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User interfaces in computer-assisted and robot-assisted surgery

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Introduction

Surgery	Visualization	Control
Traditional	Direct	Direct
Microsurgery	Microscope	Direct (micromanipulator)
Computer-assisted	Any	Direct
Robot-assisted	Any	Teleoperation

Application of computer and robot assisted surgery:

- Surgery,
- Diagnosis,
- Planning,
- Training.

In traditional surgery, the dexterousness of the doctor important.
In robot-assisted surgery, the interface is critical.

Minimally Invasive Surgery (MIS)

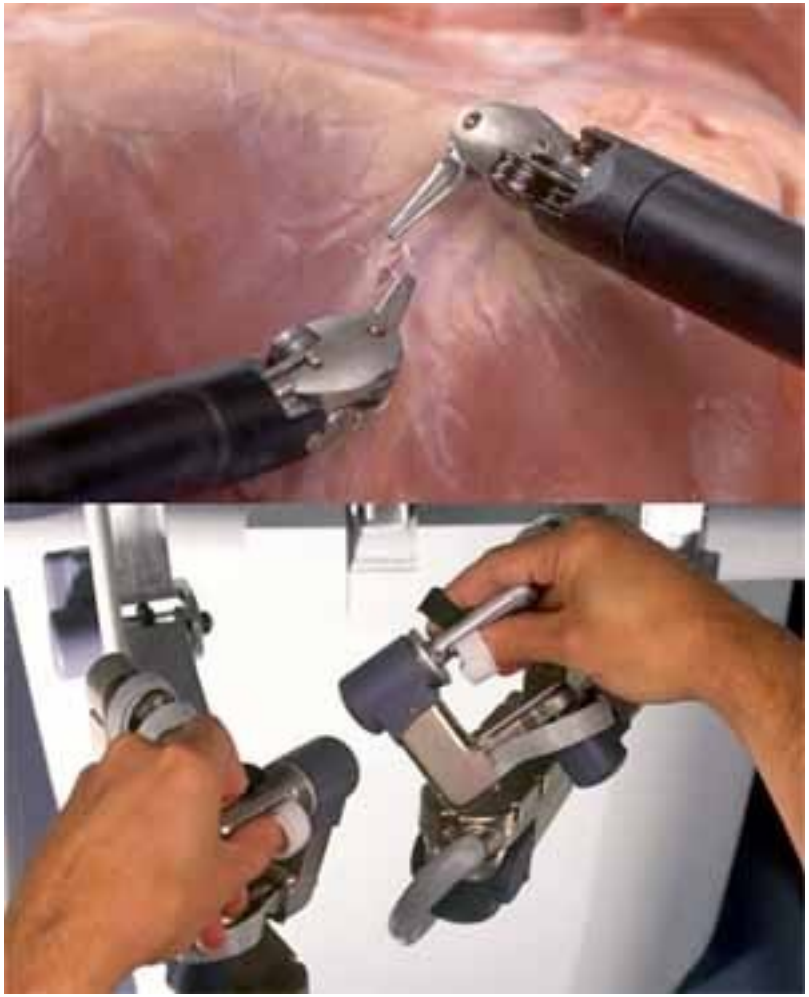
Advantages:

- Reduces tissue trauma,
- Reduces blood loss,
- Faster recovering,
- Shorter hospital stays.

Disadvantages:

- More complex setup,
- Extensive surgical training.

Da Vinci



Medical robots research

- System architecture, Software design, Mechanical design, Imaging compatible designs, Safety,
- User interface [Cleary et al, 2001]:
  - What is a suitable user interface for a medical robot?
  - Should the robot be given a commanded path or volume and then autonomously carry out the task?
  - Is a joystick or push button interface appropriate?
  - Or would the physician rather manipulate the tool directly with the assistance of the robot?
  - Is force feedback required for a high fidelity user interface?

Diagnosis, planning and training

- Diagnosis [Abolmaesumi et al, 2001]:
  - Devices and GUI (Augmented information).
- Planning [Seitel et al, 2009]:
  - Image based interface for Computer Tomography (CT). Imaging system integrated with the interface → Reduce planning time and number of CT scans.
- Training [Vuskovic et al, 2000] [Robb et al, 1996] [Syed et al, 2011] [Xianjun et al, 2010]:
  - VR, simulation of real tissue, force feedback.

Force feedback

- Commonly used in research in computer-assisted and robot-assisted surgery but not too much in real systems.
- Research to study the effect of using force feedback [Wagner et al, 2007]:
  - It reduces the applied force in experienced and inexperienced people.
  - Only benefit from the trial point of view for experienced people.

Control

- Try to increase the precision and usability.
- Novel control methods [Nishikawa et al, 2003]:
  - Face tracking system for controlling the position of the laparoscope → Hands free, natural control.
- Control in phono-microsurgery:
  - Robot system with force feedback [Wang et al, 2005].
  - Virtual scalpel (stylus on tablet) compared with other controls: micromanipulator, joystick, etc [Dagnino et al, 2011].

Tactile feedback

- Relatively new in medical robotics.
- Influence of the tactile feedback in the grasping force [Culjat et al, 2008] [King et al, 2009]:
  - FlexiForce sensors on Da Vinci.
  - Transmitted to the doctor through a haptic interface with 5 force levels.
  - Less applied force.
- Vibration patterns to transmit information [Nishino et al, 2011].
- Vibration to simulate roughness [Yamauchi et al, 2009].

Sensory fusion and substitution

- Render the sensory inputs in the corresponding senses [Chou et al, 2001]:
  - Maximize information.
  - Reduce cognitive overload.
  - Increase operator performance.
- Sensory substitution with soft-haptics [Liu et al, 2001]:
  - Render distance and collision information using color coding.
  - Simpler interface and communication system.
  - Higher training periods.

Conclusions (1/3)

- Three main areas:
  - Display (VR, 3D reconstruction and rendering, etc).
  - Control devices (3D joysticks, tracking, etc).
  - Feedback (force and tactile).
- The combination of the three of them to maximize the information flow maintaining a low cognitive load.
- Other important things: Transmission, rendering, etc.
- Solution: Trade-off between information and technical requirements.

Conclusions (2/3)

- Robot with limited DOFs:
  - Maximize the use of the DOFs.
  - Natural control. A motion in the interface corresponds with a motion in the robot.
  - Improve traditional methods (stylus).
- Visualization:
  - Limitations of the cameras (position, resolution, framerate, etc).
  - Improvements respect traditional (light frequencies, augmented reality, etc).

Conclusions (3/3)

- Replicate the traditional surgery controls and visualization (approach of Da Vinci):
  - More natural control:
    - Shorter training period.
    - Better acceptance.
  - Not always the best solution.
  - And new generations are more suitable to accept novel user interfaces.

Thanks!

Any question?