Computer-aided Surgery and **Medical Robotics (MR)**

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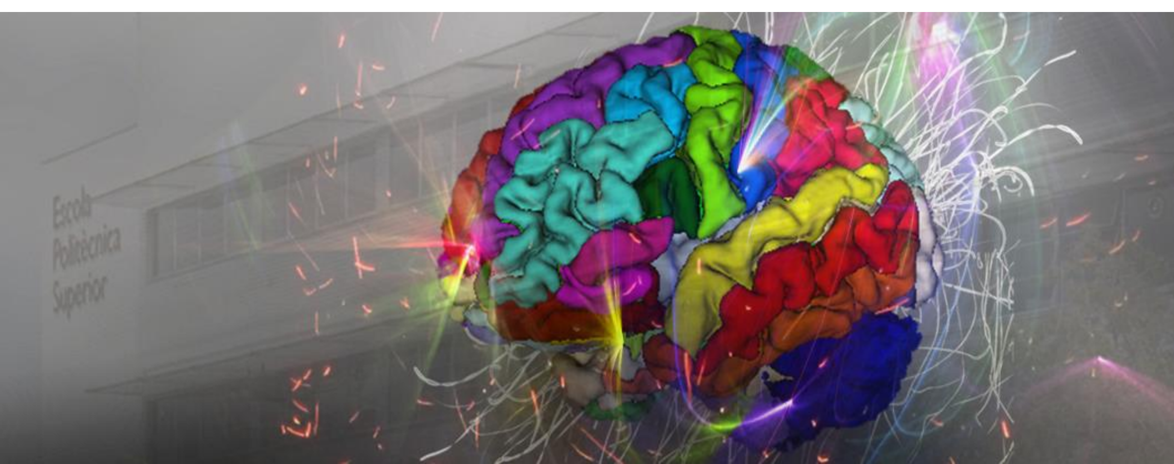

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Presentation

Robots are physical devices endowed with decision-making, perception and action capabilities and connected to the digital world, that can intervene in many ways in the context of care.

Closer to an industrial process …

- … the robot may contribute to the logistics of a health-care facility by conveying patients and transferring them from the bed to the couch or the operating table.
- … robots can also serve as an automated transport for drugs.

Robots can assist disabled or elderly people

- … a robotic walker can contribute to keeping an elderly person upright.
- … a fixed or mobile arm, or an humanoid robot can help a disabled person in daily life tasks
- … a companion "more or less" robotic can act as an assistant for a dependent person.

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Robot can be completely or partially substitute for a defective organ or limb (artificial organs, artificial limbs, prostheses)

Robot can be a medical or paramedical personnel assistant.

- … robotic platform may ease the tasks of rehabilitation staff who help patients to relearn how to walk after spinal cord injuries
- … exoskeleton could be used for rehabilitation of movement after an accident

Presentation

Concerning more instrumental side of medicine:

- Robot can <u>hold the tool</u> required by the clinician to perform a diagnostic or therapeutic gesture (surgeon, radiologist, radiation oncologist, …)
- <u>machining</u> of a bone cavity for a prosthetic
- <u>carrying and moving</u> a surgical microscope for microsurgery, an endoscope for minimally invasive surgery or a linear accelerator for radiation therapy

There are very diverse machines with very different objectives that can be grouped into "Medical Robot" term.

The "instrument holder" robot, or on the "robotic instrument": medico-surgical robot

http://allaboutroboticsurgery.com/surgicalrobots.html

Presentation

Medico-surgical robots is a part of the general theme of “computer-aided medical interventions” (CAMI)

<u>CAMI gives clinicians the hardware and software tools</u> to enable them to fully exploit the available multimodal information (previous knowledge, gesture or organs models, medical images, physiological signals,…)

in order to plan, simulate, and perform a diagnostic or therapeutic gesture that is minimally invasive and as effective as possible.

Introduction

- First experiments in the field of neurosurgery dating from 1980
- First systems were directly adapted from industrial robotics
- Medical robots have profited from different new developments: materials, sensors, actuators, real-time calculations
- Today: major and practical form of improving everyday medical practice

http://allaboutroboticsurgery.com/roboticsurgeryhistory.html

Characteristics of medical robotics

- Medical robots have specific needs (3 s's):
  - Safety in the vicinity of the patient and their careers
  - Sterility or sanitization
  - Constraints of the surgical theater

Characteristics – Safety (1st "s")

Of course is a issue of prime importance in medical robotics

Safety of the patient + safety of the medical personnel: both are very close (or in contact) with the robot (Very different to industrial robotics …)

In health sector every accident has a VERY NEGATIVE (ENORMOUS) effect for the practitioner as well for the Company marketing the service.

In theory, a no-risk situation doesn't exist and there are always occupational hazards

It is clearly expected that a procedure assisted by a robotic system should be more safe and accurate than the same procedure carried out without assistance.

Engineers have a responsibility towards the doctor who will direct the robotic system.

EVEN IF THE ROBOT AND ITS CREATORS DO NOT TAKE THE HIPPOCRATIC OATH, WE MUST AL LEAST KEEP IN MIND THE FIRST LAW OF ASIMOV FOR ROBOTS.

Characteristics – Safety (1st "s")

Robotics systems must have:

- Well defined, documented and precise protocols of use with adequate training of medical personnel
- Intuitive man-agent interfaces which are ergonomic and clear
- Procedures for termination and conversion to a conventional technique
- A doctor in the loop if possible
- Intrinsically safe robotic structures
- Mechanical fuses if forces are high
- Redundant sensors
- Electric fuses
- A limit on workspace, velocity and force
- Software procedures to test that all components are in good working order
- Procedures to insure that every step of the medical procedure is executed correctly
- An extension to the medical procedure which doesn't put the patient's health in danger

The setup and description of all these procedures and their components are necessary in order to obtain "stamps of approval"

Characteristics – Sterility (2nd "s")

Another very important constraint is sanitization for surgical procedures.

Parts directly in contact with the patient or manipulated by the surgeon and the operators should be completely sterilized, and the parts that could come into contact and cannot be sterilized should be covered in sterilized material.

Common constraints that are encountered in terms of sanitization for a surgical robot:

- Parts in contact with the patient, the surgeon and the operators must be treated by the autoclave (stem sterilization system used for disinfestation) or they must be disposable and in sterile packaging.
- Non-disposable parts which cannot be treated by autoclave should be covered with a sterile packaging following a very accurate procedure, so they not be dirty
- The personnel of the unit should be properly trained

Characteristics – Sterility (2nd "s")

Characteristics – Surgical theatre (3rd“s”)

A medical robot has to adapt to the specific environment of the operating room.

With the exception of robotized radiotherapy, very few hospital rooms exist which are specifically designed to accommodate a robotic system.

In addition to certification of medical equipment (“quality stamps”) constraints specific to the operation room are mainly dimensional, ergonomic and concerning availability.

Is preferable:

- Reduce obstructions as much as possible
- Clear the working area as much as possible (using SCARA structures …)
- Be able to transport the robotics system and its controller (if possible using one person)
- Be able to easily take the robotics system in and out of the operating room unless that room is entirely dedicated to the robotic unit (radiotherapy)
- Define specific procedures for storing and maintaining the accessories
- Conduct preferential maintenance
- Put in place effective management in case of failures
- Ensure electric and magnetic compatibility with other pieces of equipment
- Avoid the need to call additional specialized personnel

Potential advantages of MR

Potential advantages of using a robot in a medical procedure

Road from the laboratory to the robotics system used in surgical procedures is particularly long and difficult.

Success stories are relatively few … but we have to ask ourselves what success is in these cases !!

Scientific and technological success when a technological achievement has been achieved: scientific publications and certificates in the field of robotics …

Success for surgeon who has accomplished something for the first time with a robot …

There is above all surgical success when a robot improves the quality of treatment for a patient.

Commercial success when a Company successfully puts a medical robotic system onto the market and makes a profit

Engineer or Robotics researcher cannot master all the skills needed to guarantee success at all levels.

Potential advantages of MR - 2

Potential advantages of using a robot in a medical procedure

Before starting a new research and development project, what questions is important to ask ?

1. Is a medical quality assessment in the field of the Project possible ?

2. Does the laboratory prototype, depending on additional developments, have a reasonable chance of becoming a system which can be used on a patient ? Could it be certified (EU, FDA) ? Does it respond to 3 s ?

3. Will the robotics system objectively improve the procedure practiced by the doctor ?

4. Is this improvement potentially significant for the patients of for the medical personnel ?

Although is difficult to respond this last question without carrying out comparative surgical trials (robotized vs manual procedures), it is possible to respond to the other queries at the beginning of a Project or during this discussion.

Positive response to 2n question is necessary to be able to carry out clinical validations

Positive response to 3d question assumes the team have identified practical advantages of using a robot

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Potential advantages of MR - 3

Potential advantages of using a robot in a medical procedure

Possible advantages of using a robot are the same than in other fields :

- Velocity
- Accuracy
- Precision
- Automatically following a trajectory
- Capacity to execute position, velocity and force controls
- Compensation for excessive force
- Fusion of multimodal information in real-time
- Automatically record completed commands

AND … in case of tele-operated robotic systems:

- Scaling of movements and effort
- Increase in sensory feedback
- Performance at a distance, or in a hostile environment
- Increase in the number of DOF and dexterity
- Automatic filtering-out of physiological movement and shaking

Potential advantages of MR - 4

Potential advantages of using a robot in a medical procedure

We must take into account the superior qualities of a woman or a man over a robot:

- Capacity to analyze a situation and make a decision
- The option of adapting. "Improvisation"
- Capacity to train and educate
- Integration of complex information from multiple sources

This demonstrate the need for the presence of a doctor for as much time as possible when a robot is being used. Robot must be above all a medical tool at the service of a doctor.

Some of the functions listed above can also be performed by "navigation" systems. These systems work on the principle of GPS !! (see navigation article: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3627858/)

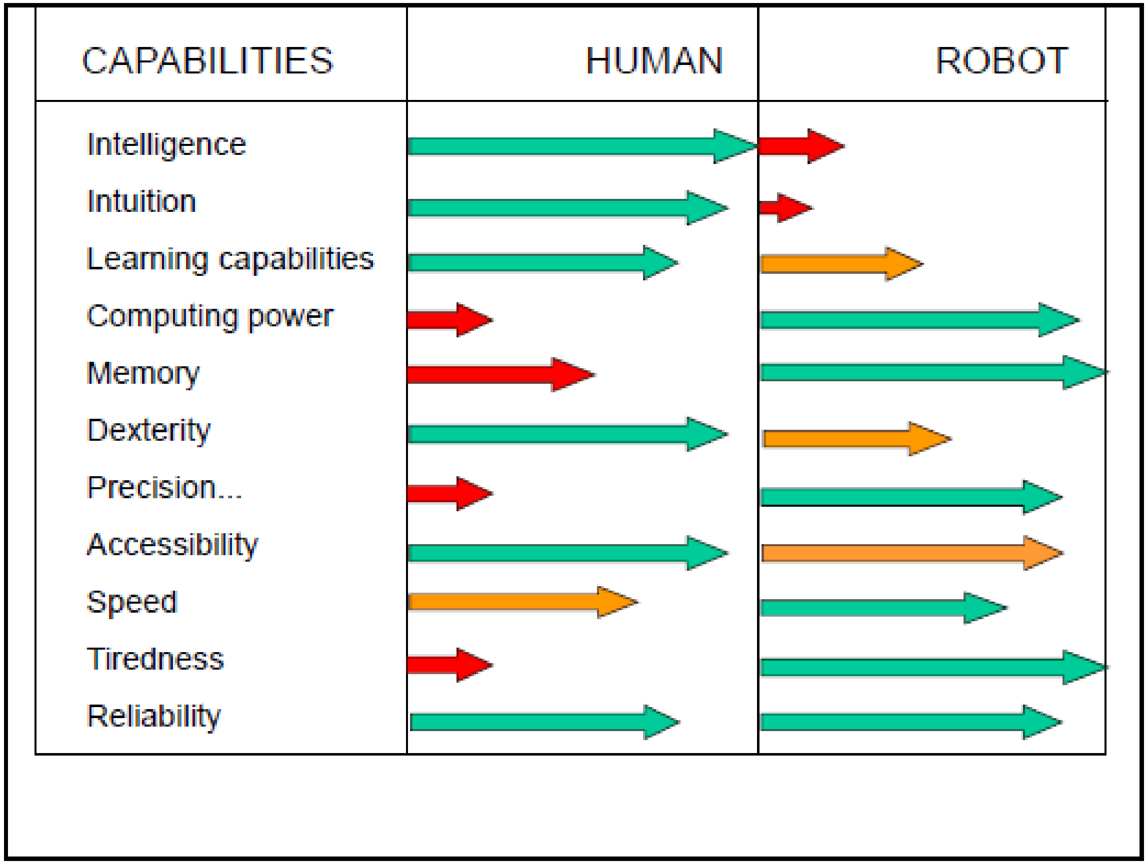
http://www.medtronic.com/us-en/healthcare-professionals/products/neurological/surgical-navigation-systems.html

In these systems a **localizer enables us to follow the position and orientation of the objects (surgical instruments, sensors, anatomical structures) in real-time** and the system delivers a stream of information to the clinician on the action which is being performed, possibly related to a recorded plan or according to pre-operative data.

These systems are largely used, and are genuine "competition" for medical robotics.

Robots must suppose added value to other options like navigators

Potential advantages of MR - 5



From Prof. Alicia Casals (Polytechnical University of Catalonia, Barcelona)

Future

The Future

In less than a century since the term "robot" was coined, robotic surgery has found an increasingly growing niche in medicine and is here to stay. No longer experimental, robotic surgery systems are safe and may result in improved patient satisfaction and quality of care when accuracy is improved and a minimally invasive alternative to conventional surgery is possible with the use of robotic technology. The costs associated with robotic surgery systems are significant: the da Vinci surgical system costs $1,000,000 with physician training costs of $250,000, annual maintenance costs of $100,000 and the cost of robotic surgical instruments, which must be replaced after 10 uses.[13] When robotic surgery is associated with decreased length of hospitalization, as has been suggested for cardiac and prostate surgery, an overall cost benefit may be realized. The success of commercial systems has led to a renewed interest by the military in battlefield applications, and in 2005, SRI International, Inc. (Menlo Park, CA) won a 2 year, 12 million dollar contract from DARPA to develop a telerobotic surgical system for use in the battlefield that would allow medical personnel to treat wounded patients from a remote location.[14] In the future, more widespread use of robotic systems, with greater applications in both the commercial and military sectors can be expected.

Robotics in Surgery: History, Current and Future Applications
https://books.google.es/books?isbn=1600213863
Russel A. Faust - 2007 - Medical