Towards cognitive supervision in robot-assisted surgery

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- **surgical robotics** and...

- **...artificial cognitive systems**
  (read: artificial intelligence)
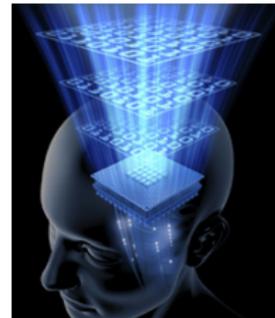
The age of pioneers (~1980's)

Need for robots in the operating room?

- better accuracy
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└─Introduction
   └─History of surgical robotics
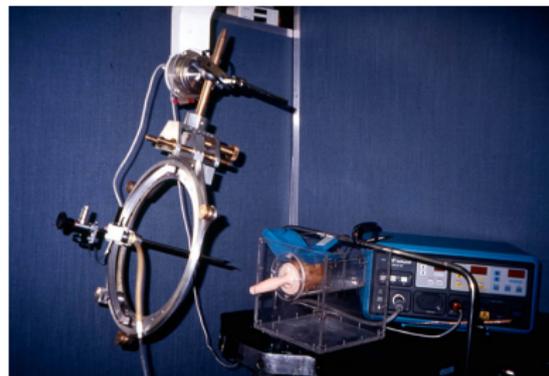
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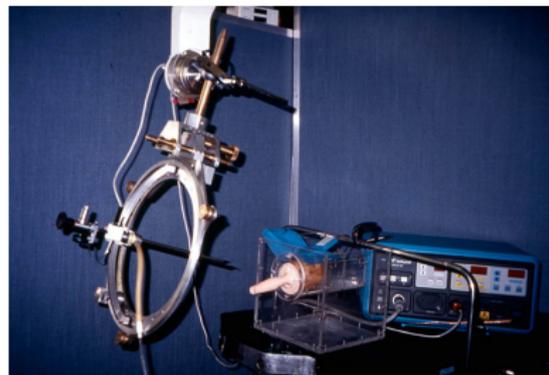
Robots help surgeons in doing tasks *better than either can do alone*

The age of ASRs (~1990's)

Early promise of medical robotics failed to materialise [1]

[1] B. Davies, *Robotic Surgery: From autonomous systems to intelligent tools*, 2007.

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     (think about safety)
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Do we really need surgical robots?

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From ASRs to intelligent tools (2000 – today)

- no more Autonomous Surgical Robots (ASRs)
- robots are not intended to replace the surgeon
- intelligent tools at the direct command of the surgeon
- augment a surgeon's ability

Artificial Intelligence and Surgical Robotics?

Can AI help in making surgical robots more intelligent ?
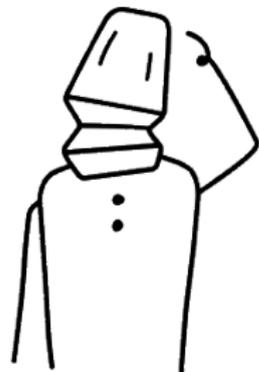
Artificial Intelligence and Surgical Robotics?

Can AI help in making surgical robots more intelligent ?

Classic AI limitations:

- no awareness
- the real world problem
- what about unexpected circumstances?

Weak AI[2]

Computers are superior in

- acquire/process huge amounts of *quantitative* informations
- integrate many data sources

Let's exploit such abilities to approach open problems!

_____

[2]also known as *Synthetic AI*

Objective evaluation of surgical performance

Is it possible to model a surgeon's expertise?

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[3] S. Sinigaglia *et al.*, *Defining metrics for objective evaluation of surgical performances in laparoscopic training*

[4] C.E. Reiley *et al.*, *Decomposition of robotic surgical tasks: an analysis of subtasks and their correlation to skill*

Objective evaluation of surgical performance

Is it possible to model a surgeon's expertise?

Yes, by means of Hidden Markov Models (HMM)! [3] [4]

1. record the motions of skilled surgeons
2. train an HMM over the recorded signals
3. use the model for prediction
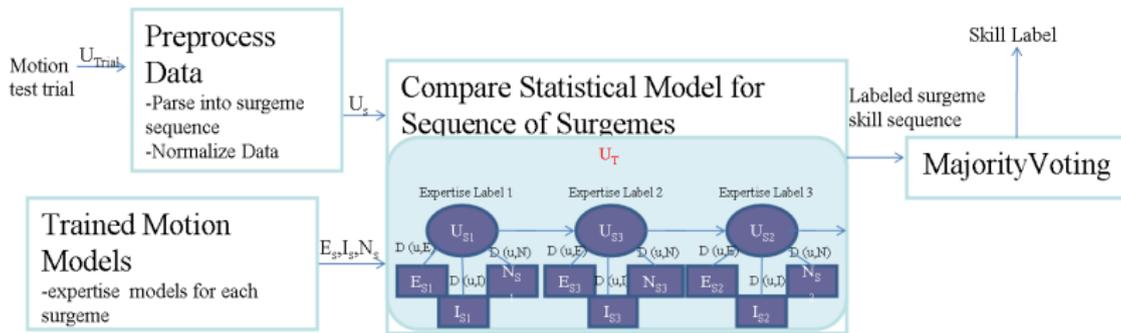
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Towards energy-directed systems

Future surgical robots will be energy directed rather than mechanical instruments[5]

[5] R.M. Satava, *Future directions in robotic surgery*

Towards energy-directed systems

Future surgical robots will be energy directed rather than mechanical instruments[5]

Untangible physical effects:

- laser
- ultrasound
- etc.

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[5]R.M. Satava, *Future directions in robotic surgery*

The Microralp project

Micro-technologies and systems for robot-assisted laser *phonomicrosurgery*:

- treatment of vocal cords lesions
- laser as surgical tool

Open problems:

- how much energy delivered to the surgical site?
- how to minimize the *thermal stress* of the tissue?
- how to minimize *carbonization*?
- choice of laser parameters?

The Microralp project

An artificial cognitive system can help!

- learn and predict changes of the surgical site
- generate alarms when dangerous situations are detected
  - changes in laser power or focus
  - estimation of tissue temperature is above a safe threshold
  - provide an objective evaluation (nice extra!)

Hierarchical Temporal Memory [6]

Seems a promising technology because

- combines together well-established approaches

   neural networks, probabilistic reasoning, HMM, deep architectures

[6] J. Hawkins and D. George, *Towards a mathematical theory of cortical micro-circuits*, 2009.

Hierarchical Temporal Memory [6]

Seems a promising technology because

- combines together well-established approaches

  neural networks, probabilistic reasoning, HMM, deep architectures

- able to integrate various sources of information
- explicit use of time during learning

  ability to learn temporal sequences!

- predict future inputs
- detect unexpected patterns

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[6] J. Hawkins and D. George, *Towards a mathematical theory of cortical micro-circuits*, 2009.

Conclusion

Surgical robots

- becoming specialized, intelligent tools
- of the future likely to be energy-directed systems

Weak AI approaches

- proved to be effective for modeling surgical expertise
- can help in reducing the cognitive overload

Thanks!

Contacts

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Questions?