Volterra,
19 giugno 2014

Bioingegneria e Robotica nei processi di diagnosi e terapia

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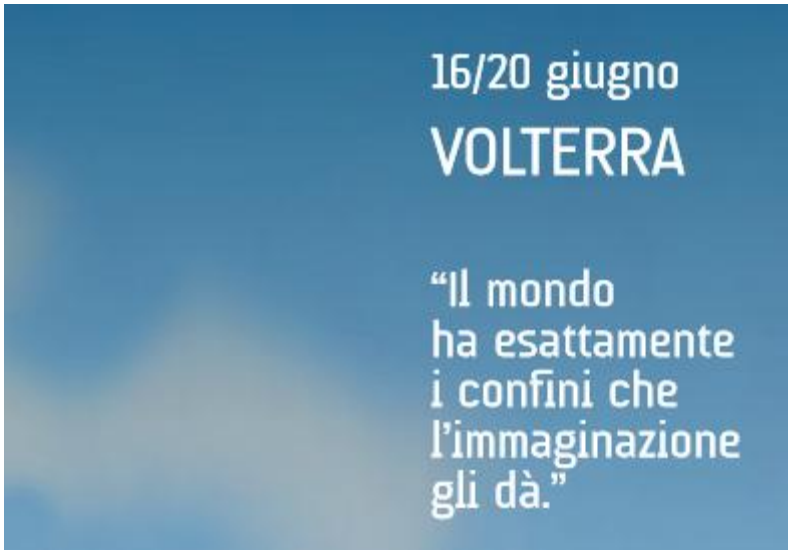
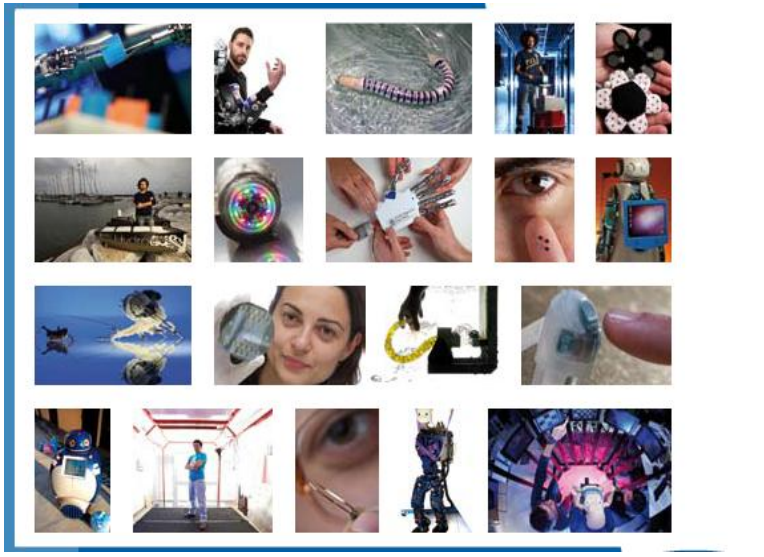
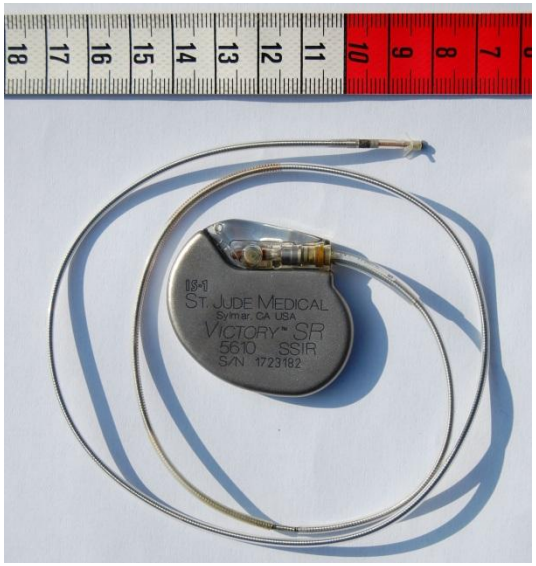
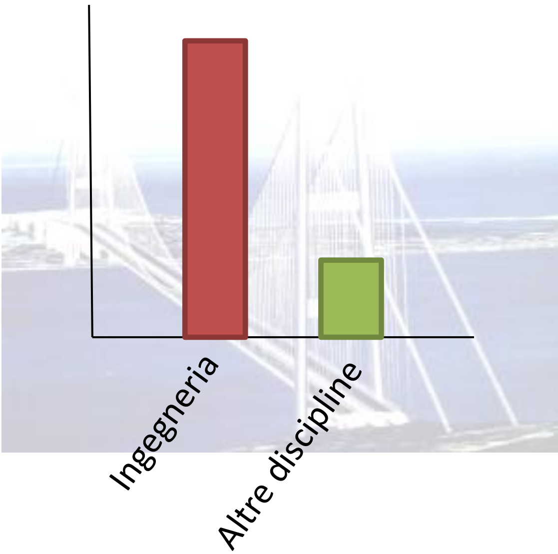


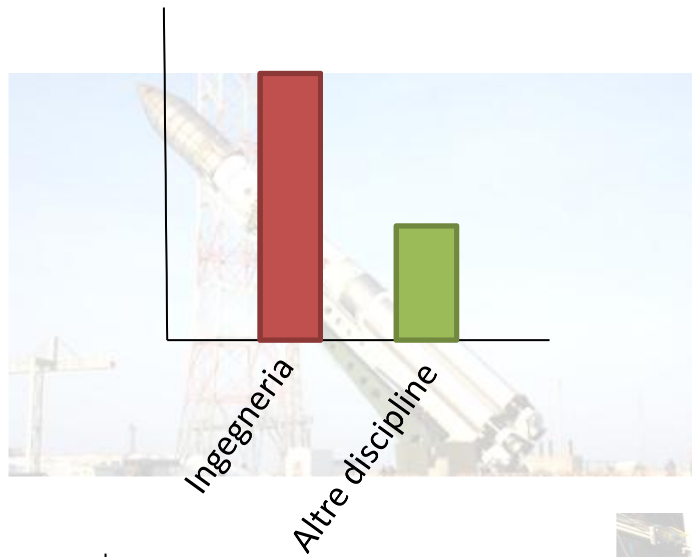


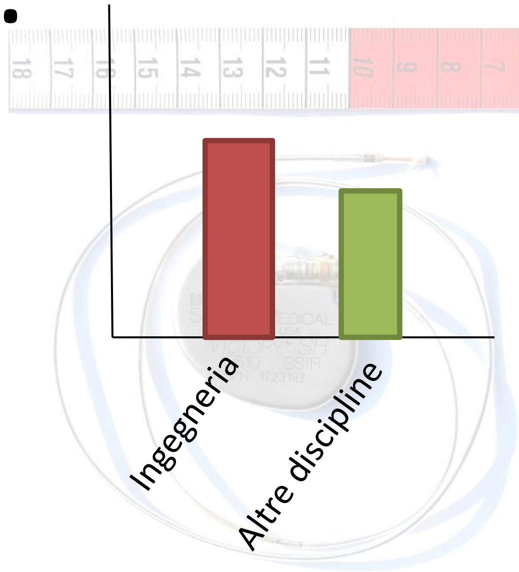
Quanta «ingegneria» c'è dentro questi sistemi ?

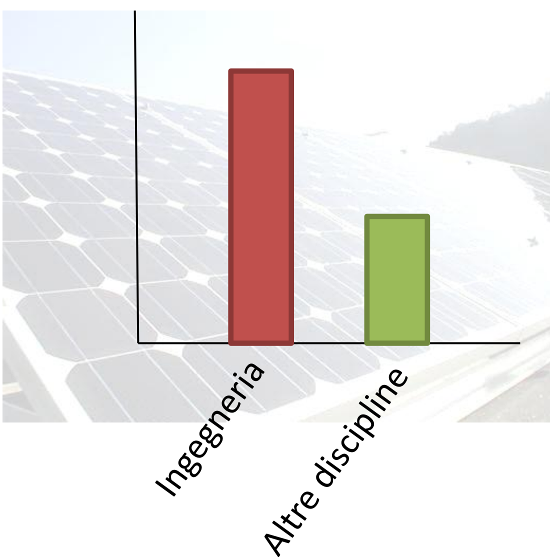


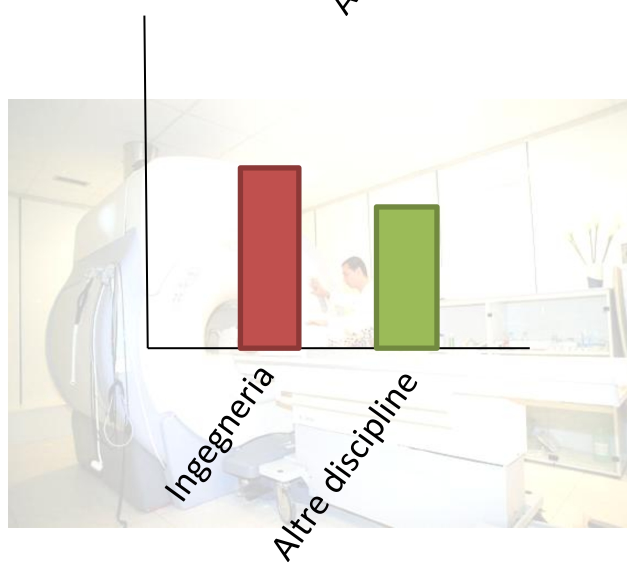
Quanta «ingegneria» c'è dentro questi sistemi ? **… Percezione comune …**

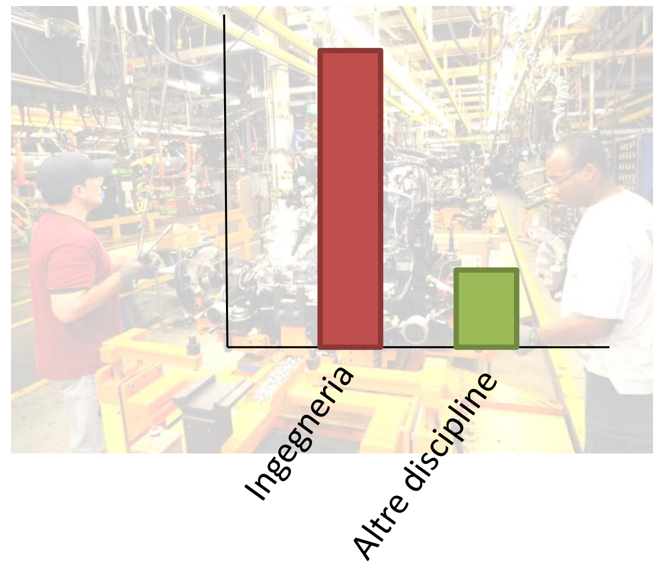




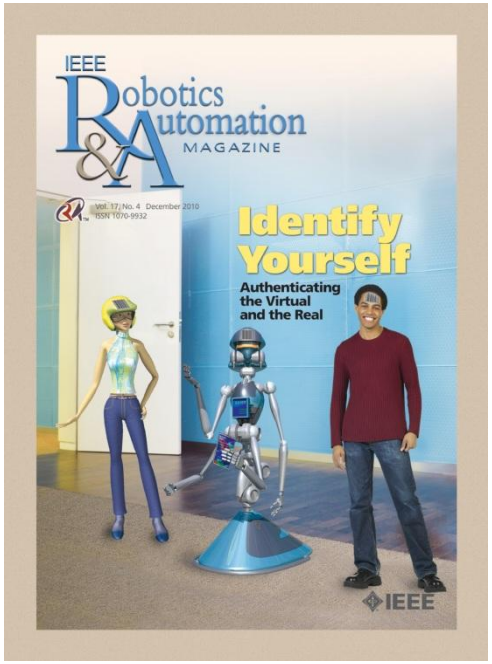


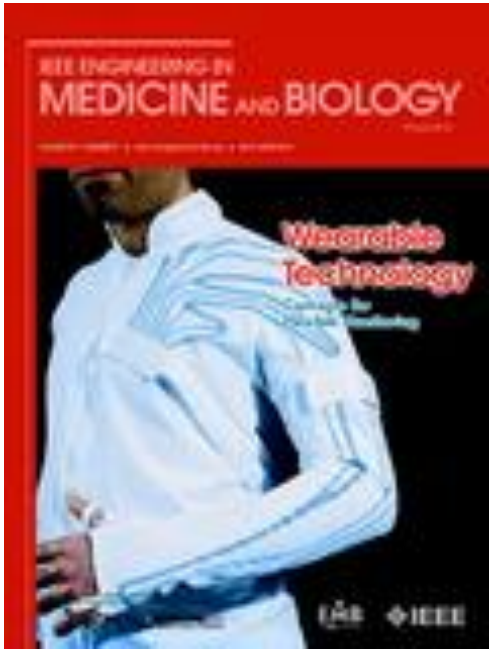






Eppure l'ingegneria biomedica è un settore in forte crescita, con un impatto importante a livello sociale. Richiede contributi e competenze che derivano dall'ingegneria meccanica, elettronica, automatica, chimica, informatica…



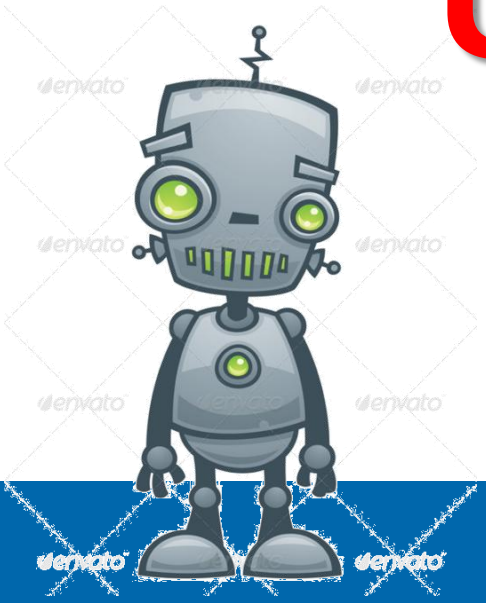


…ma anche dalle scienze di base (fisica, biologia) e dalla medicina.

Si parla di «Bioingegneria e Robotica nei processi di diagnosi e terapia»

… Intanto vediamo …

CHE COS'È UN ROBOT?



Definizioni di Robotica

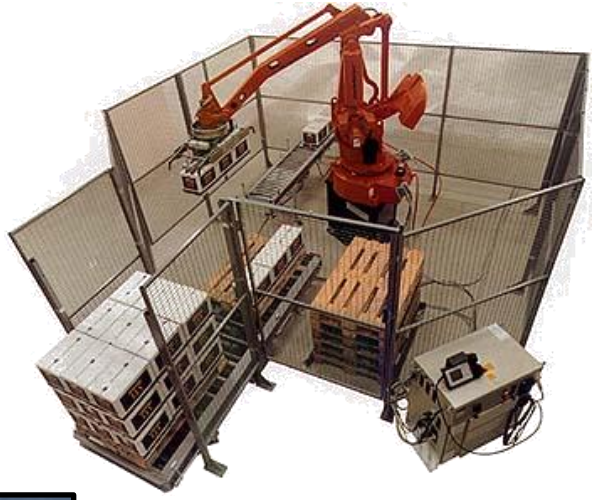
- A robot is a re-programmable, multi-functional, manipulator designed to move material, parts, or specialized devices through variable programmed motions for the performance of a task

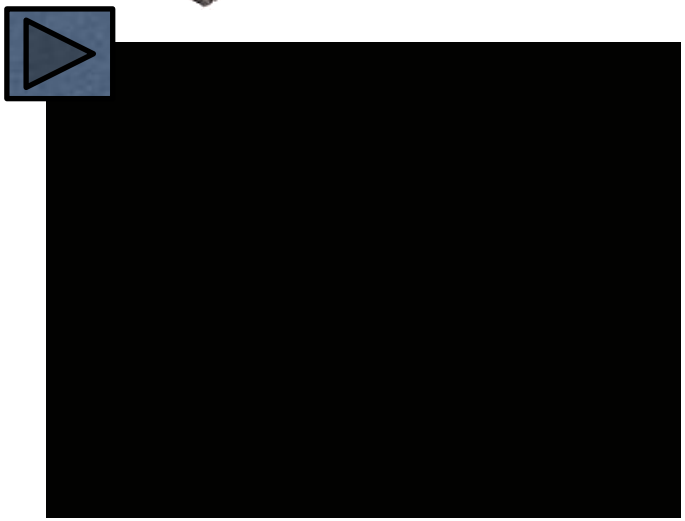
- *Un robot è un manipolatore multifunzionale riprogrammabile progettato per muovere materiali, componenti, o dispositivi specializzati, attraverso movimenti variabili programmati per lo svolgimento del compito*

Robotics Industry Association (~ 1980)

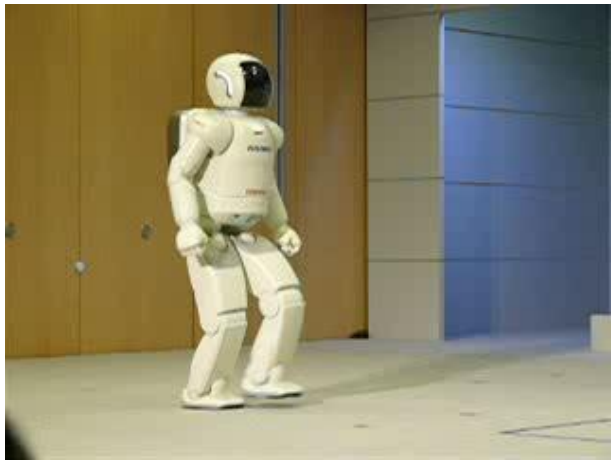
Jablonsky J., Posey J. 1985. "Robotics Terminology", in *Handbook of Industrial Robotics*, ed. S. Nof, J. Wiley, New York, pp.1271-1303

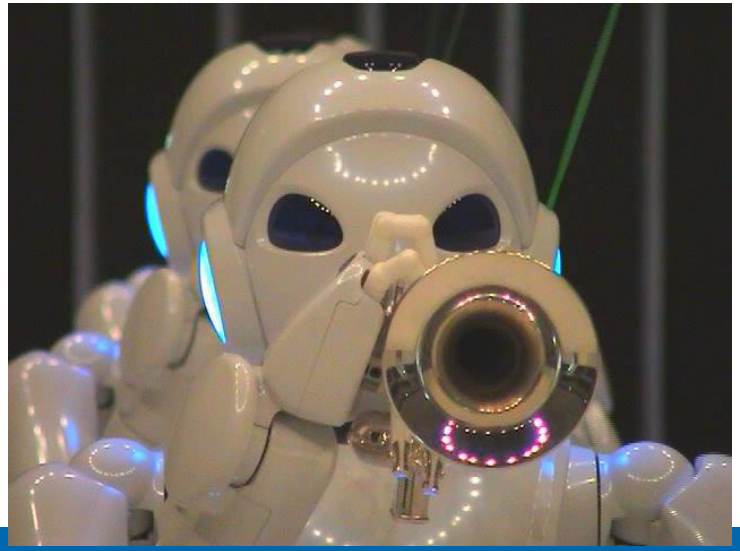
Questo è un robot



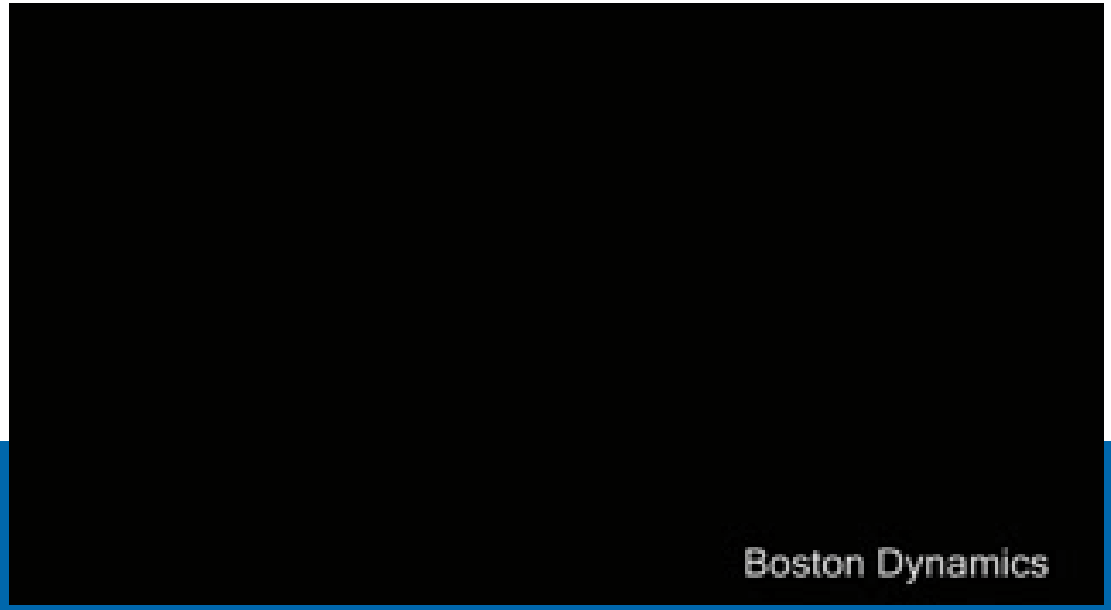


Questi sono robot





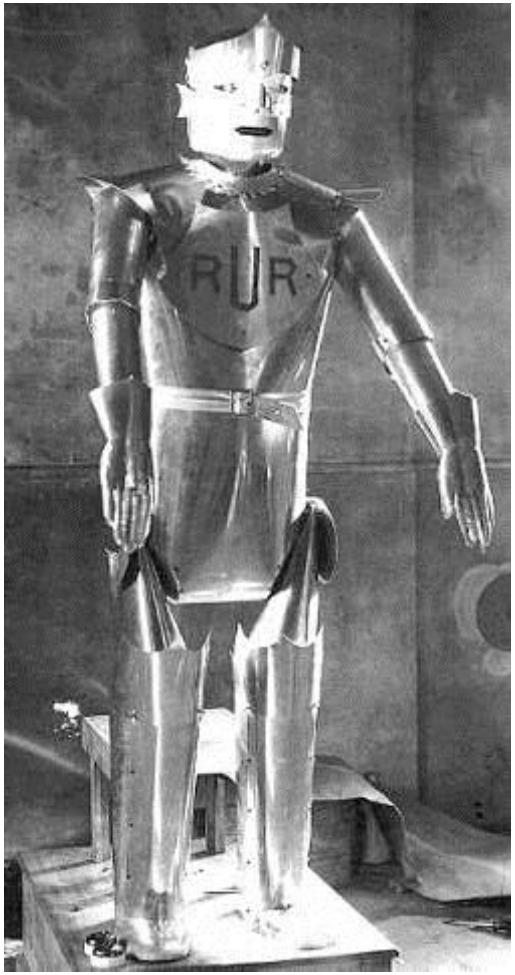
E sono anche questi robot… molto più «cedevoli» e con *link* non sempre rigidi



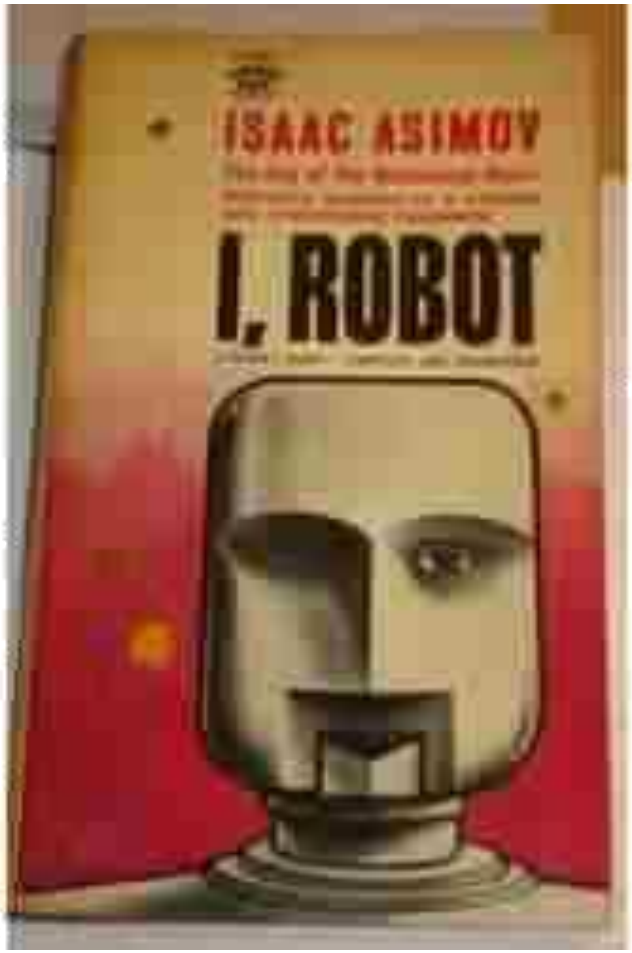
I fratelli Čapek

Il termine ***robot*** fu usato per la prima volta dallo scrittore ceco **Karel Čapek**, nel **1920** nel suo romanzo *R.U.R. (Rossum's Universal Robots)*. Deriva dal termine **ceco *robota***, che significa "**lavoro pesante**" o "**lavoro forzato**".

In realtà il vero inventore della parola *robot* fu il fratello di Karl Čapek, **Josef**, anche lui scrittore e pittore cubista, il quale utilizzò la parola "*automat*", (automa), in un suo racconto del **1917**, ***Opilec*** ("L'ubriacone).
Il termine greco ***autòmaton*** significa " che si muove da se".

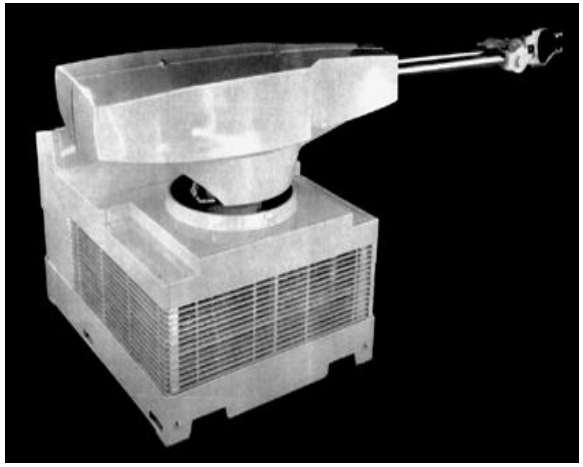


La Robotica moderna (1)

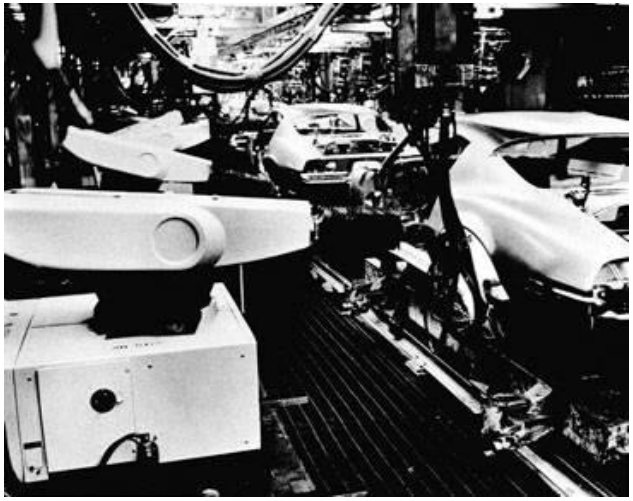


Il termine "**robotica**" venne usato per la prima volta (su carta stampata) nel racconto di Isaac Asimov intitolato *Circolo vizioso* (*Runaround*, 1942), presente nella sua famosa raccolta *Io, Robot*.

La Robotica moderna (2)



UNIMATE
Il primo robot industriale



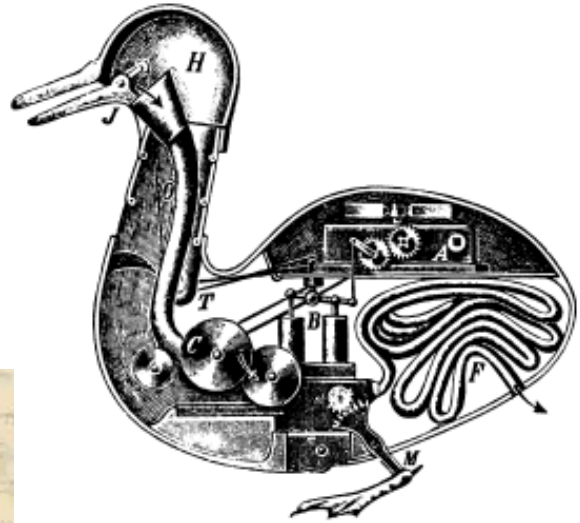
Joseph Engelberger
Ingegnere

Nel 1960 il primo robot industriale fu installato presso un impianto produttivo General Motors in New Jersey (USA)

I robot odierni sono stati preceduti da quelli descritti nella mitologia e dagli automi meccanici

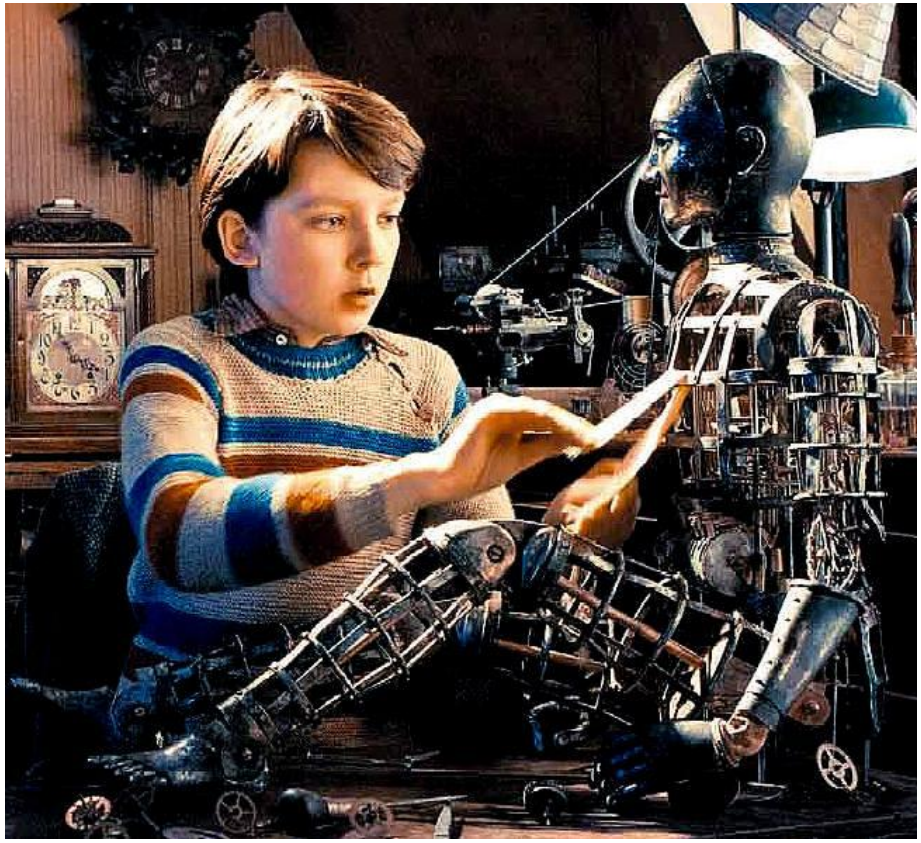
Leggenda di Efesto, dio della metallurgia, forgiatore di armi per gli dei dell'Olimpo, creava giovani fanciulle fatte d'oro e inventava tripodi semoventi (*Iliade*, Libro XVIII vv. 509-15)

Jacques de Vaucanson nel 1738 fabbricò un androide suonatore di flauto in grado di prodursi in movimenti complessi; celebre – dello stesso de Vaucanson – l'anatra meccanica in grado di mangiare e defecare.



Cavaliere meccanico di Leonardo Da Vinci

L’attenzione per i «giocattoli» meccanici nei secoli scorsi e … anche in film recenti (Hugo Cabret)



Un’evoluzione del concetto di sistema robotico

Sogno umano di auto-replicarsi

NECESSITA’ di macchine utili

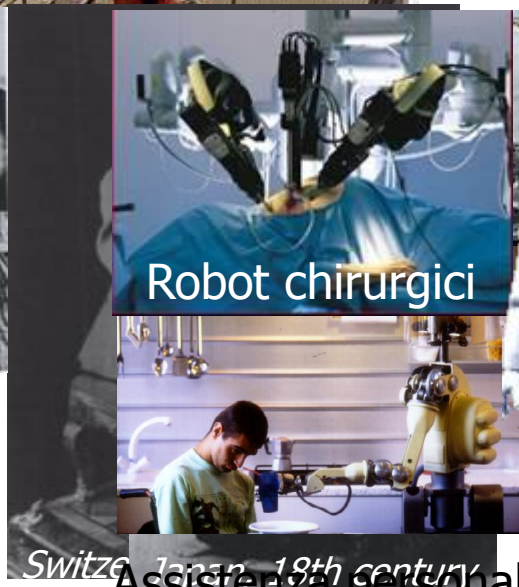
Robotica Industriale

Automazione industriale

Applicazioni spaziali

Robotica di servizio

Leonardo, 16° secolo



Switzerland, Japan, 18th century

Robot chirurgici

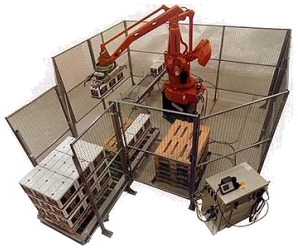
Assistenza personale

Robot medicali

Applicazioni cliniche

Robot personali

La salute e le macchine? …intanto togliamo le «gabbie» ai robot. E poi…



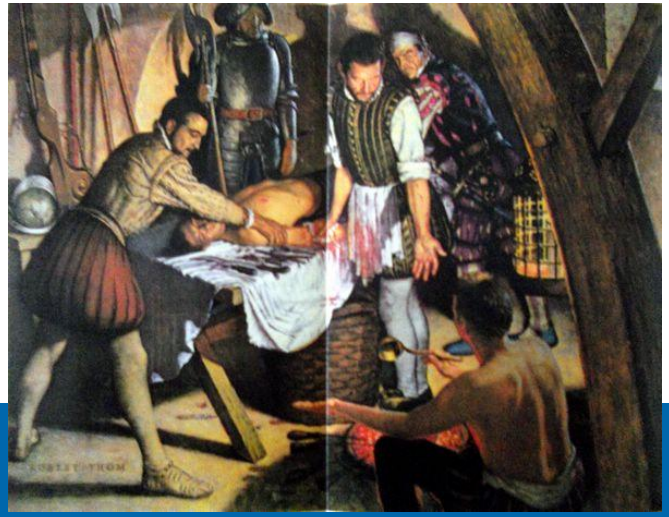
Quando pensate alla salute pensate a qualcosa del genere?

O a qualcosa del genere?

La salute e le macchine? …intanto togliamo le «gabbie» ai robot. E poi…

Quando qualcuno si deve sottoporre a una terapia, preferite un ambiente del genere?

O a qualcosa del genere?



La salute e le macchine? …intanto togliamo le «gabbie» ai robot. E poi…

Per descrivere il processo diagnostico, terapeutico o riabilitativo che vi sembra «migliore», usate aggettivi del genere…

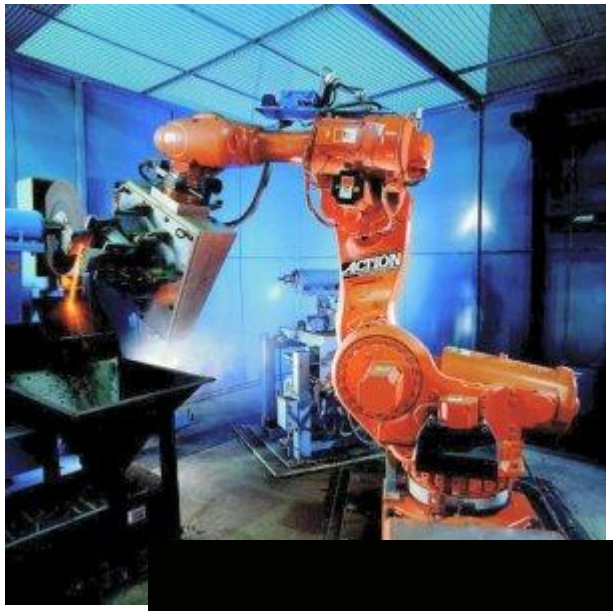
Accurato, preciso, operatore-indipendente, efficace

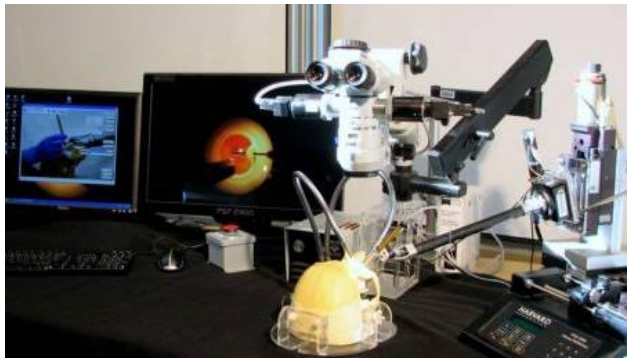
Oppure qualcosa del genere…

Approssimativo, operatore-dipendente, non risolutivo

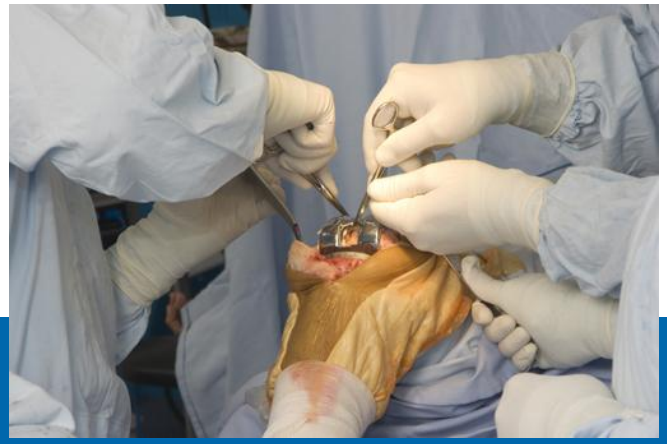
Perché non possiamo ottenere anche in chirurgia, diagnosi e terapia la stessa precisione e accuratezza che caratterizzano i processi di automazione industriale?

Preciso, accurato, ripetibile, veloce.

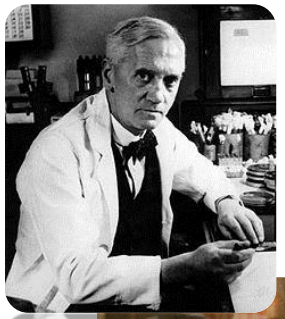


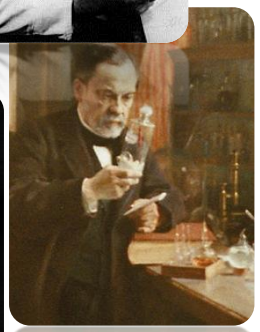


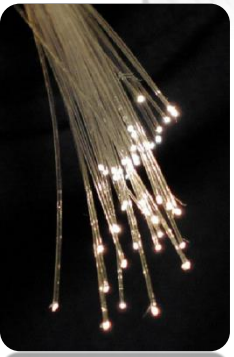
Il contributo delle tecnologie robotiche alle pratiche terapeutiche ed interventistiche.

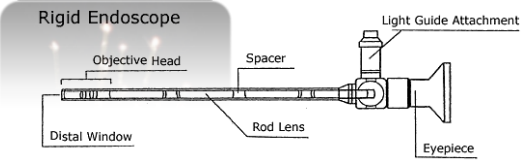


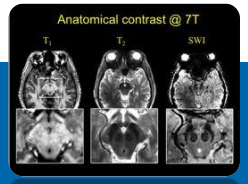
Alcune considerazioni sull'importanza della "convergenza" di tecnologie per l'avanzamento della scienza e di numerose discipline: CONVERGENZA ALLA TERAPIA ROBOT-ASSISTITA











Anesthetics

Antiseptics

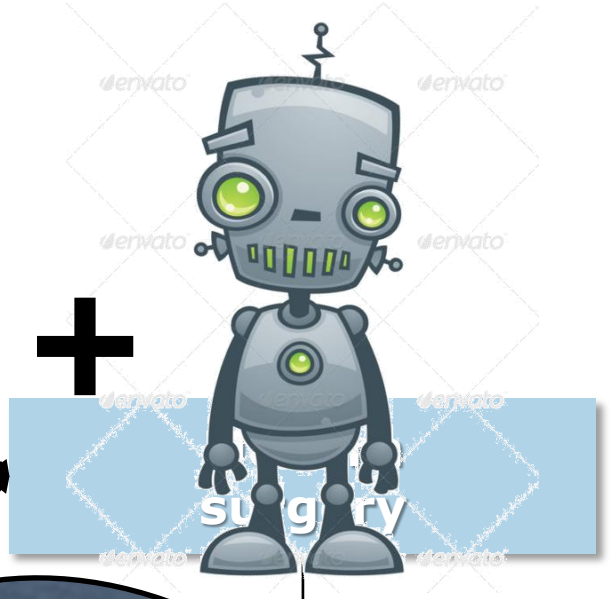
Anticoagulants

Antibiotics

Analgesics

Endoscopic instruments

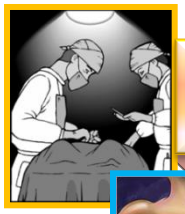
Medical imaging



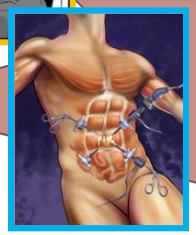
Minimally invasive surgery

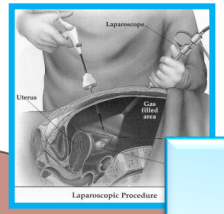
Computer-assisted surgery

Robot per chirurgia: la nostra visione



TECNICHE TRADIZIONALI





CHIRURGIA LAPAROSCOPICA

RIDUZIONE DEL TRAUMA DI ACCESSO IN CHIRURGIA

CHIRURGIA ROBOTICA

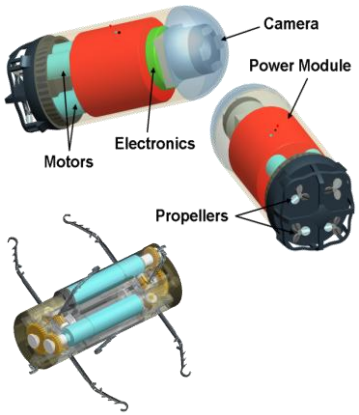
Piattaforme di intervento

ROBOTS = VETTORI all'interno del corpo

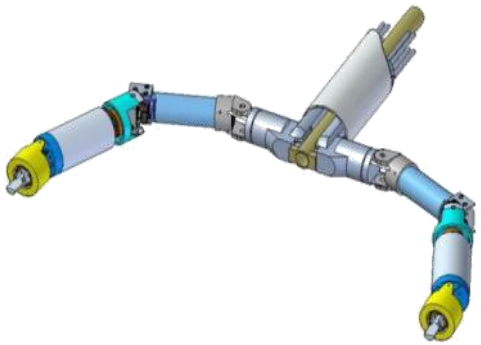
L'obiettivo è portare strumenti terapeutici in grado di eseguire operazioni chirurgiche all'interno del corpo umano, sfruttando orifizi naturali oppure assicurando una chirurgia "senza cicatrici"

Casi di studio

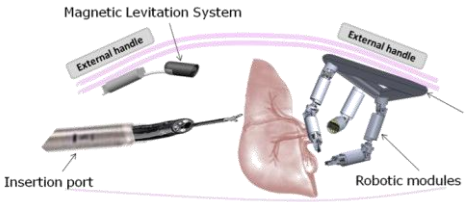
Tratto Gastrointestinale (dall'esofago al retto) : D = 10 - 30 mm



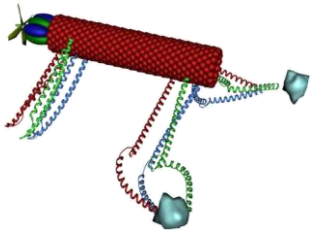
Addome, con accesso "Single Port": D = 20-32 mm



Addome, con accesso mediante Trocar: D = 10-15 mm



Sistema vascolare: D < 8-5 mm



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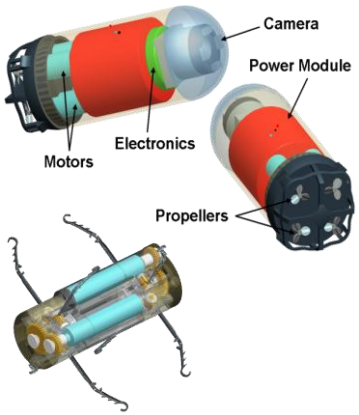
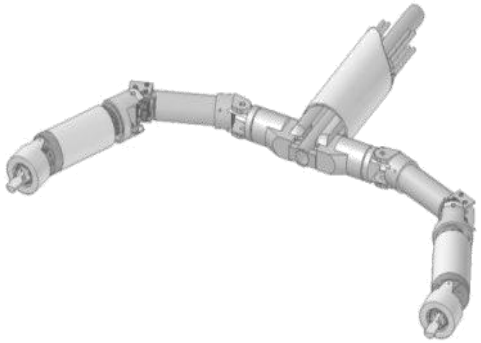
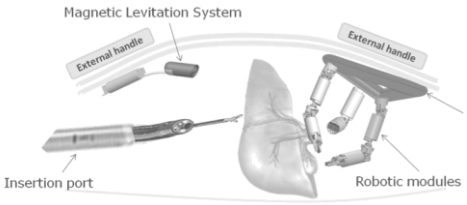


Addome con accesso "Single Port": D = 20-32 mm



Addome con accesso mediante Trocar: D = 10-15 mm



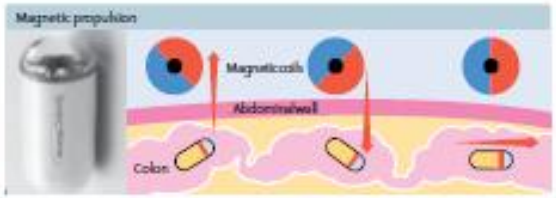
Sistema vascolare: D < 8-5 mm

Obiettivo: oltrepassare le limitazioni delle capsule endoscopiche passive

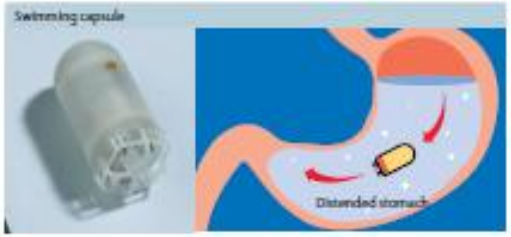
MINI 'BOTS FOR A WIDE RANGE OF JOBS

To make miniature robots that can operate in the digestive tract, engineers must find ways of controlling their locomotion and fine movements wirelessly and in real time. And they must fit the required tools, imaging sensors and power supply into a capsule small enough for a patient to swallow. Here are some examples of the diverse tasks engineers want tiny robots to do, and how they are trying to overcome the technical challenges.

LOCOMOTION
The movements of endoscopic robots can be controlled either by onboard actuators, such as legs, paddles, propellers or cilia-like appendages, or by magnetic fields generated outside the patient's body.



TISSUE DISTENSION
One way to push tissue out of the way—to clear a passage or to gain a view—is to give the robot powerful arms that can push. A less energy-intensive method is to have the patient drink water, which distends the digestive tract enough to allow propeller-driven capsule to maneuver.

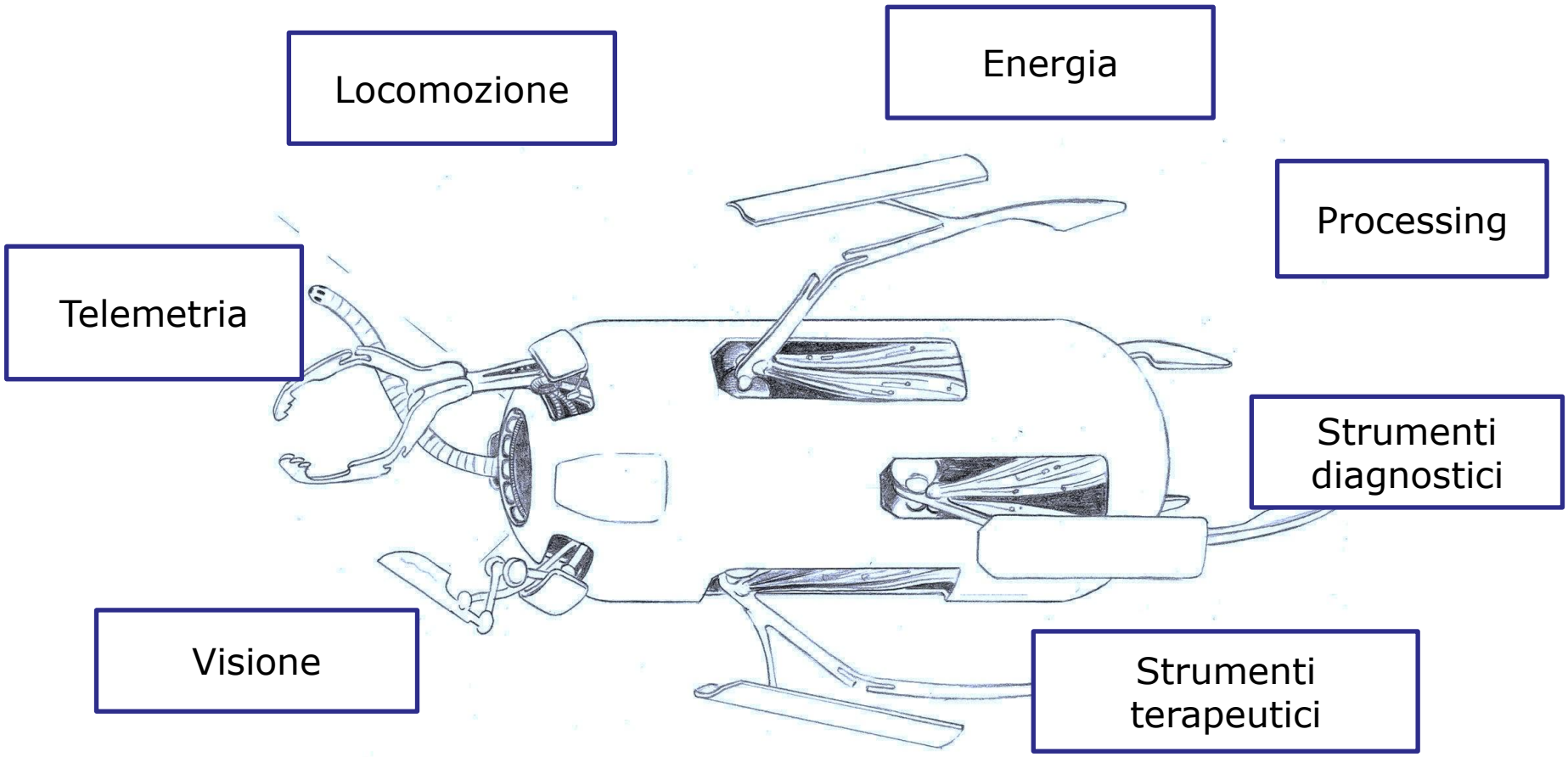


DIAGNOSIS/TREATMENT
A capsule can carry a wide range of tools: a spectroscopic camera that sees cells underneath the surface layer of tissue; a clip for taking a tissue biopsy; or a well that holds a dose of medication.

P. Dario & A. Menciassi
Scientific American, Agosto 2010

OBIETTIVO: fornire al sistema robotico locomozione attiva e strumenti diagnostici/terapeutici

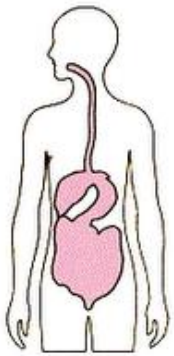
Capsula attiva wireless per endoscopia

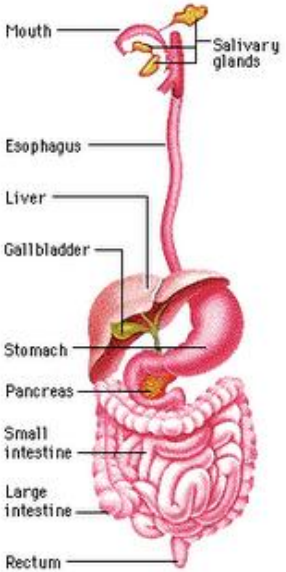


Il design costituisce una SFIDA TECNOLOGICA: tutte le componenti devono rientrare all'interno di una dimensione "deglutibile" (**Ø ~12 mm x L~ 32 mm**)

Sviluppo di un sistema di locomozione a zampe

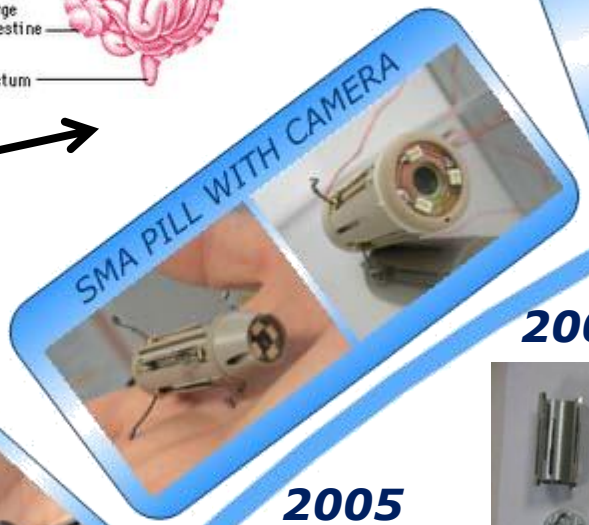
Accesso orale





Accesso rettale

2004



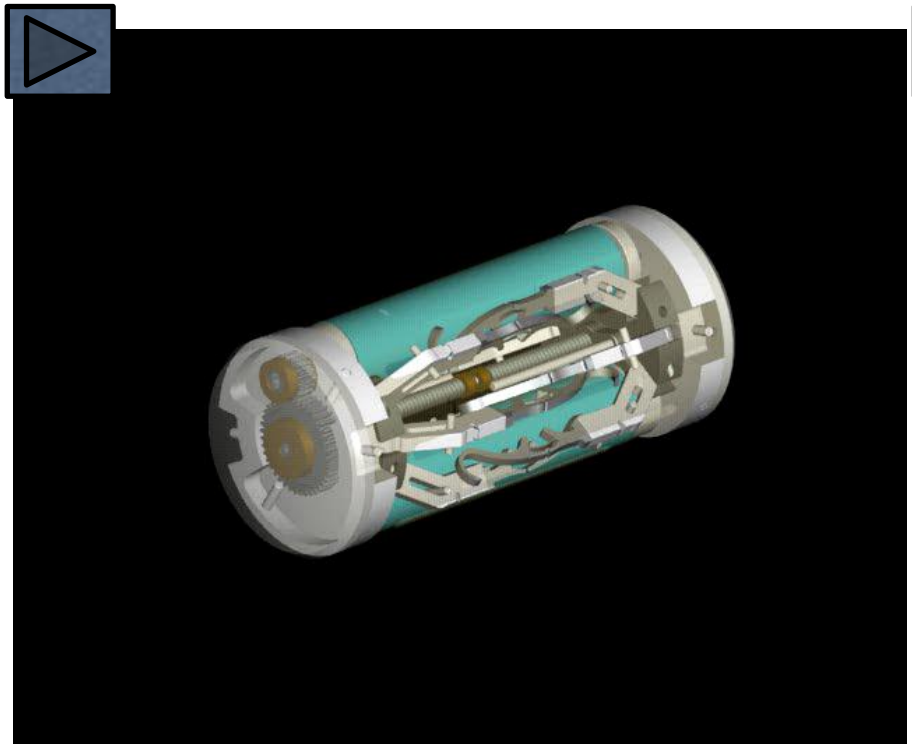
2005

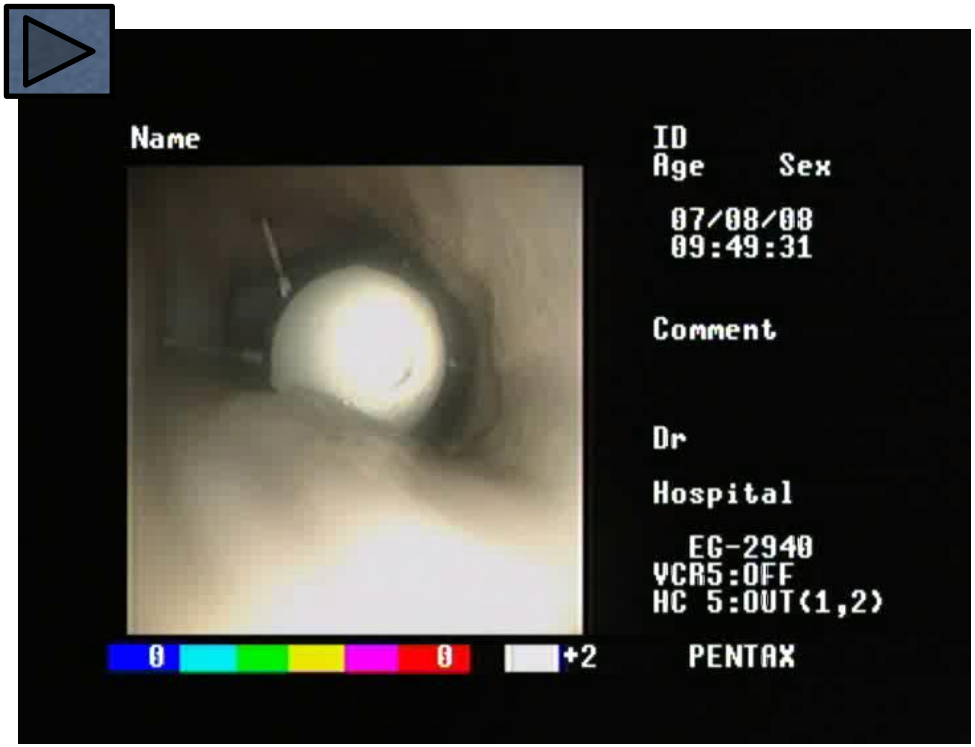
2006

2007

2008 …more

Locomozione all'interno del colon

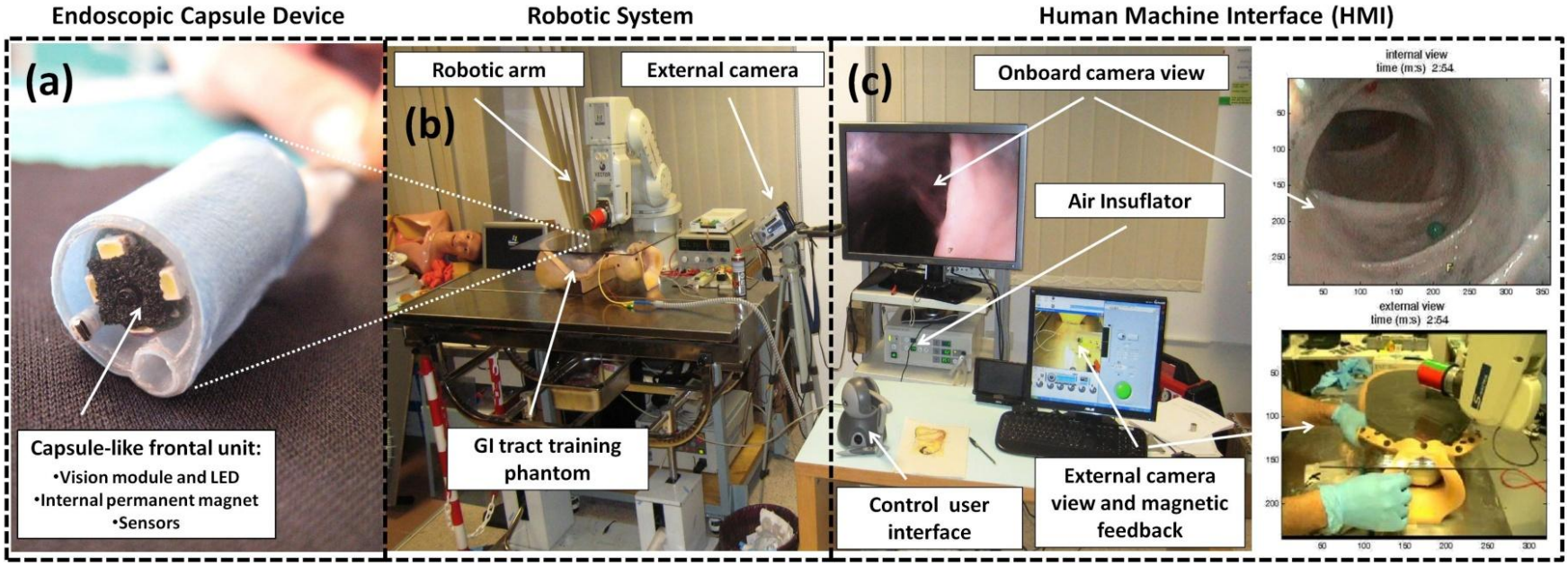


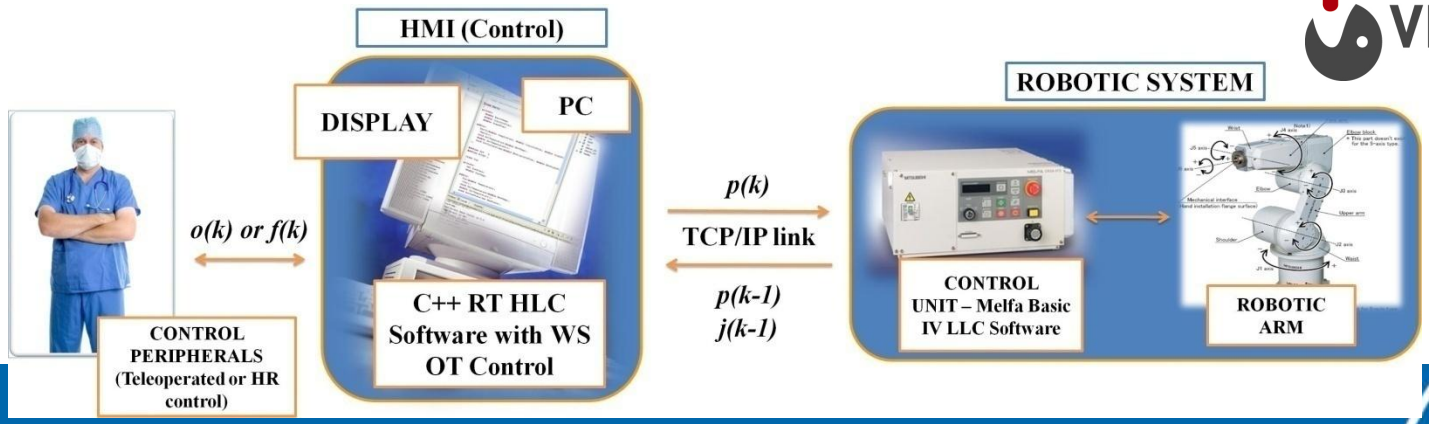


PROBLEMA: I moduli di locomozione e di alimentazione richiedono spazio

Una possibile soluzione per ovviare a questo problema consiste nell'utilizzare un APPROCCIO DI LOCOMOZIONE MAGNETICO ESTERNO

Piattaforma per endoscopia assistita da robot

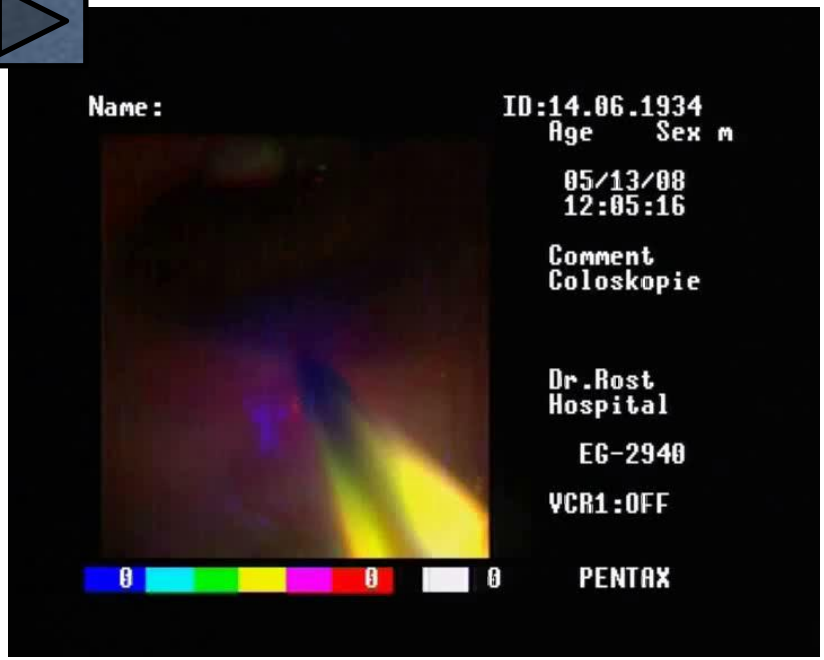




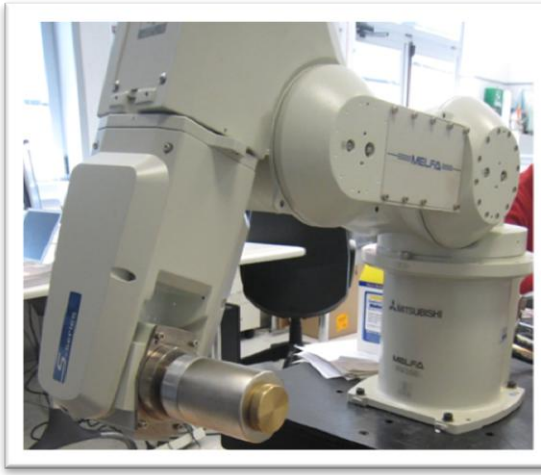
Piattaforma per endoscopia assistita da robot

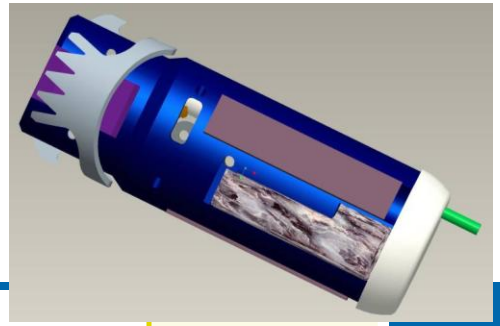
Vista interna dell’endoscopio

Capsula endoscopica per il rilascio di clip superlelastica



OTSC CLIP



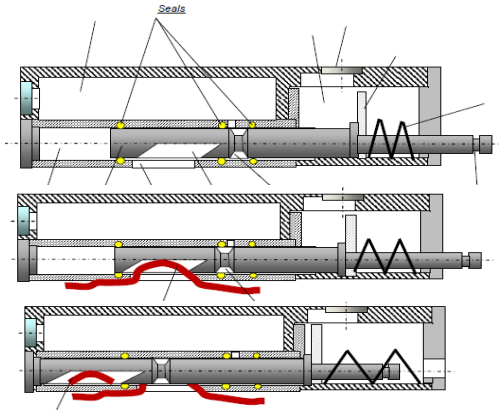


VECTOR

ovesco

Capsula per biopsia wireless

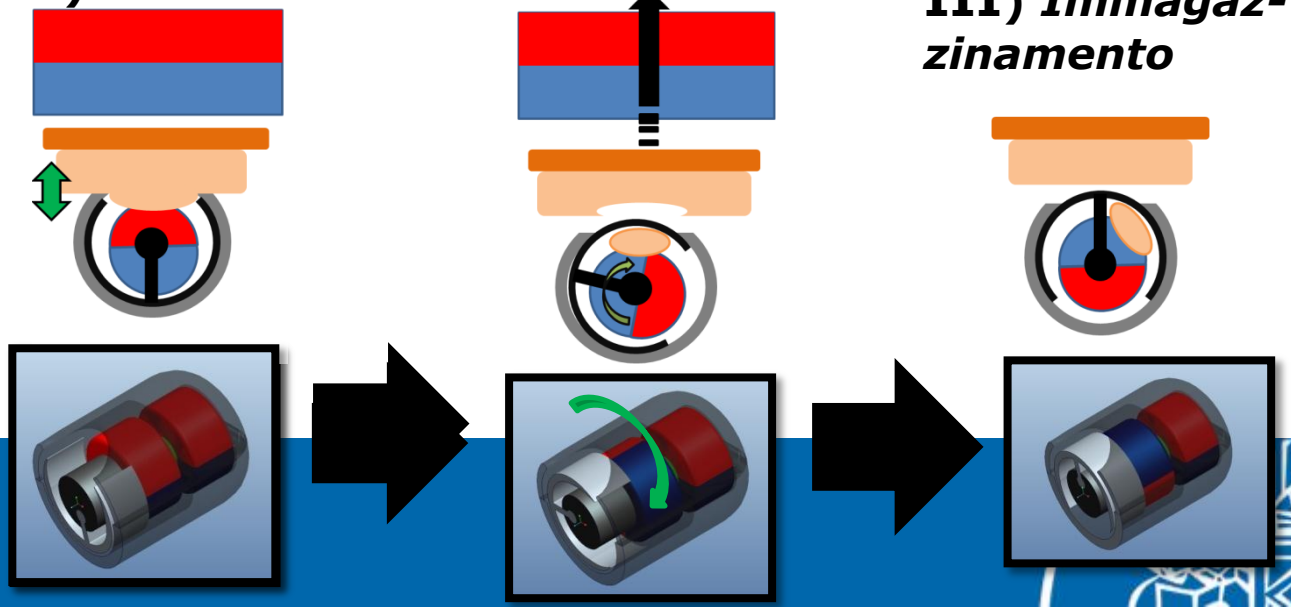
- Meccanismo bistabile
- Attivazione mediante campo magnetico esterno
- Buona adesione alla parete intestinale



I) *Adesione*

II) *Biopsia*

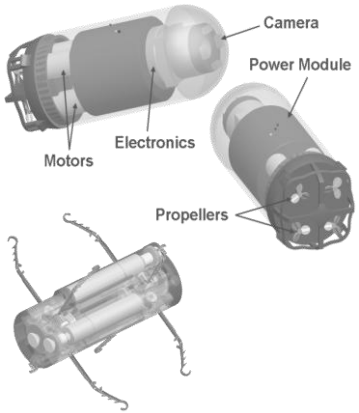
III) *Immagaz-zinamento*



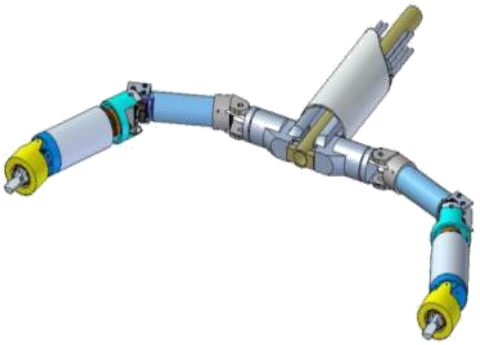
L'obiettivo è portare strumenti terapeutici in grado di eseguire operazioni chirurgiche all'interno del corpo umano, sfruttando orifizi naturali oppure assicurando una chirurgia "senza cicatrici"

Casi di studio

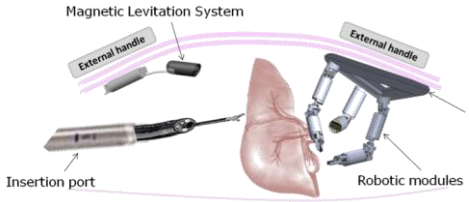
Tratto gastrointestinale (dall'esifago al retto): D = 10 - 30 mm



Addome mediante accesso "Single Port": D = 20-32 mm

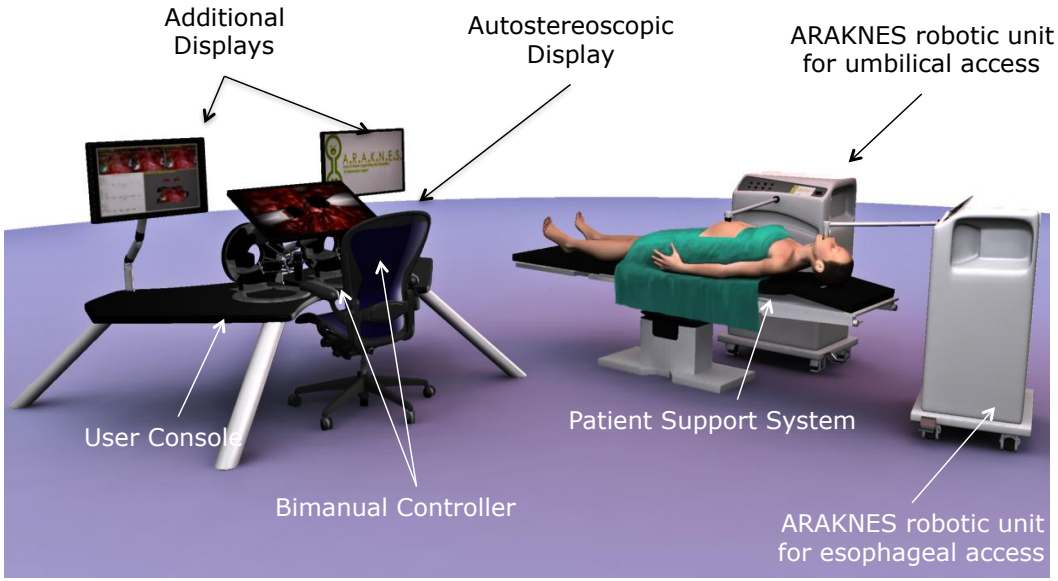


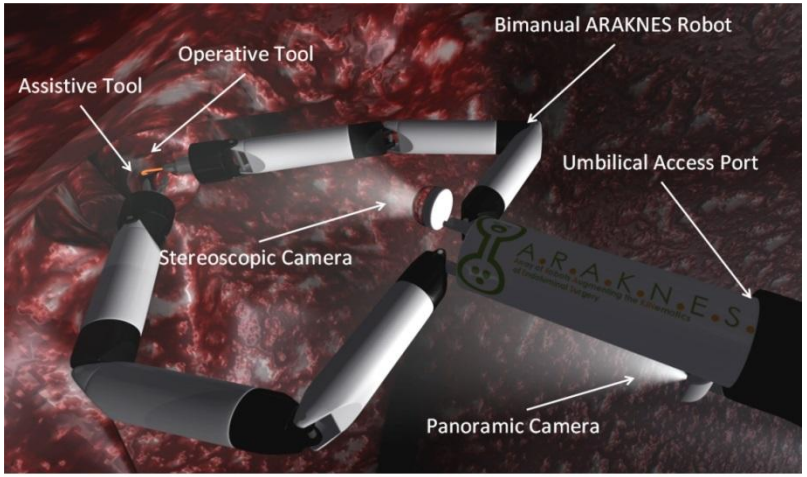
Addome, con accesso mediante Trocar: D = 10-15 mm

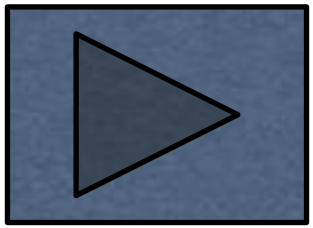


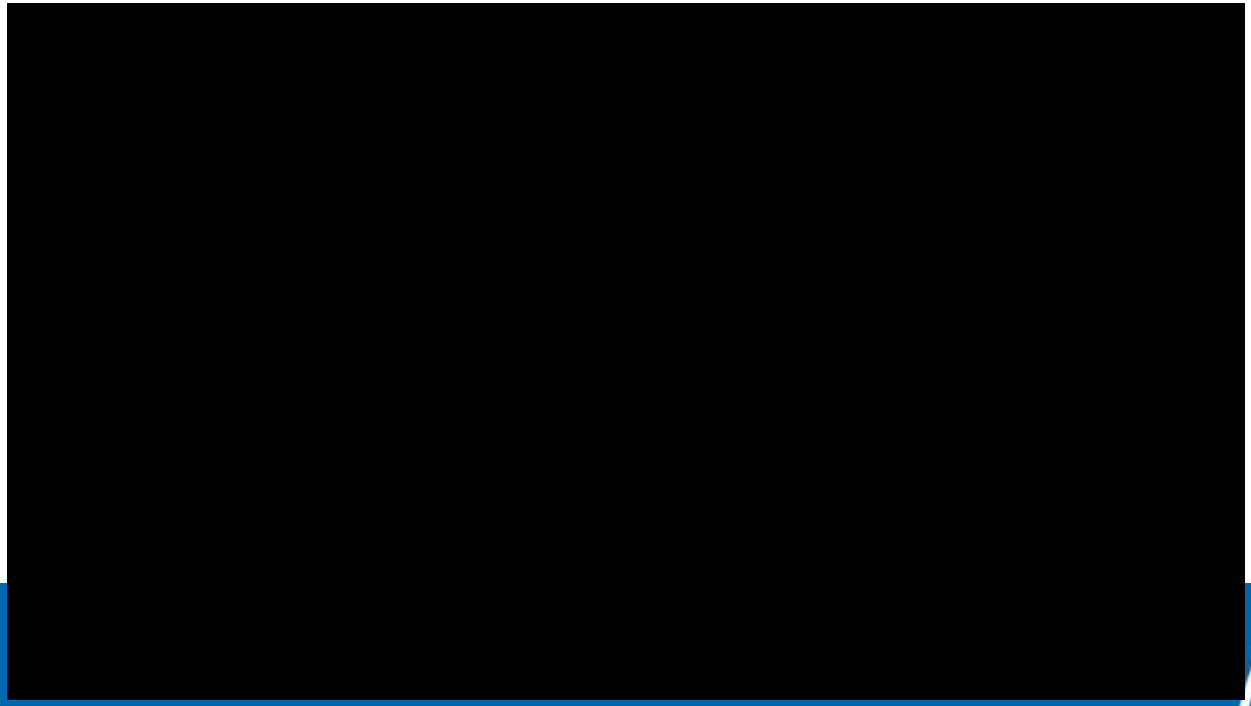
Sistema vascolare: D < 8-5 mm

Piattaforma ARAKNES

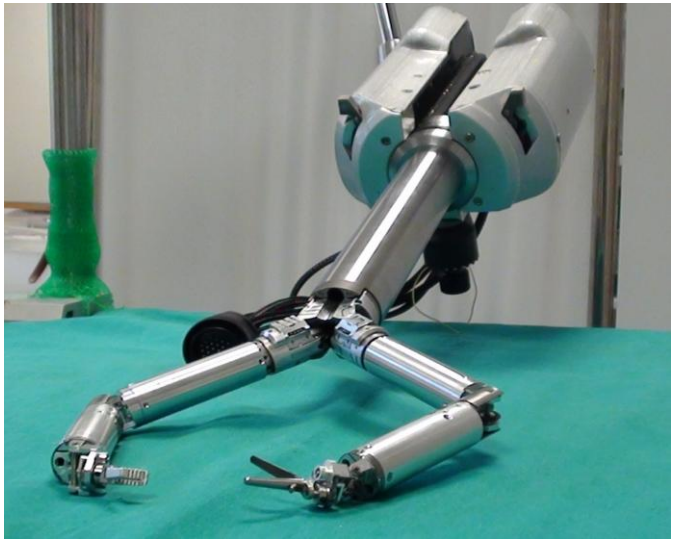




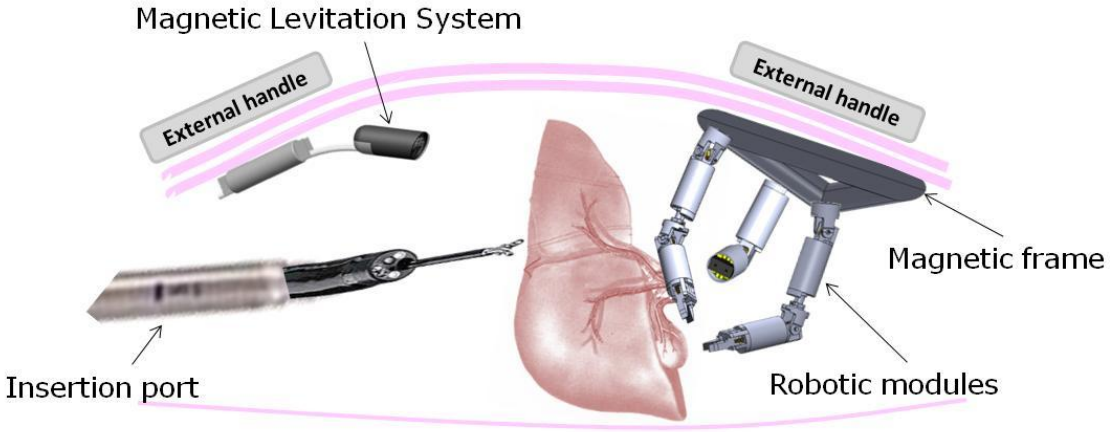




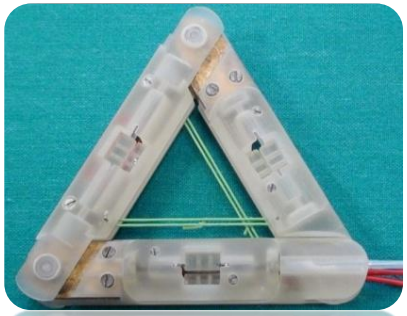
SPRINT Robot: Test su animale



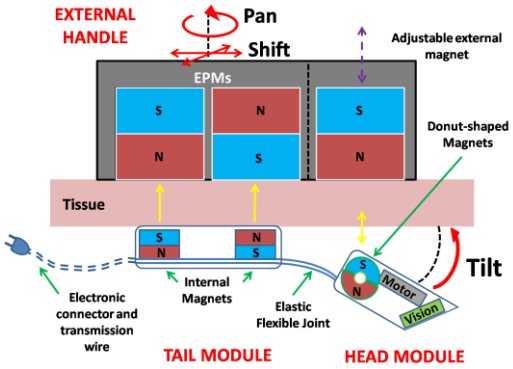
ARAKNES – Piattaforma di ricerca

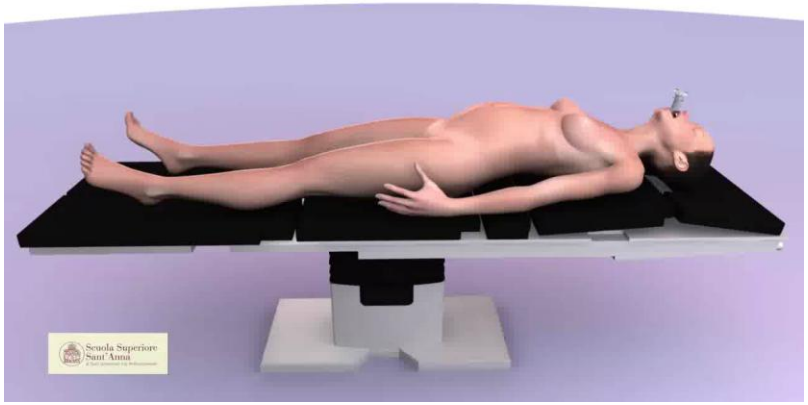


Meccanismo di ancoraggio

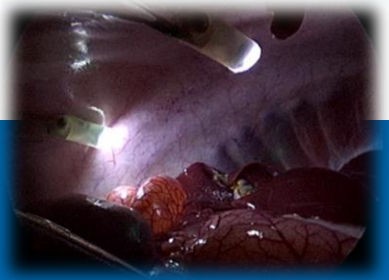


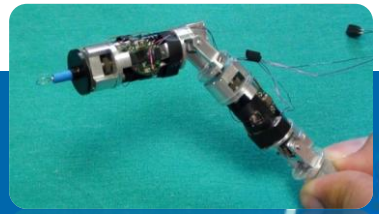
Telecamera magnetica





UNITA' ROBOTICHE MODULARI





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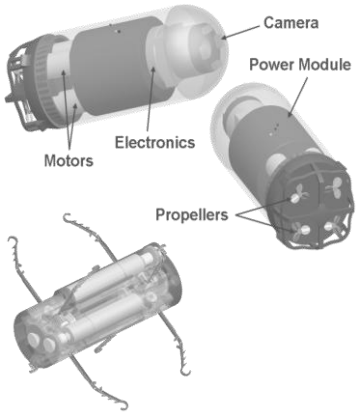
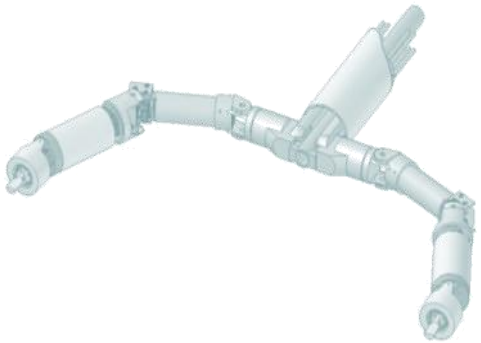
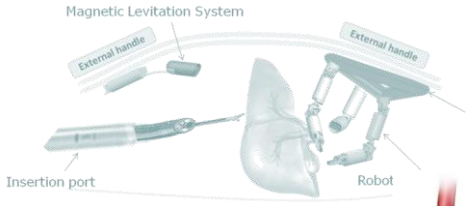


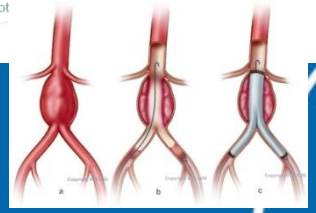
Addome mediante accesso "Single Port": D = 20-32 mm



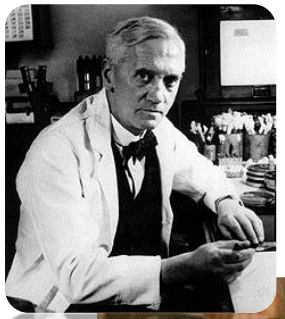
Addome, con accesso mediante Trocar: D = 10-15 mm

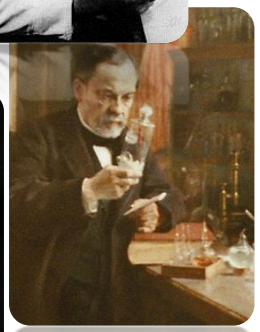


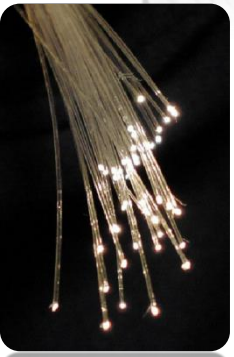
Sistema vascolare: D < 8-5 mm

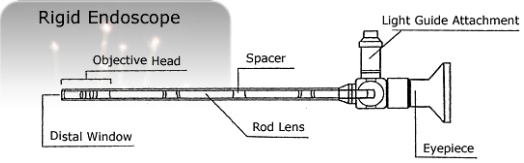


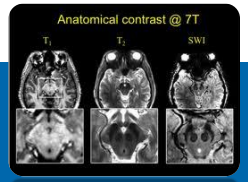
Alcune considerazioni sull'importanza della "convergenza" di tecnologie per l'avanzamento della scienza e di numerose discipline: CONVERGENZA ALLA TERAPIA ROBOT-ASSISTITA











Anesthetics

Antiseptics

Anticoagulants

Antibiotics

Analgesics

Endoscopic instruments

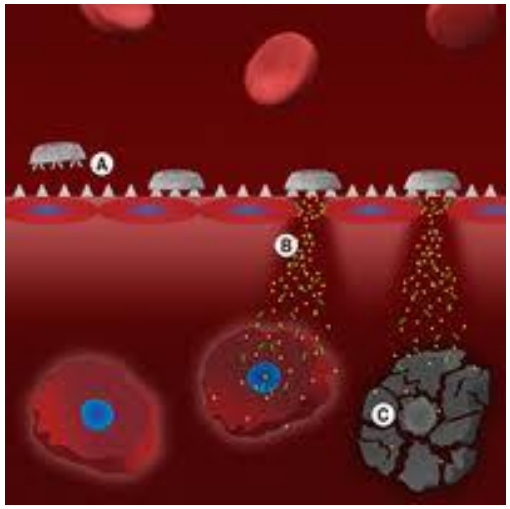
Medical imaging

Modern surgery

Minimally invasive surgery

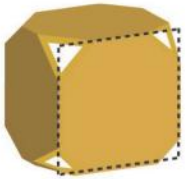
Computer-assisted surgery

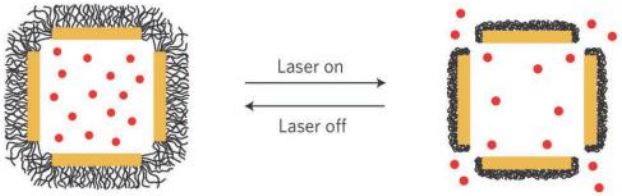
Quali enabling technologies contribuiranno all'evolversi della TERAPIA ROBOT-ASSISTED?

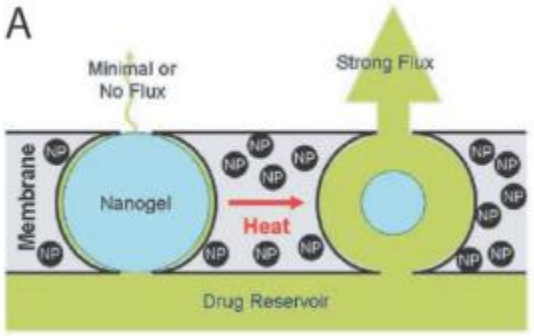


- Materiali "responsive"
- Nanotecnologie
- Sorgenti di energia wireless
- Bioingegneria
- …?…

Targeted and Patient specific therapy







National Cancer Institute

PHYSICAL SCIENCES in ONCOLOGY

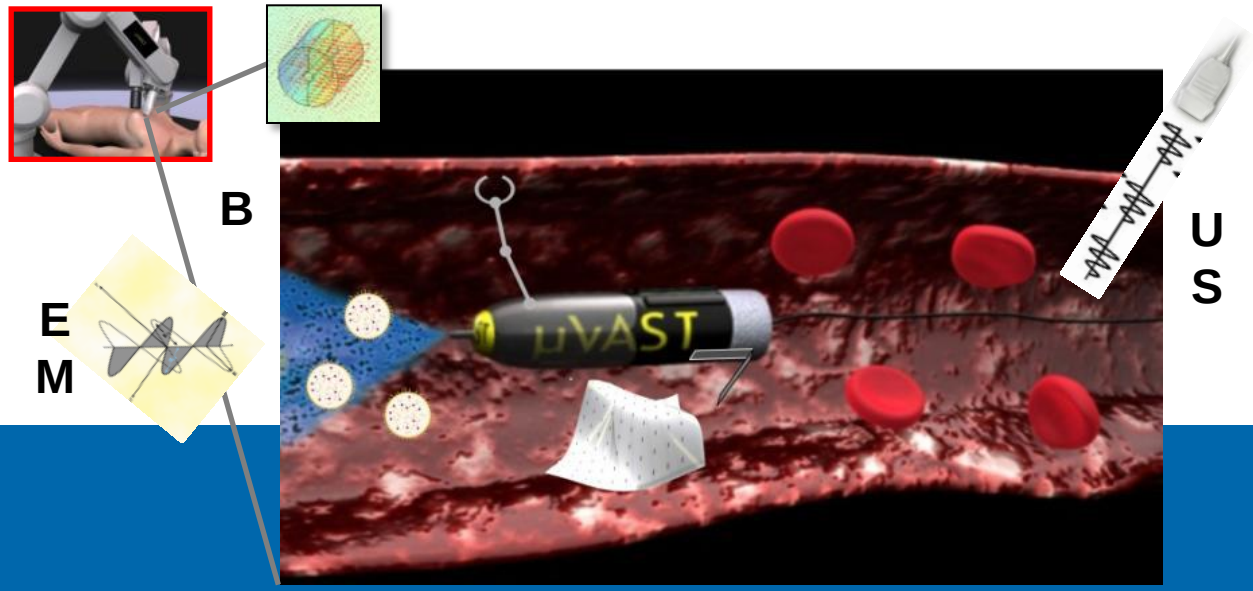
The problem: finding and destroying the vulnerable plaque in blood vessels

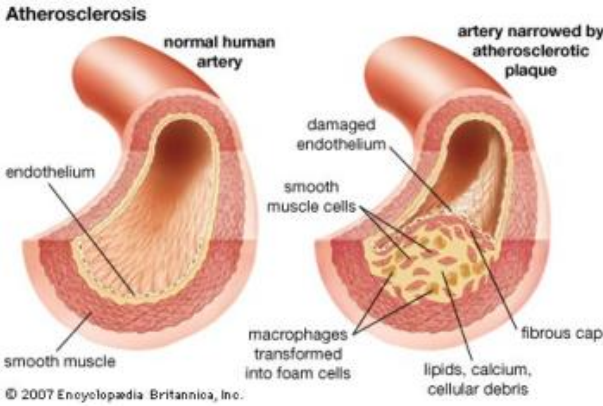
❑ **Cardiovascular disease** is the leading cause of death in industrialized countries (1.9 million deaths in the European Union). Within this group **coronary heart disease (CHD)** is a major cause of death mainly due to **atherosclerotic plaque rupture**, accounts for the largest part

❑ **More than 50% of plaque ruptures occur without significantly observable stenosis**. Identification of relevant anatomical structure and definitive therapy for atherosclerotic lesion is still far from being achieved

1	Ischaemic heart disease	6·3
2	Cerebrovascular disease	4·4
3	Lower respiratory infections	4·3
4	Diarrhoeal diseases	2·9
5	Perinatal disorders	2·4
6	Chronic obstructive pulmonary disease	2·2
7	Tuberculosis (without HIV infection)	2·0
8	Measles	1·0
9	Road-traffic accidents	0·99
10	Trachea, bronchus, and lung cancer	0·94

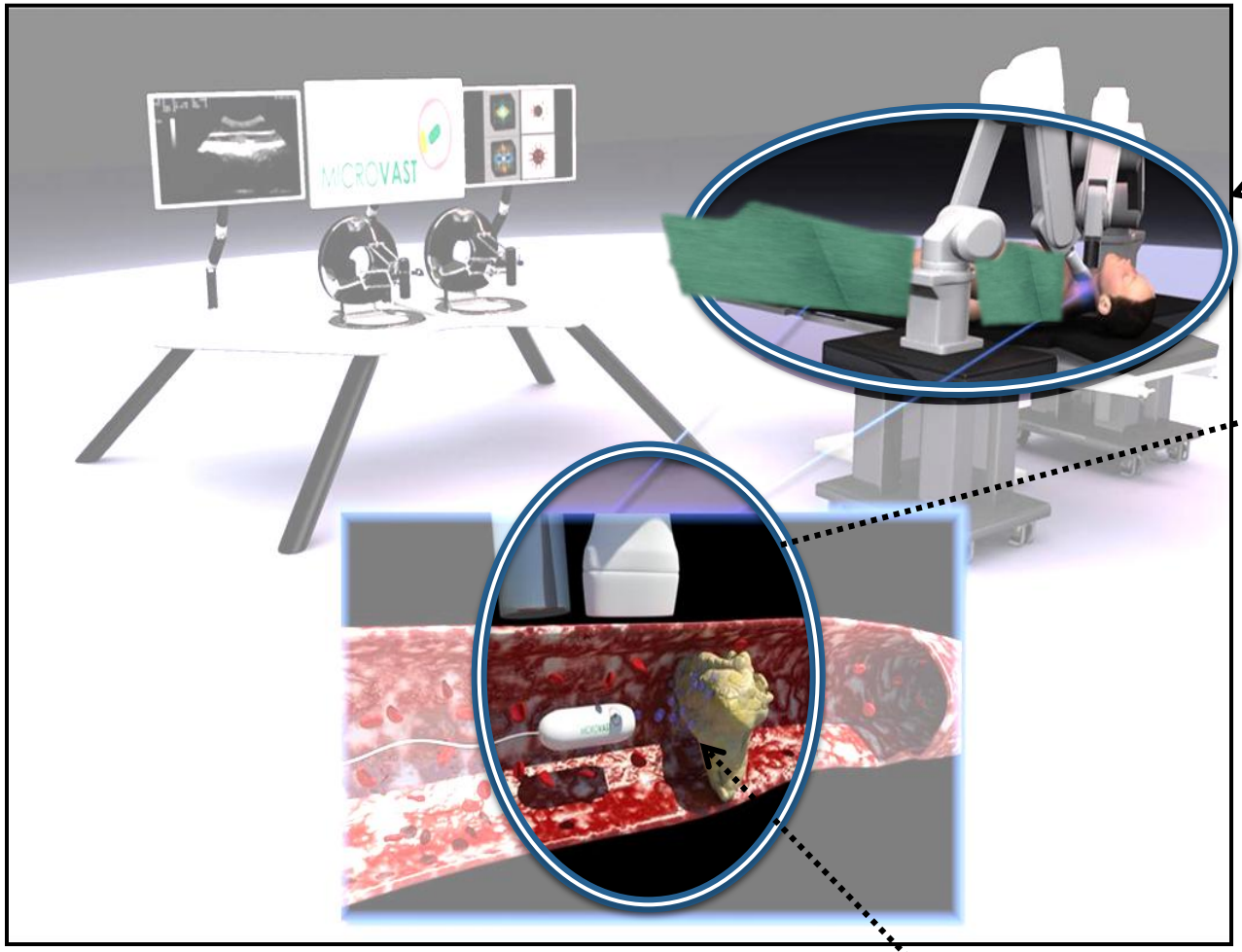
First ten causes of death worldwide in million of decease (The Lancet, 1997)





The Micro-VAST Platform

Navigation module: **External robots** holding a permanent magnet and a diagnostic US probe.

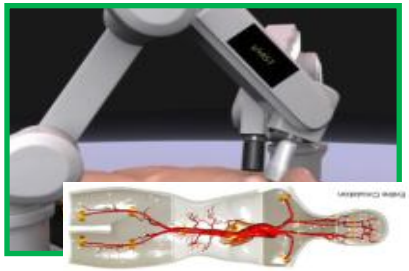


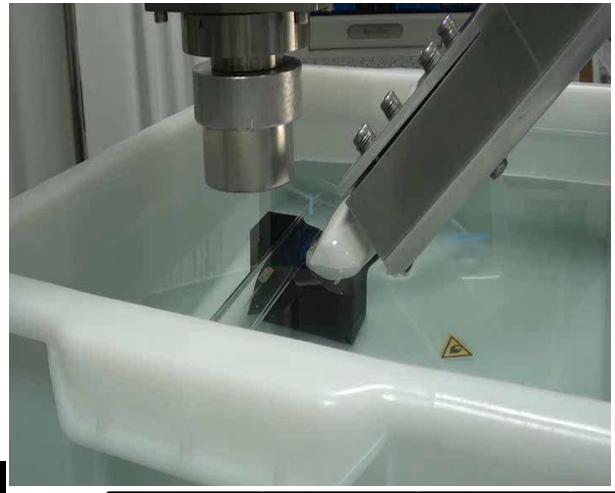
Therapeutic module: Focused US thrombolysis enhanced by microbubbles released by means of a magnetic internal mechanism

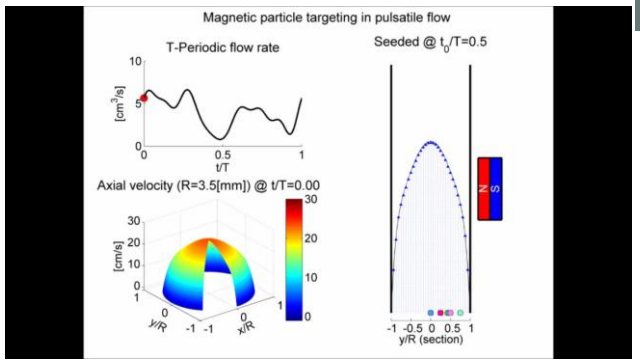
Debris collection module: Binding of magnetic particles to thrombus for collection and retrieval of debris.

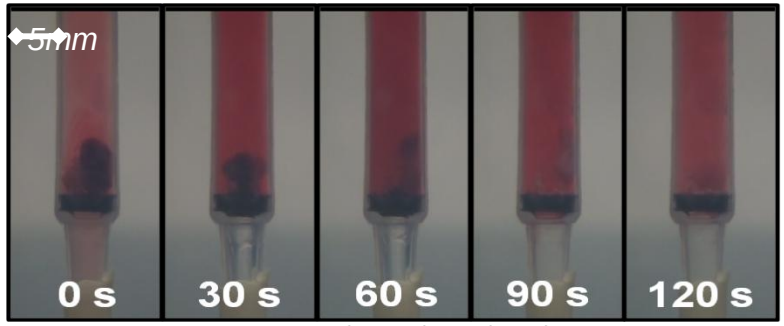
Micro-VAST Modules: navigation, therapy, post-therapy treatment

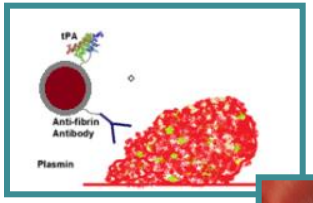
Navigation Module

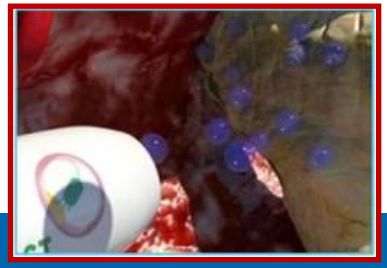












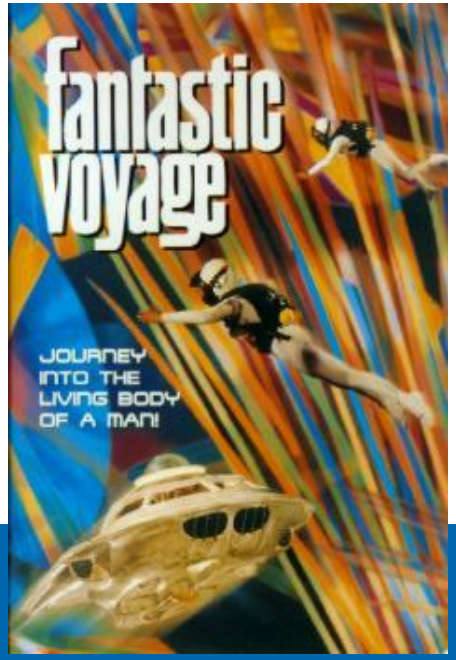
Clots dissolved in approximately 2 minutes.

Freq. 1MHz - Power 65W - Pulse Length 450µs - Duty Cycle 1:10 - Flow rate 2ml/min

Accessory module

Therapeutic module

Is it the time to revisit science fiction?



Isaac Asimov, *Fantastic Voyage*, Bantam Books, Inc., 1966.

FANTASTIC VOYAGE—FROM FICTION TO REALITY

ÉCOLE POLYTECHNIQUE DE MONTRÉAL RESEARCHERS MAKE NEW INROADS FOR CANCER TREATMENT BY USING MRI TO TRACK AND PROPEL DEVICES THROUGH THE BLOODSTREAM.

By Véronique Barker

ISSUE #29 // JULY-AUGUST 2007

PROJECT

In the same vein as the 1960s classic movie, Fantastic Voyage, where a crew of scientists are miniaturized and injected into the bloodstream, Sylvain Martel [1], director of the NanoRobotics Laboratory at École Polytechnique de Montréal, has successfully made travel through a living animal's bloodstream possible. "This is really what we are doing, except that we

S. Martel, CANADA

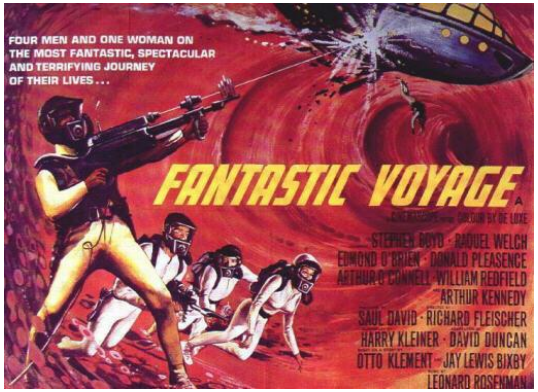
… Current research may not be lagging too behind

- **Functions of different modules:**

pilot→ navigation

surgeon→ operation

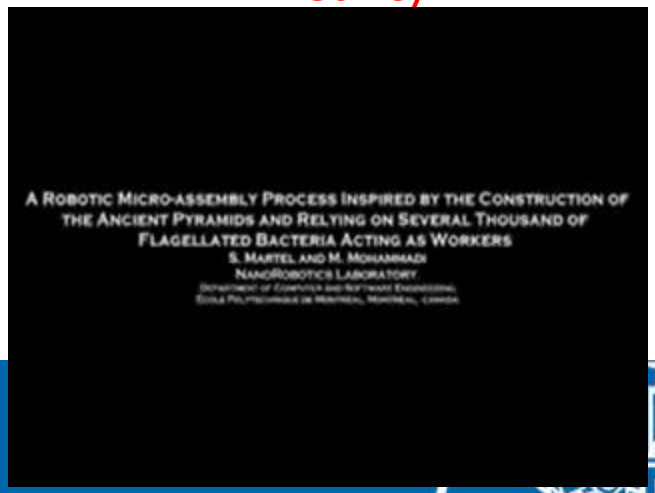
nurse→ assistance tasks



1966 science fiction movie (Dir. R. Fleischer)

Cinematography

Reality



- **Tasks:**

1. Locomotion
2. Cooperation and Manipulation
3. Therapy

… Current research may not be lagging too behind

- **Tasks:**

1. Locomotion
2. Cooperation and Manipulation
3. Therapy

Cinematography

Reality

S. Martel (2009), Ecole Polytechnique de Montreal, Canada

… Current research may not be lagging too behind

- **Tasks:**

1. Locomotion
2. Cooperation and Manipulation
3. Therapy

Cinematography

Reality (targeted drug delivery)

The overall vision

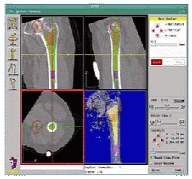
$1=10^0$ [m] 10^{-1} 10^{-2} 10^{-3}

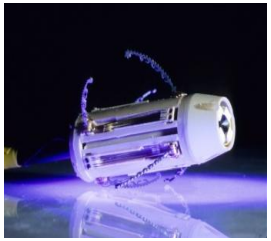
Robotic surgery

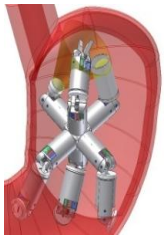
Capsule endoscopy

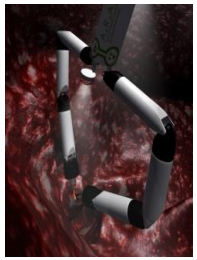
Reconfigurable endoluminal platforms

Intravascular robotics



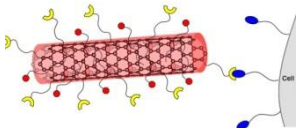


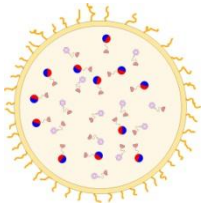


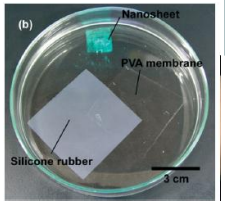


SYSTEMS INTEGRATION AT MULTIPLE LEVELS

Interventional platforms in the mesoscale combining robotic accuracy with wireless operation and enhanced imaging/energy delivery







Nano-particles, nano-tubes, nano-shells

Functionalized nano-carriers, advanced drugs

Smart structures

SYSTEMS INTEGRATION AT MULTIPLE LEVELS

10^{-9} [m] 10^{-6} 10^{-3}

Lezione per questo pomeriggio:

un’idea per …

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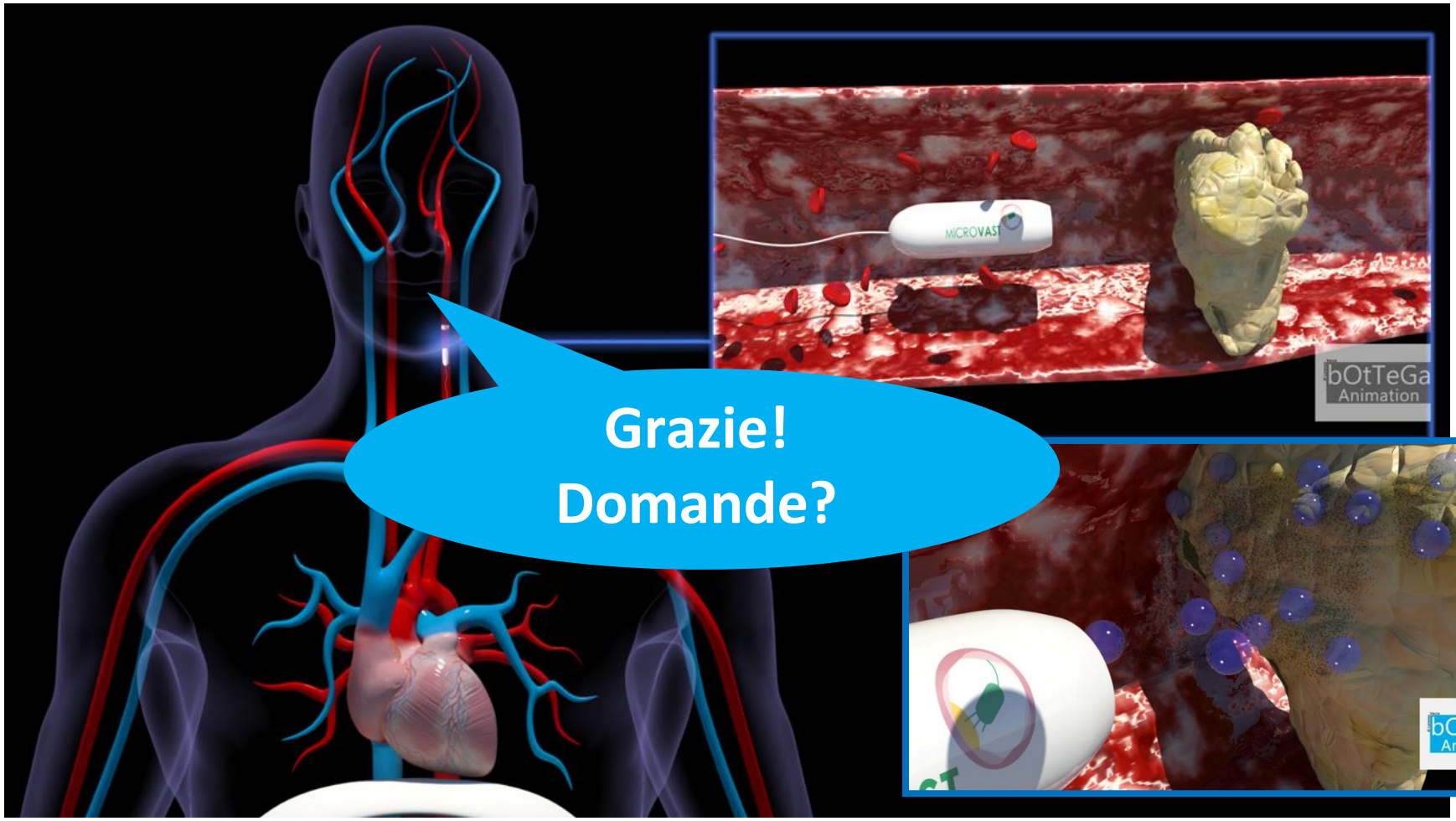
Future and Emerging Technologies

Future and Emerging Technologies (FET) go beyond what is known! Visionary thinking can open up promising avenues towards powerful new technologies.

The visionary aspects and exploratory characteristics of FET might make it sound like a kind of magic, but the mission of FET is actually very concrete: to turn Europe's excellent science base into a competitive advantage.


MICROVAST
bOtTeGa
Animation
Grazie!
Domande?
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Animation