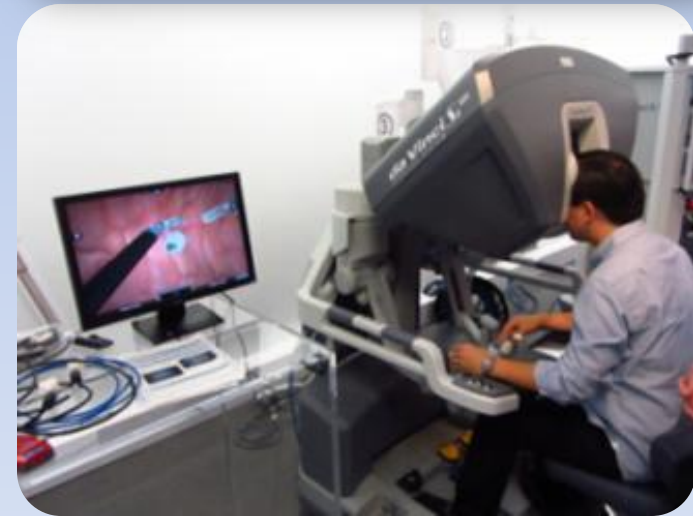
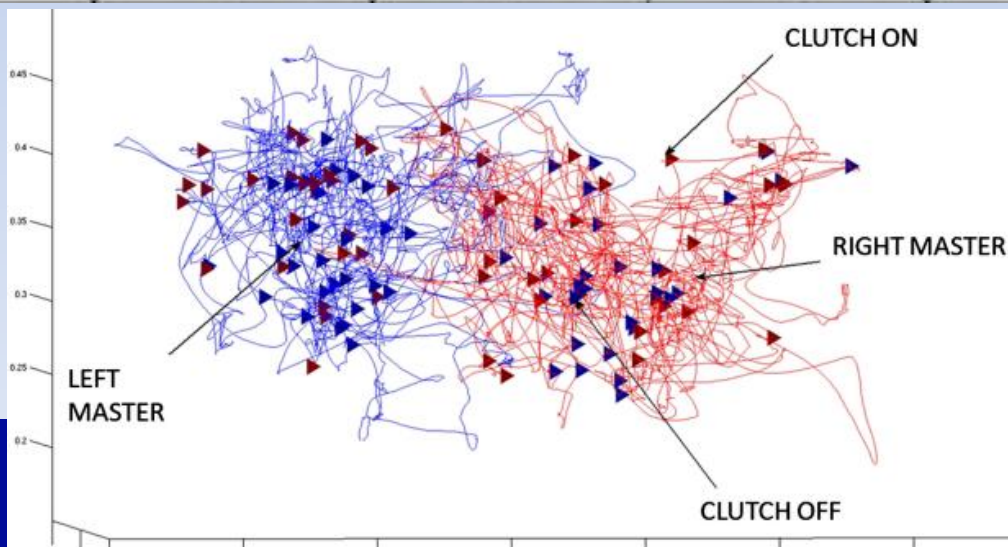
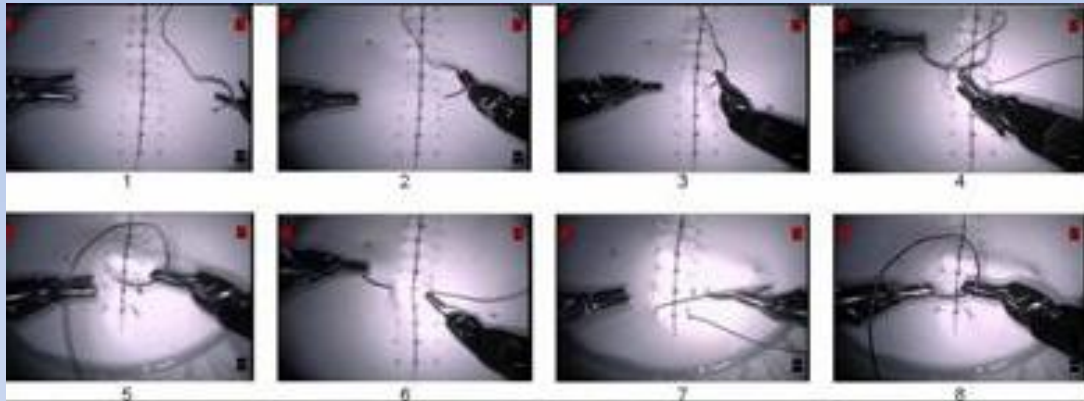




# Step II: analyze surgery

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

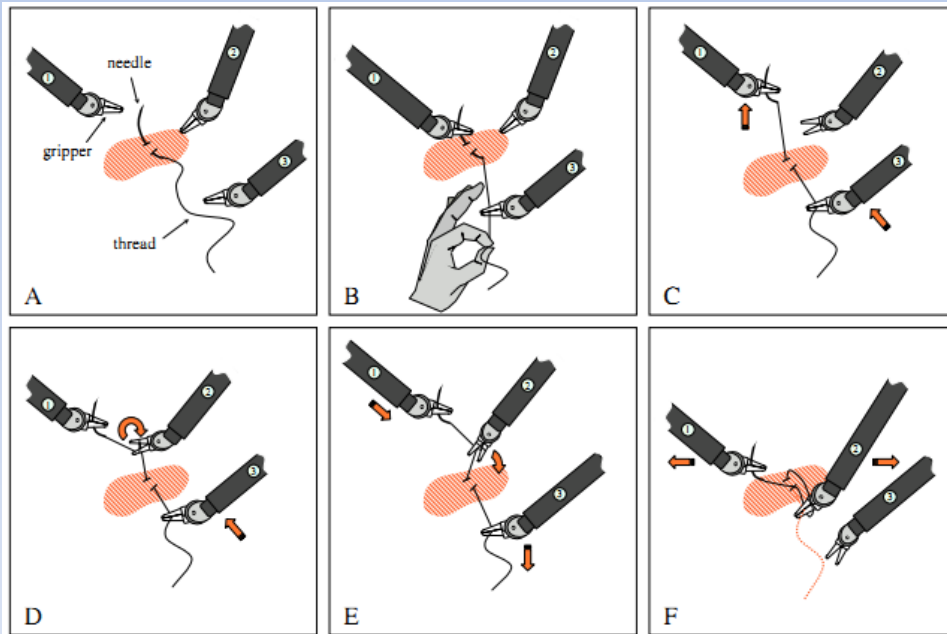
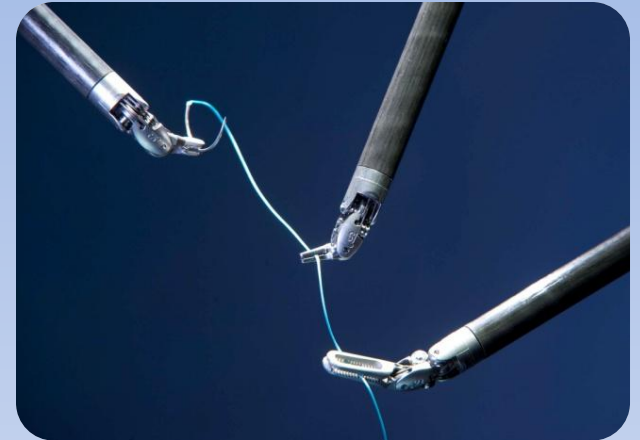




# Step III: repeat surgery

## TUM knot tying setup

- Learning the “perfect knot”
  - Artificial intelligence methods



## First cardiac ablation

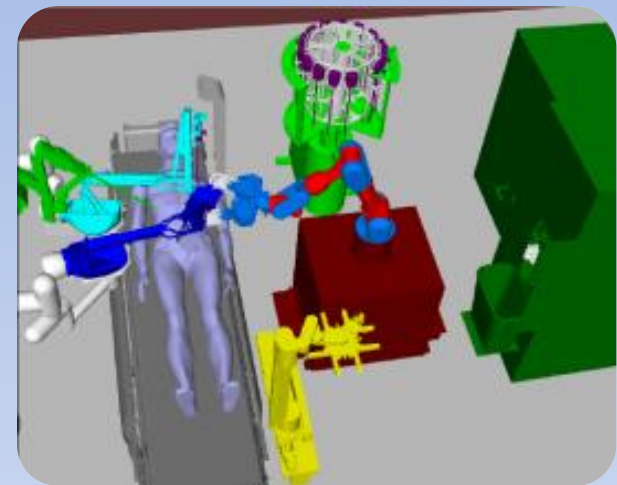
- A remotely-controlled catheter guiding robot used in 2006;
- Teleproctoring to Milan from Boston  
*[Pappone et al., 2006]*

## Robotic anesthesia

- 2008- McGill University hospital

## Suturing

- Getting there at various groups



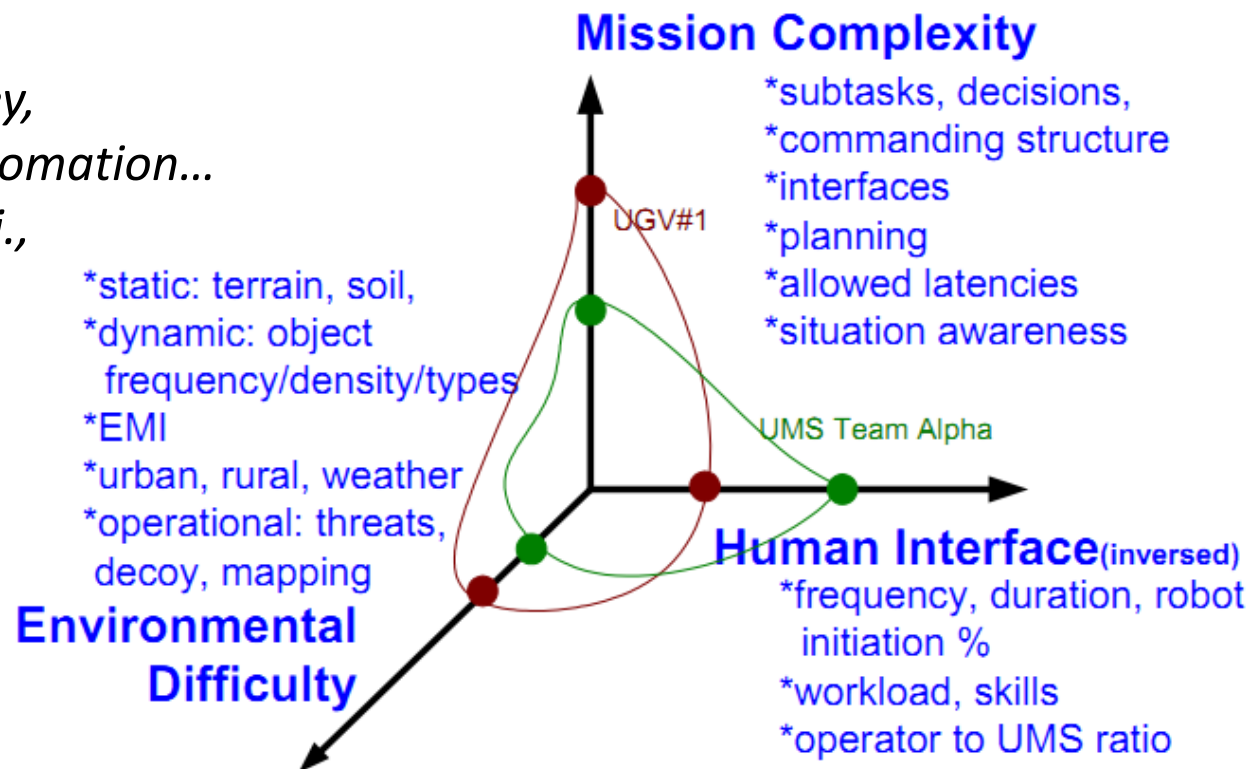
# Standards following

## 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*



## 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: Gurminder 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)



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



*Robotics & Automation Society*



**Thank you for your attention!**

# Post script

*For more information:*

## SurgRob

a blog on CIS and medical robotics

<http://surgrob.blogspot.com>



Links

- [All publications](#)
- [Autonomous Telepresence in Robotic Surgery](#)
- [The Robot Doctors](#)
- [IMU robot video](#)
- [CIS](#)
- [Personal Blog - The Rio Idea](#)
- [-----](#)
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- [Medical Robotics Blog \(in Chinese\)](#)
- [Unleashing Blog on Surgical Robotics](#)
- [-----](#)
- [All About Robotic Surgery](#)

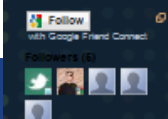
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Surgical Robotics here and there

wednesday, april 14, 2010

### ●●● CIS news

Spring is here with a lot of happenings in the realm of CIS:

- [RSI demos with the RT at the National Robotic Week](#)
- [Finally, the Robotic Surgery Center in Qatar is taking off \(in coop with Imperial and other Colleges in London\)](#)
- [New study on the advantages of robotic TKA](#)
- [US' first robot-assisted multi-artery cardiac bypass at UC Davis](#)
- [MSI provides robot-assisted at UT Austin's ortho dept](#)
- [Video coverage on surgery for hepatocellular with da Vinci](#)
- [Eunice Kim: providing single-port tools for the da Vinci](#)
- [Surgical Medical Center's new mission](#)
- [Robotic-assisted liver resection](#)
- [Roimich released an iPhone version of its navigation software](#)
- [Robline Technologies for image-guided Robotic Interventional Procedures workshop](#)
- [2010 Int. Conf. on Technology and Medical Robotics](#)
- [AMT research progress in Singapore](#)
- [Texas Science about new robotic limbs at TAMU](#)
- [New DNA test for cancer](#)
- [SurgRob featured in the Mavell magazine](#)



Posted by T. at 11:45 PM

2 comments

thursday, april 8, 2010

### ●●● Robotic surgery concerns

While the da Vinci's success story continues (according to Intuitive, they've reached 90% penetration in LRP in the USA), and [upon the President's stand](#) around with it, many people expressed their concerns about the economic and patient benefits.

Primary concern is the price of the device, where not even the initial 0.75-1 M USD is really a hit, but the maintenance and tool costs.

NY Times featured an article some time ago, citing the [JAMA study](#) (seriously misused here) to emphasize the lack of clinical benefits. (Henderson also covered the story.)

Others questioned the use of the robot with heart procedures ([see Robotic's Good Idea for Cardiac Surgery?](#) by [Chad Summalla](#)), while they admit, trends lead towards robotic surgery.

[David Henderson](#) wrote about the [surveys versus the medical literature](#) surrounding the evidence whether robotic surgery offers oncologic outcomes comparable to chemotherapy. Interestingly, they cite [the same article](#) that was written by [the group](#) who pushed the whole procedure through the FDA. [Other studies are in favor](#) of the robotic head-and-neck procedures.

After all, the numbers clearly show the success of the marketing and Intuitive, leaving the throne of the da Vinci unthreatened.

Posted by T. at 12:12 AM

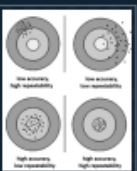
2 comments

friday, april 2, 2010

### ●●● FDA workshop on medical robotics standards

Robotic devices should provide significant patient benefits and allow for refined treatments that are not possible by other means. It is crucial to test for the application accuracy of a system, to define the expected overall task execution error. After 20 years of development, there is still a great need for objective measures in medical robotics.

Realizing this fact, FDA organized a workshop on Medical Care Robots in



**“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/**

