Force feedback in MIS

Bert Willaert

Supervisors: Prof. H. Van Brussel
Prof. D. Reynaerts

Robot-Assisted Surgery group
Department of Mechanical Engineering K.U.Leuven

1. Introduction

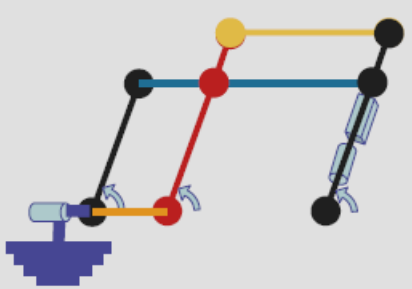
Goal: a master-slave system for MIS with relevant force feedback

- Slave (ZEUS)
- Force measurement system
- Controller
- Master (PHANToM)

2. Slave system

How to deal with the trocar?

- Existing concepts:
  - Passive joint at end-effector (AESOP, ZEUS,…)
  - Remote centre of rotation (Da Vinci,…)
  - Virtually fixed centre of rotation

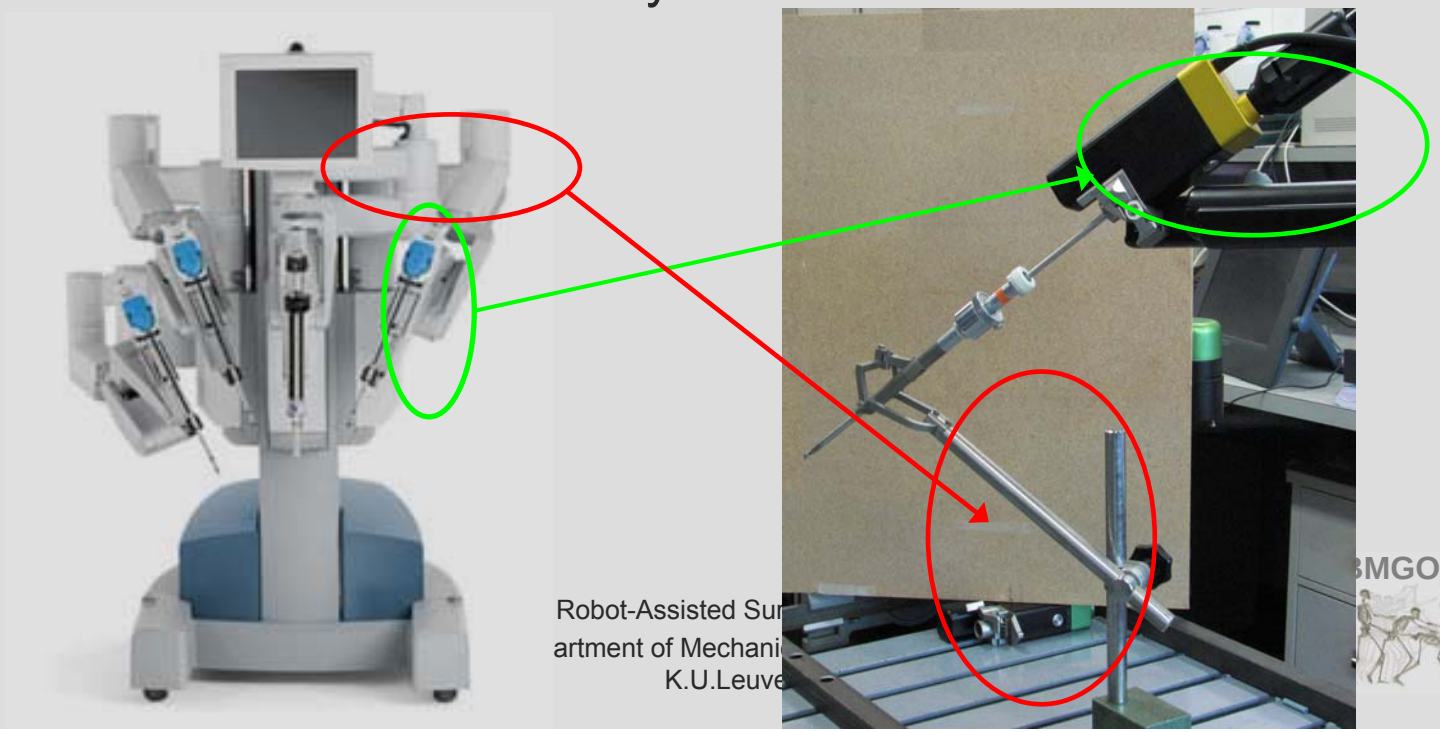


- New concept:
  - Passive joint at end-effector + passive mechanism to position the trocar (2 DOF's)

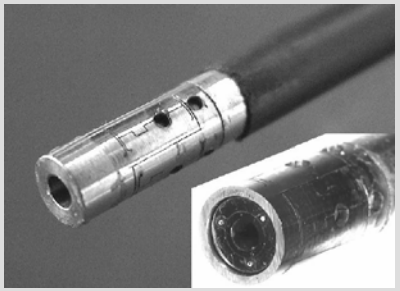
2. Slave system

Advantages

- No special kinematic configuration for robot
- Accurate positioning instrument tip
- Intuitive placing of trocar mechanism
- Table-mounted slave system

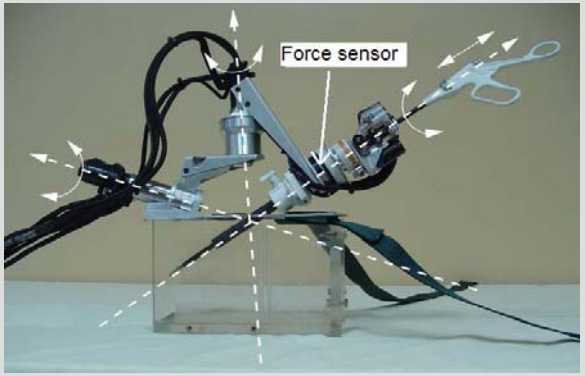


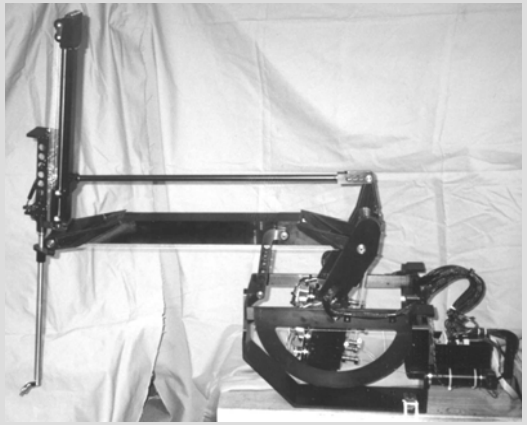
3. Force measurement system

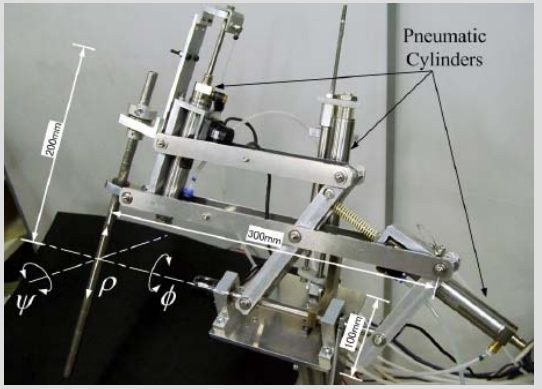


Existing concepts:

- Force sensor at instrument tip (DLR, PMA,…)
- Force sensor at end-effector (Univ. of Tokyo)
- Force sensor in trocar for patient-mounted robot (Paris)
- Position error or motor current based force estimation
  (back-drivable systems: cable-driven, pneumatic…)







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3. Force measurement system

New concept:

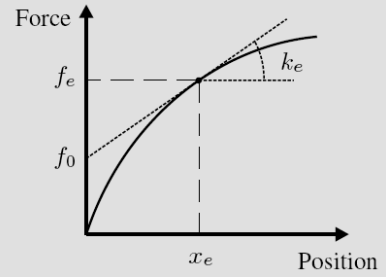
- Force sensor integrated in trocar
  - trocar in passive mechanism for trocar positioning
- Force sensor at end-effector robot
  - ⇒ Difference of forces at both sites = forces at instrument tip

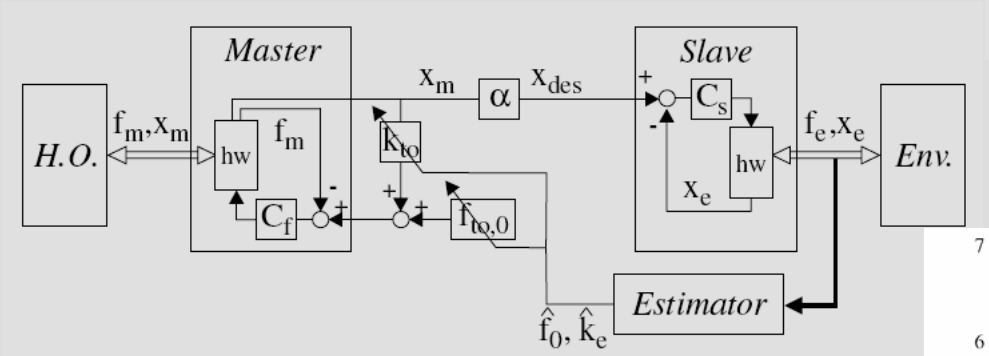
- Advantages:
  - No disturbance of forces at trocar
  - Less miniaturization constraints
  - Force sensing not integrated in the instrument
  - No modelling of friction in transmission necessary

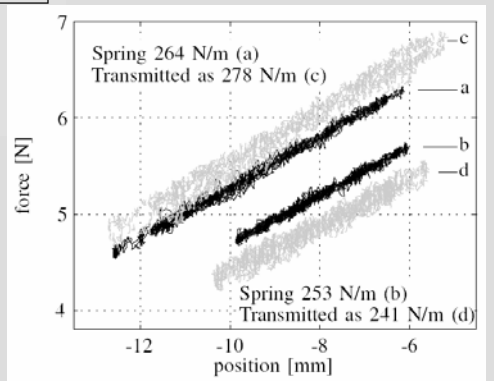
4. Controller

Design goal: stiffness transparency for soft environments and absolute stability

- *On line shaped impedance reflection teleoperation* (G. De Gersem)
  - $f_{des\_m} = f_o + k_{to}.x_m$
  - $k_{to} = K.k_e^{\sigma}$ 'enhanced sensitivity'







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4. Controller

Optimalization

- Performance
  - To date, only experimentally tested for soft linear springs
  - Study of behaviour of Kalman filter for different parameters of the Kalman filter
    - Simulations: different stiffnesses, changes in stiffness and non-linearities
    - Experiments
  - Goal: to define group of environments/situations for which the “optimized” controller is performant

4. Controller

Optimalization

- Stability
  - To date, experimentally tested stable for soft linear springs
  - Study of approaches to make existing controller stable, e.g. PO/PC, Frequency domain stability observer,…

5. Future perspectives

After integration to experimental master-slave system

- Users test with ‘enhanced sensitivity’
  - Useful in which situations?
  - How and when to switch between normal mode and ‘enhanced sensitivity’ mode
- Testing damage models (Nele Famaey)
  - Relation between tool-tissue interaction forces and internal stress
  - Relation between internal stress and tissue damage

Any questions or advice?

Thank you

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