2019 Netval Summer Conference
September 18, 2019
CNR, Rome, Italy

Biomedical Technologies for Clinical Innovation

Eugenio Guglielmelli

Prorector for Research
Università Campus Bio-Medico di Roma

Vice-President for Publication Activities,
IEEE Robotics & Automation Society

e.guglielmelli@unicampus.it

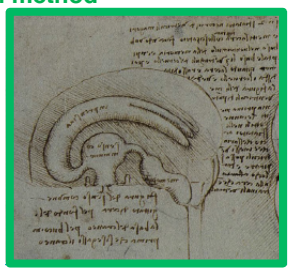
Università Campus Bio-Medico di Roma - Via Álvaro del Portillo, 21 - 00128 Roma – Italia
www.unicampus.it

The cerebral ventricles in Leonardo's anatomical drawings

Based on arabic and medieval medical sources (1490)

According to the Aristotelian theory of soul, the three ventricles are the sites of sensation, reason, and memory. This drawing is a perfect example of so-called theory-loaded knowledge.

Based on innovative experimental method (1504–07)



The refined anatomical knowledge of the brain, combined with further knowledge regarding cranial nerves (auditory and trigeminal) obtained through this procedure, led Leonardo to abandon the functional theory not supported by this newly acquired empirical evidence.

Leonardo's wax injection method clearly shows that scientific progress is often driven by revolutionary uses of existing tools rather than by groundbreaking ideas.

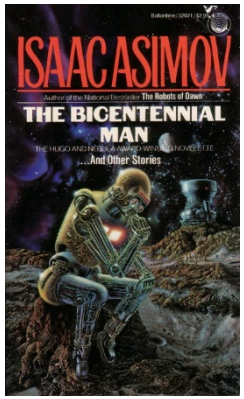
Di Stefano, N., Ghilardi, G., & Morini, S. (2019). The cerebral ventricles in Leonardo's anatomical drawings. The Lancet, 393(10179), 1412.

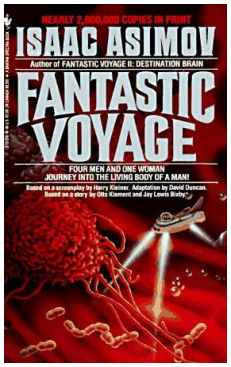
FAST – Institute of Philosphy of Science and Technology – Università Campus Bio-Medico di Roma

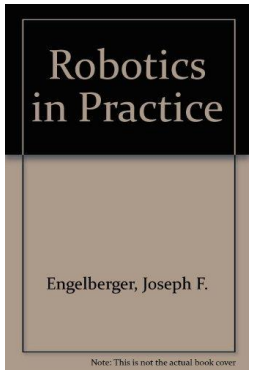
Innovation forecasting is challenging….

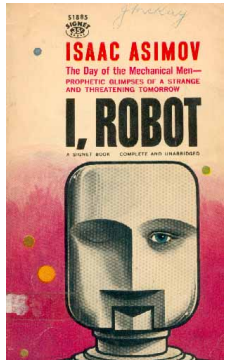
1982
(based on P. Dick's novel published in 1969)

Martin Cooper, Motorola. 1973

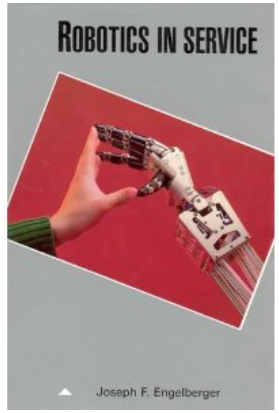

ISAAC ASIMOV
THE BICENTENNIAL MAN
...And Other Stories


ISAAC ASIMOV
FANTASTIC VOYAGE
FOUR MEN AND ONE WOMAN JOURNEY INTO THE LIVING BODY OF A MAN!


Robotics in Practice
Engelberger, Joseph F.
Note: This is not the actual book cover


ISAAC ASIMOV
The Day of the Mechanical Men—
PROPHETIC GLIMPSES OF A STRANGE AND THREATENING TOMORROW
I, ROBOT


UNIMATE
PUMA 500
Antenen Research


ROBOTICS IN SERVICE
Joseph F. Engelberger

The Future of Medicine

1.0 **Symptom-based**
Intuition medicine

Stethoscope

Theophile Hyacinthe Laennec (1816)

L. BORGHI, A. ONETTI MUDA, Università Campus Bio-Medico di Roma
La bioingegneria per il benessere e l'invecchiamento attivo, M.C. Carrozza, E. Guglielmelli, R. Pietrabissa, Patron Editore 2016

The Future of Medicine

1.0 **Symptom-based**
Intuition medicine

2.0 **Interaction-based**
Measure medicine

The Future of Medicine

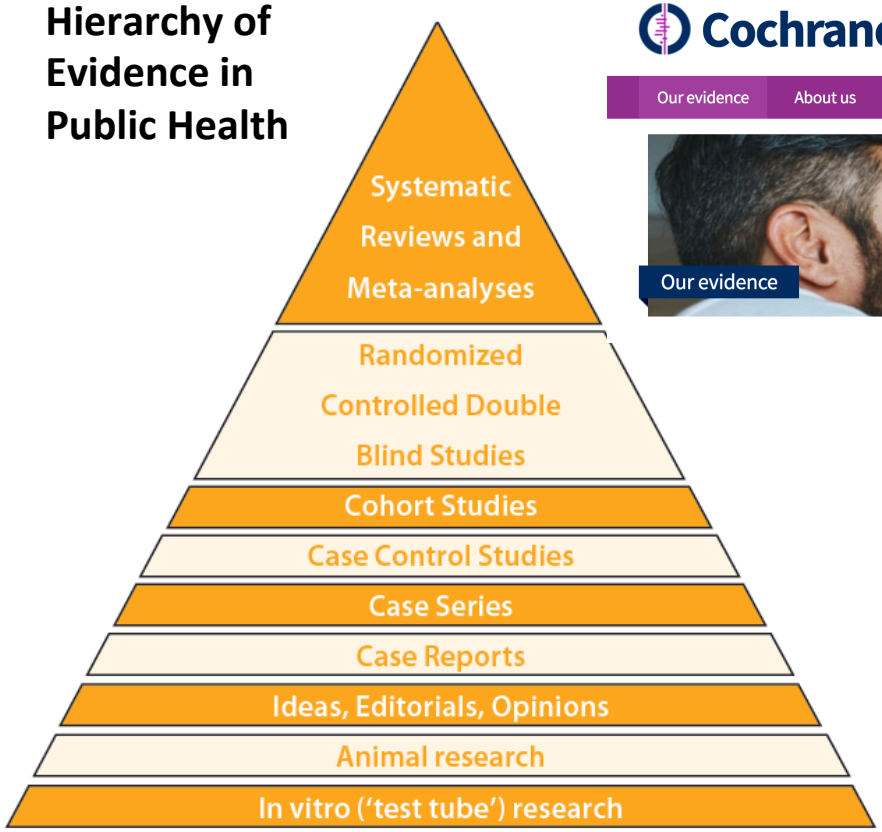
1.0 **Symptom-based**
Intuition medicine

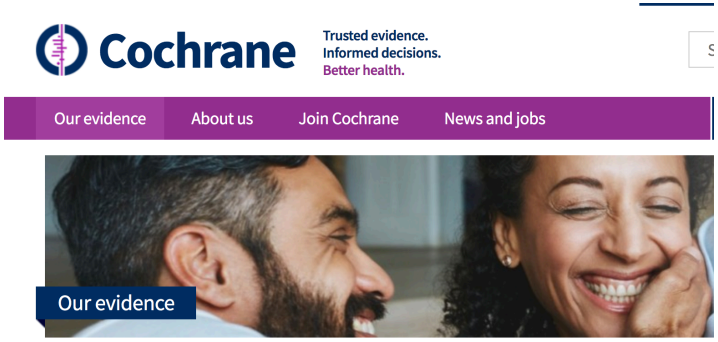
2.0 **Interaction-based**
Measure medicine

3.0 **Pattern-based**
Evidence medicine

Evidence Medicine - *Pattern-based*

Hierarchy of Evidence in Public Health

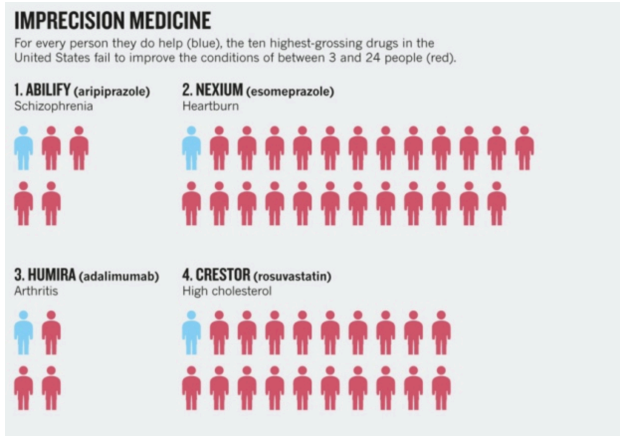




The death valley

Butler, Nature 2008

Evidence Medicine - *Pattern-based*



Personalized medicine: Time for one-person trials

Nicholas J. Schork

29 April 2015

Precision medicine requires a different type of clinical trial that focuses on individual, not average, responses to therapy, says Nicholas J. Schork.

nature


COMMENT

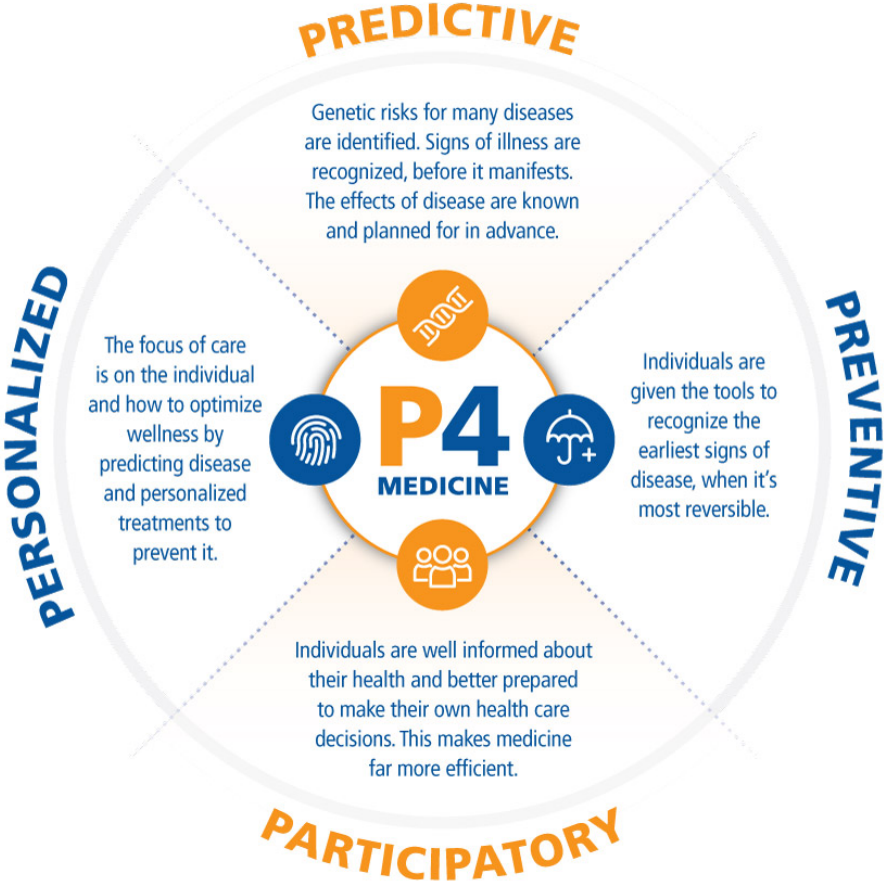
Time for one-person trials

Precision medicine requires a different type of clinical trial that focuses on individual, not average, responses to therapy, says Nicholas J. Schork.

The Future of Medicine

Scientific wellness embodies

P4 MEDICINE:



The Future of Medicine

1.0 **Symptom-based**
Intuition medicine

2.0 **Interaction-based**
Measure medicine

3.0 **Pattern-based**
Evidence medicine

4.0 **Algorithm-based**
4P medicine


The NEW ENGLAND JOURNAL of MEDICINE

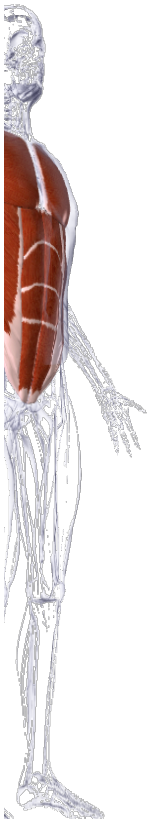
HOME | ARTICLES & MULTIMEDIA | ISSUES | SPECIALTIES & TOPICS | FOR AUTHORS | CME

Perspective

Lost in Thought — The Limits of the Human Mind and the Future of Medicine

Ziad Obermeyer, M.D., and Thomas H. Lee, M.D.

N Engl J Med 2017; 377:1209-1211 | September 28, 2017 | DOI: 10.1056/NEJMp1705348



BIOMEDICAL BIG DATA

- ✓ Wearable system for the continuous monitoring of physiological parameters
- ✓ Environmental conditions monitoring
- ✓ Real-time data collection and storage
- ✓ Human-computer interfaces (HCI) to assess the patient's progress and to enhance the patient's engagement

Breathing rate
Breathing volumes

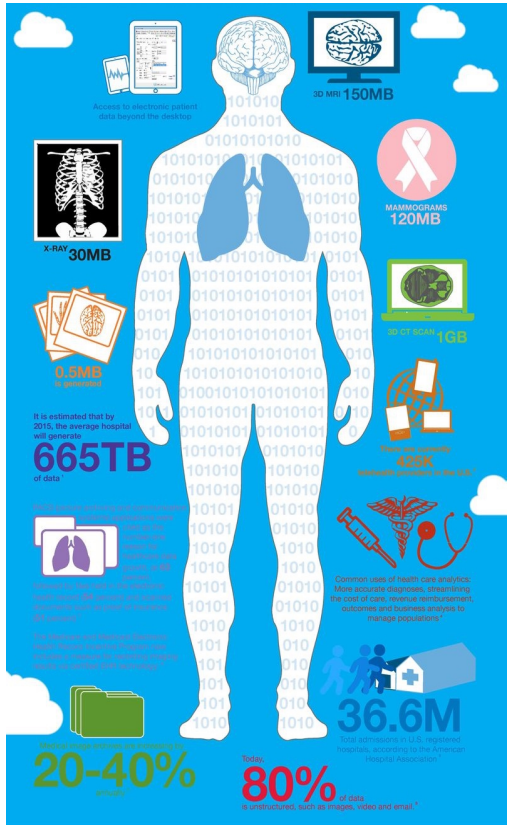
Breathing biomechanics

Heart rate

MR Magnetic resonance compatible

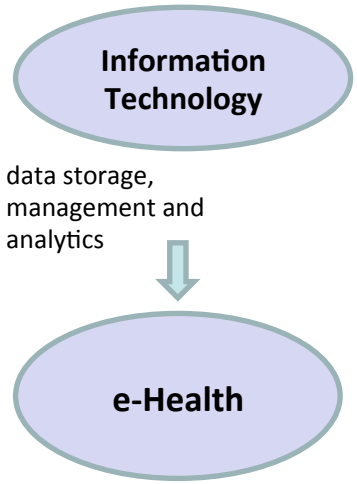
AI for personalized medicine - Radiomics

- Integration of
  - Pathomics, Genomics, Phenomics and Exposome Data
  - Images routinely collected in cancer diagnosis and treatment to
    1. Forecast tumour prognosis
    2. Clinical decision personalization
    3. Treatment selection
    4. Update treatment plans

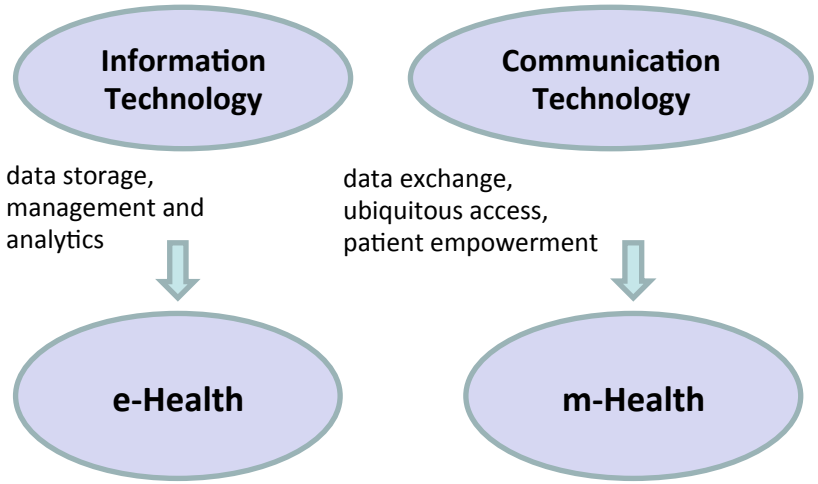


Joint Laboratory on Precision Medicine and BioData Analytics
Università Campus Bio-Medico di Roma & Centro Diagnostico Italiano

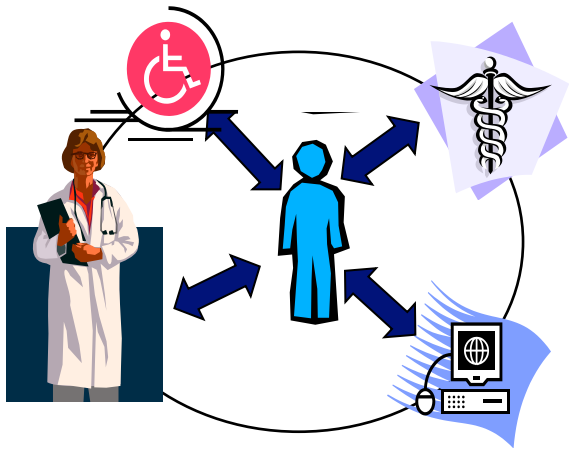
Evolution of Enabling Technologies for Innovation in Healthcare



Evolution of Enabling Technologies for Innovation in Healthcare



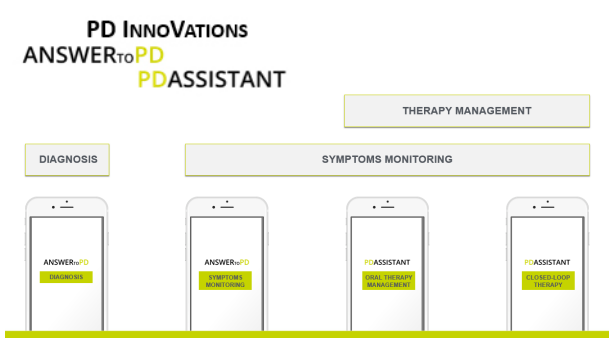
Mobile Health - Ubiquitous Medicine



- Patient awareness and empowerment
- ICT-based services
- Self-administered assessment and therapy
- Early discharge of patients at home
- Home\Remote delivery of therapy to reduce treatment-related mobility costs
- Lack of spaces where delivering therapy

BRAIN INNOVATIONS SRL – «CAMPUS BIO-MEDICO DI ROMA» UNIVERSITY SPIN-OFF
(Lazzaro Di Biase, MD, PhD Student in Neurology)

Il progetto è stato premiato da Zcube con un finanziamento di 25 mila euro



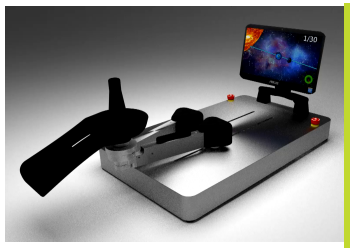
BRAIN INNOVATIONS proposes complete solution that addresses all the needs of Parkinson's Disease patients with the following instruments:

- **Answer to PD - Diagnosis device**
- **Answer to PD - Symptoms monitoring device**
- **PD Assistant - Oral Therapy device**
- **PD Assistant - Infusional therapy device**

ICONE

The only *all-in-one & plug-and-play* rehabilitation system

ICan Robotics



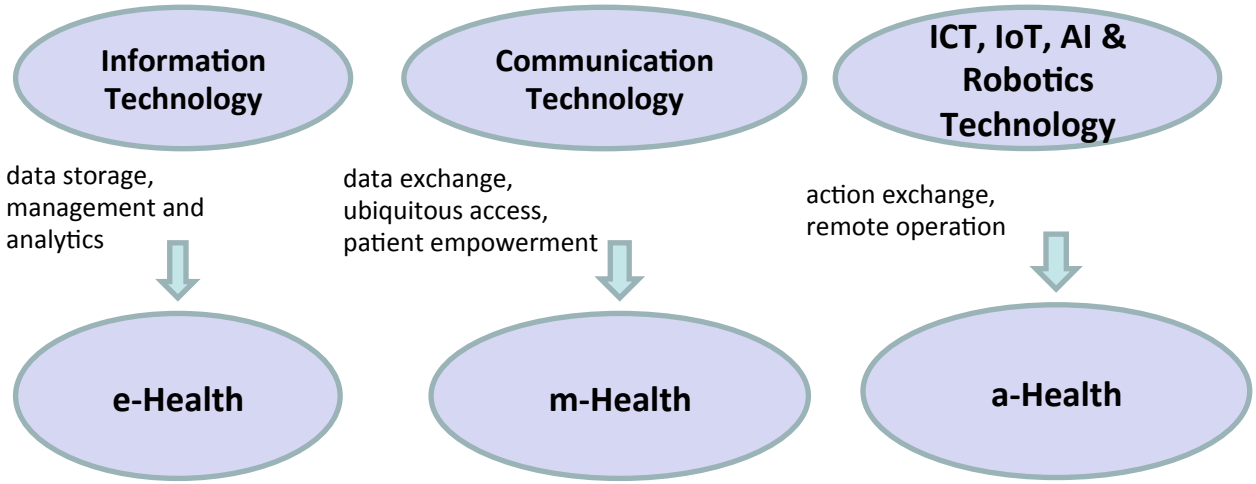
- *Enabling home rehabilitation scenarios*
- *Portable, low weight and size*
- *Better interactive performance with patients*
  Performance evaluation

(patent pending)

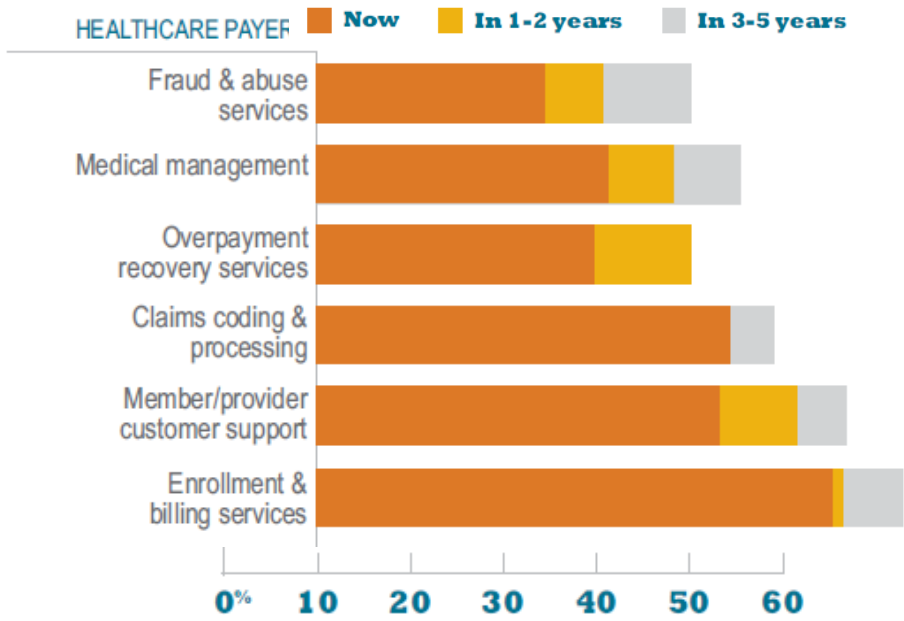
heaxel

Heaxel is a newco of ICan Robotics & VERTIS SGR, the 1st spin-off accredited by UCBM ***www.haexel.com***

Evolution of Enabling Technologies for Innovation in Healthcare



From electronic-Health and mobile-Health to..... automated-Health

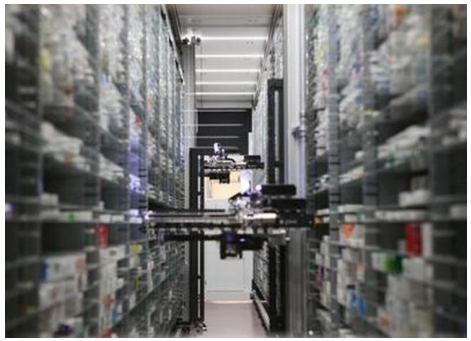


Percent of process automation as gauged by workflow

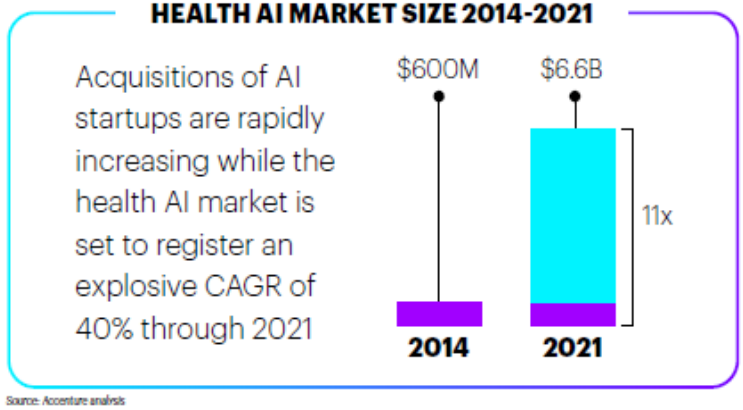
RPA
Robotic
Process
Automation

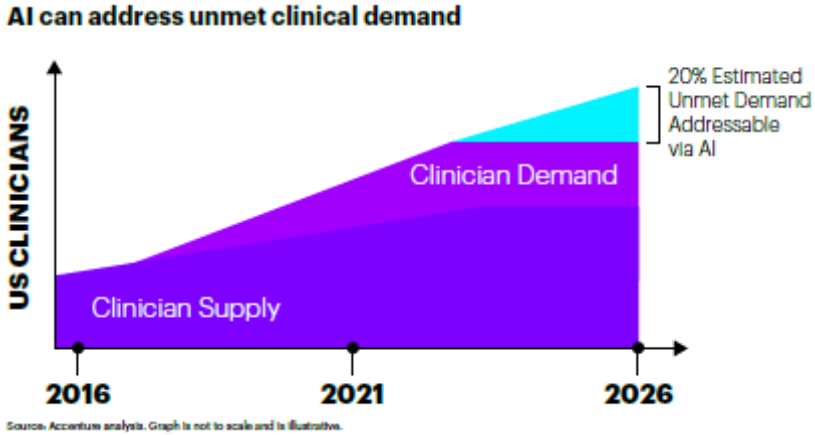
The Robot and I: How New Digital Technologies Are Making Smart People and Businesses Smarter by Automating Rote Work, Cognizant Report, 2015

Robotic systems for service applications in hospitals



Health AI Market





	APPLICATION	VALUE*
	Robot-Assisted Surgery**	$40B
	Virtual Nursing Assistants	$20B
	Administrative Workflow Assistance	$18B
	Fraud Detection	$17B
	Dosage Error Reduction	$16B
	Connected Machines	$14B
	Clinical Trial Participant Identifier	$13B
	Preliminary Diagnosis	$5B
	Automated Image Diagnosis	$3B
	Cybersecurity	$2B
	TOTAL =	~$150B

ARTIFICIAL INTELLIGENCE: Healthcare's New Nervous System, Accenture Report

Robot-assisted Surgery

Robot-assisted Surgery

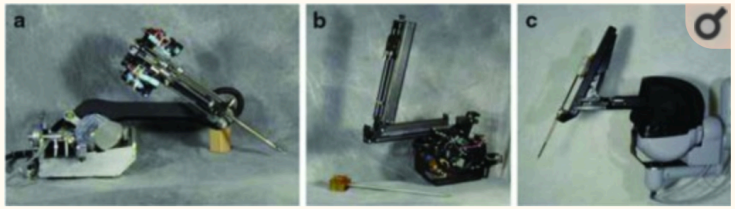


Figure 8.

Lenny, Mona, and da Vinci patient-side manipulators.

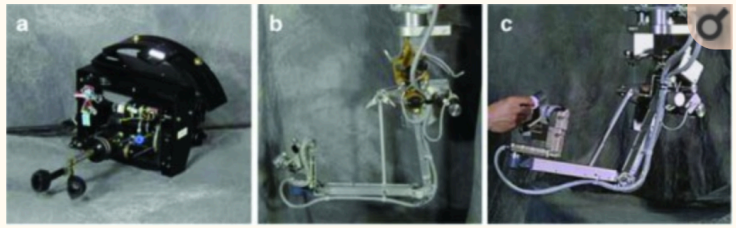


Figure 9.

Lenny, Mona, and da Vinci master controllers.

JSLS Journal of the Society of Laparoendoscopic Surgeons

JSLS. 2018 Oct-Dec; 22(4): e2018.00039. PMCID: PMC6261744
doi: 10.4293/JSLS.2018.00039 PMID: 30524184

Origins of Robotic Surgery: From Skepticism to Standard of Care

Evalyn I. George, BS, COL Timothy C. Brand, MD, COL (Ret) Anthony LaPorta, MD, Jacques Marescaux, MD, and COL (Ret) Richard M. Satava, MD[a]

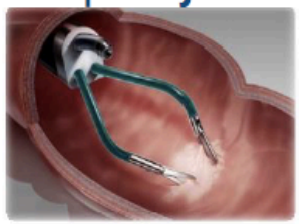
Robot-assisted Surgery

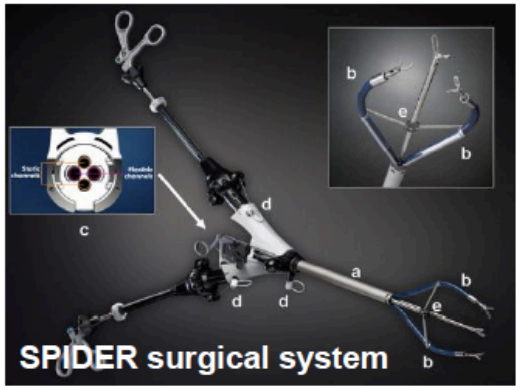
An example setup of the *da Vinci Si* system. (Image credit: Intuitive Surgical Inc.)

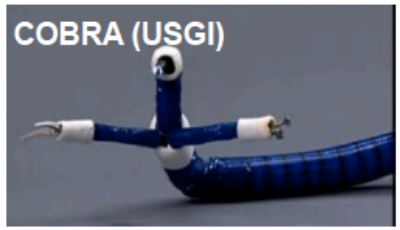
Surgical Robotics

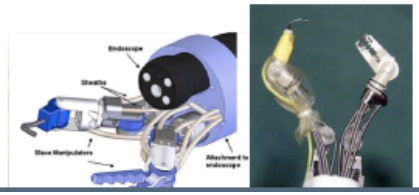
NOTES: flexible endoscopic multitasking platforms

Direct Drive Endoscopic System

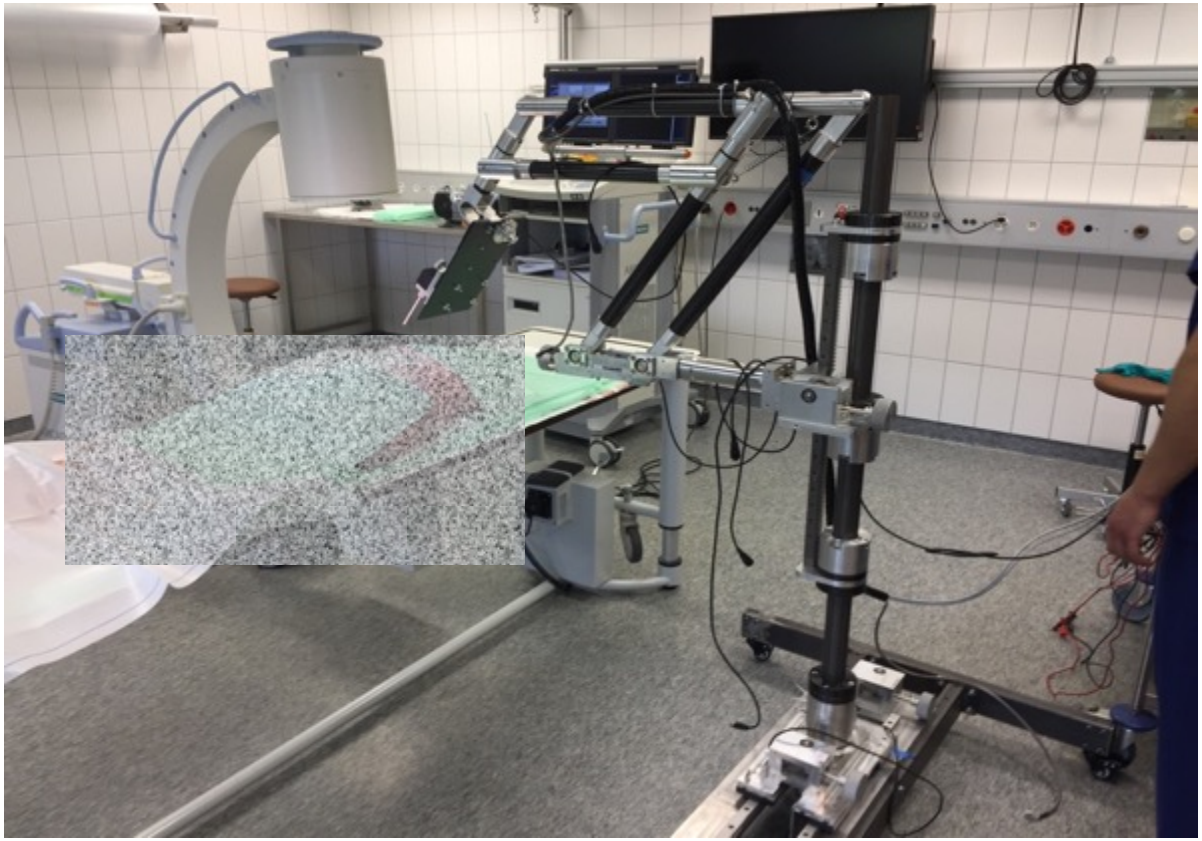








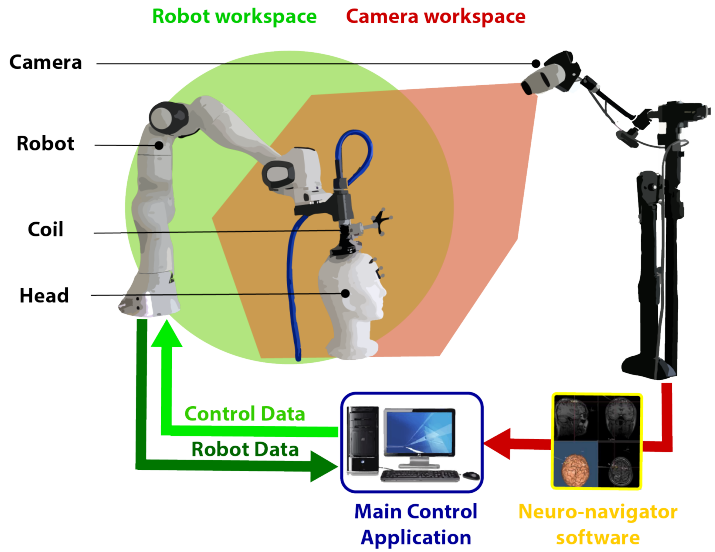
Co-operative Surgical Robots

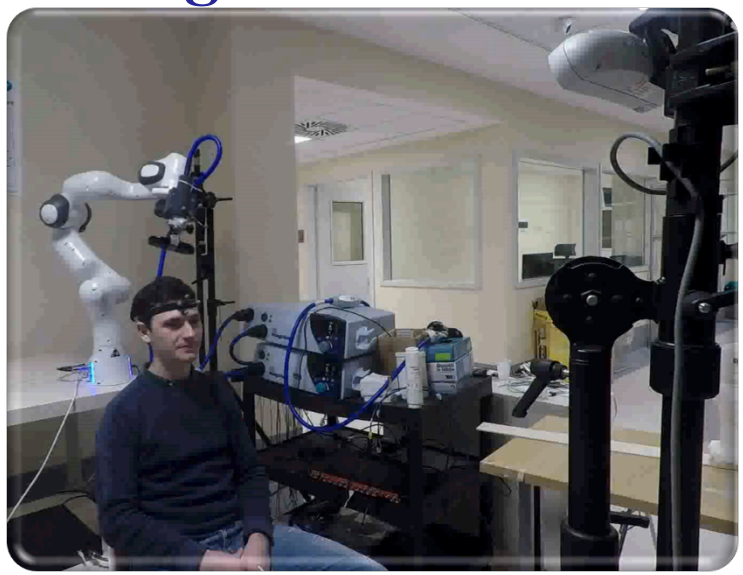


CADAVER TEST: May 24th-25th, 2018

I.Portaccio, G. Vadalà, D. Accoto et al., UCBM, BIOROB 2016

Robot-aided Transcranial Magnetic Stimulation





- High accuracy in coil positioning
- High repeatability stimulating the same site
- Automatic hot-spot identification
- Head motion compensation

- High stiffness in stimulation plane → high accuracy
- Compliant behavior perpendicular to the head → safety and comfort for the subject

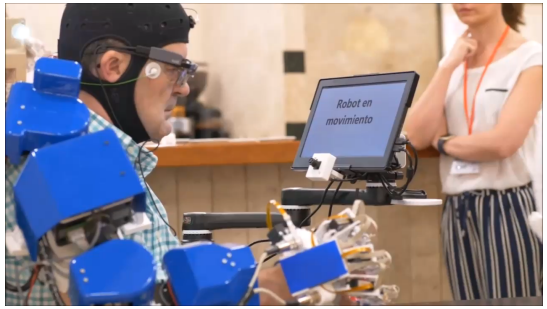
BIO-COOPERATIVE ROBOTIC SYSTEMS FOR REHABILITATION

Robotic arm controlled by subjects with Spinal cord injury

AIDE
Adaptive Multimodal Interfaces to Assist Disabled People in Daily Activities
European Commission

Final prototype tested on a patient affected by SLA

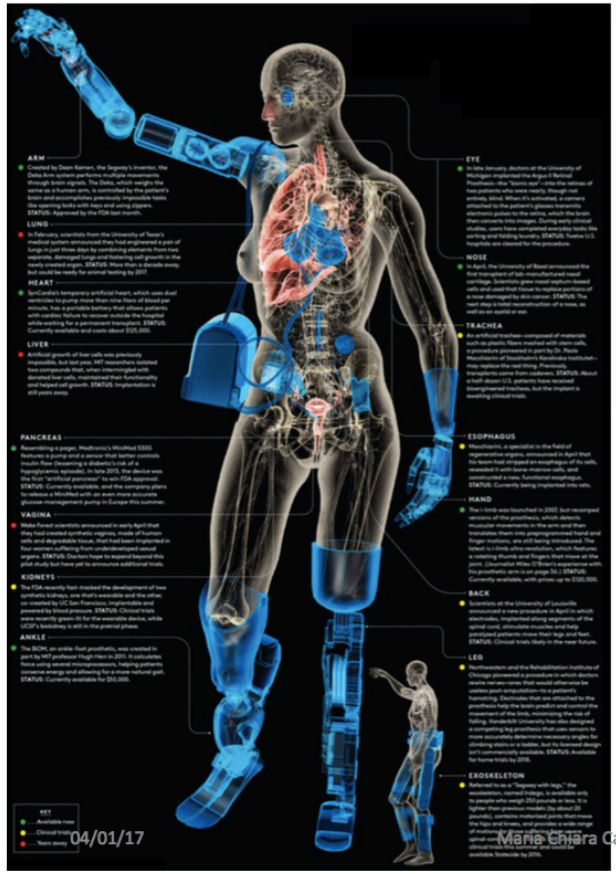
3x



Crea S., Nann M., Trigili E., Cordella F., Baldoni A., Badesa F.J., Catalán, J.M., Zollo L., Vitiello N., Aracil N.G., Soekadar S.R, "Feasibility and safety of shared EEG/EOG and vision-guided autonomous whole-arm exoskeleton control to perform activities of daily living", Scientific Report, vol.8, no.1, 2018.

Lauretti C., Cordella F., Ciancio A.L., Trigili E., Catalan J.M., Badesa F.J., Crea S., Pagliara S.M., Sterzi S., Vitiello N., Aracil N.G., Zollo L., "Learning by demonstration for motion planning of upper-limb exoskeletons", Frontiers in Neurorobotics, 2018

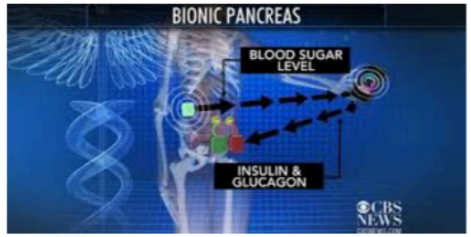
BIONICS

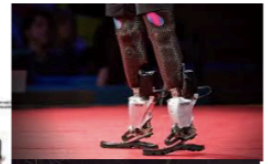


Bionic Organs (c. of Paolo Dario)

Bionic Heart

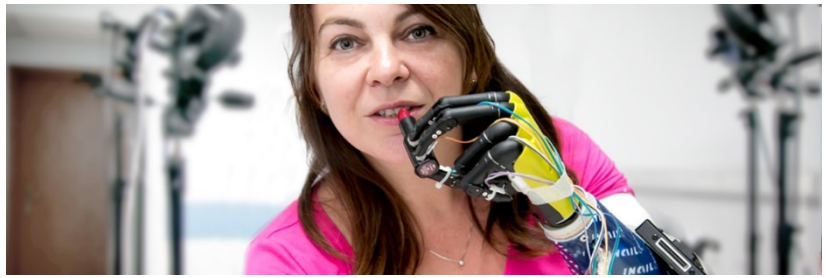
Bionic Liver






GRAZIE!
CONVEGNO SCIENTIFICO
MANO BIONICA
DALLE ORIGINI DELLA RICERCA ALLE SPERIMENTAZIONI SU SOGGETTI AMPUTATI
Giovedì 21 febbraio 2019
ore 09.00
Accademia Nazionale dei Lincei
Palazzo Corsini
via della Lungara, 10
Roma
INAIL
EPFL
Sant'Anna
Università Campus Bio-Medico di Roma
Università Cattolica del Sacro Cuore
Gemelli

Science Robotics



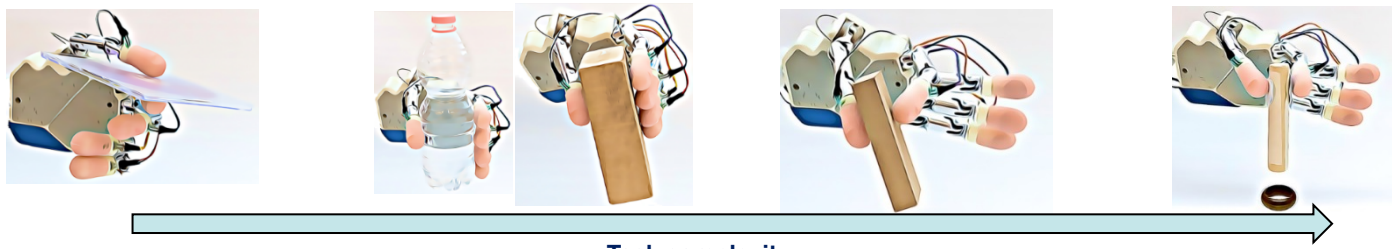
PPR2 project:
Control of upper-limb prosthesis with neural invasive interfaces

To recover sensorimotor integration through neural electrodes and to enable real-time closed-loop control of bionic hands in tasks of fine grasp and manipulation, by using routed sensory information.

L. Zollo, et al., E. Guglielmelli, Restoring tactile sensations via neural interfaces for real-time force-and-slippage closed-loop control of bionic hands. Science Robotics 4, eaau9924 (2019).

Increasing complexity and improvement over time

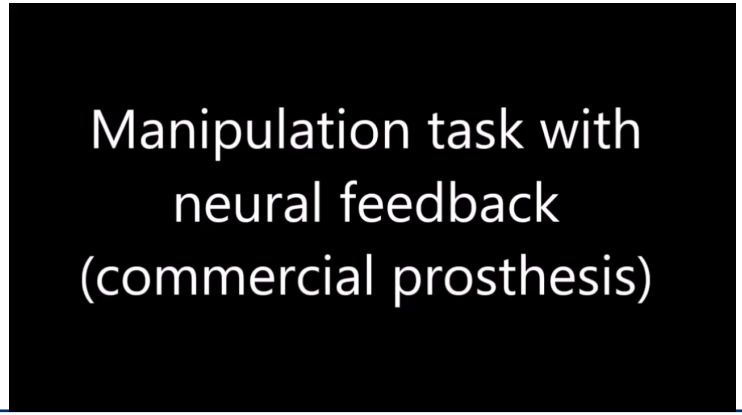
Lateral grasp ***Pick and place with Power grasp*** ***Pick and place with Precision grasp*** ***Manipulation task***



Task complexity

- Improvement of grasping and manipulation capabilities over time
- Interoperability: one research prototype and one commercial hand.

L. Zollo, et al.. Science Robotics 4, (2019).



Market Trends

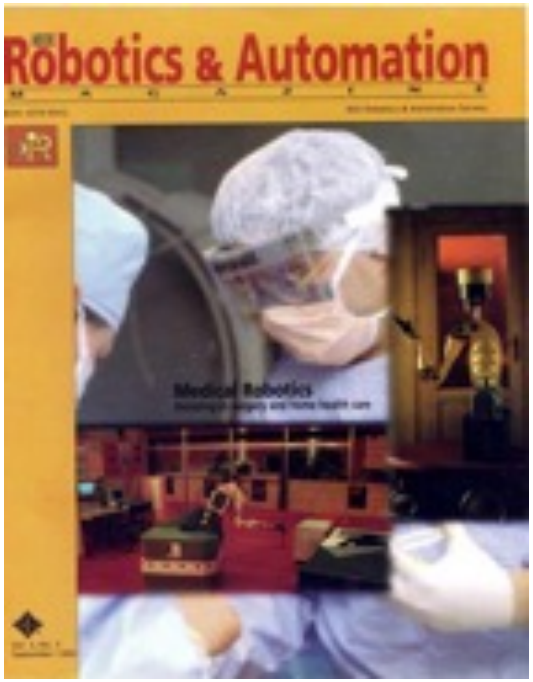
- The **Medical Robots** market is projected to reach USD 12.80 billion by 2021 from USD 4.90 billion in 2016, growing at a CAGR of 21.1% during the forecast period.

- In 2016, the **Surgical Robots** segment commanded the largest share of medical robot systems. However, the **Rehabilitation Robot** systems are likely to grow at the highest CAGR during the forecast period.

- The global **Medical Robotics & Bionics** market was valued at USD 15,348 million in 2016, and is expected to garner USD 29,160 million by 2023, registering a CAGR of 9.6% during the forecast period.

Fonti: http://www.marketsandmarkets.com/Market-Reports/medical-robotic-systems-market-2916860.html
https://www.alliedmarketresearch.com/medical-bionics-market

IEEE Robotics & Automation Magazine, Vol. 3, No. 3, 1996



Paolo Dario, Eugenio Guglielmelli, Benedetto Allotta and Maria Chiara Carrozza*

Robotics for Medical Applications

- Diagnosis
- Assisted Surgery and Acute Treatments
- Assisted Recovery, Post-acute Treatments
- Independent Living, Multi-cronicity

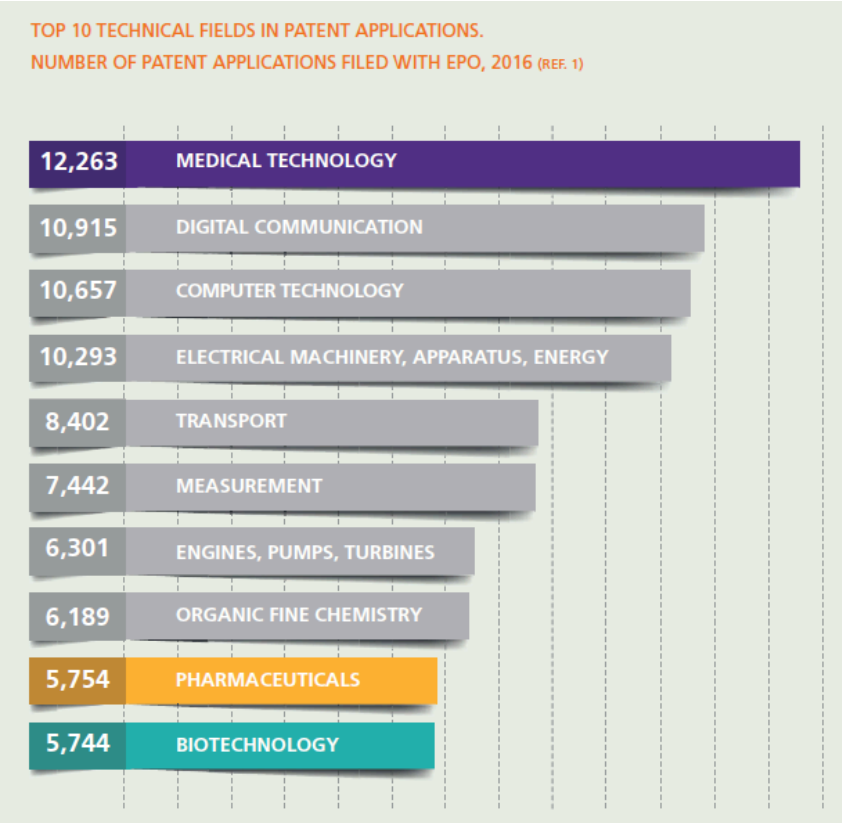
IEEE TRANSACTIONS ON

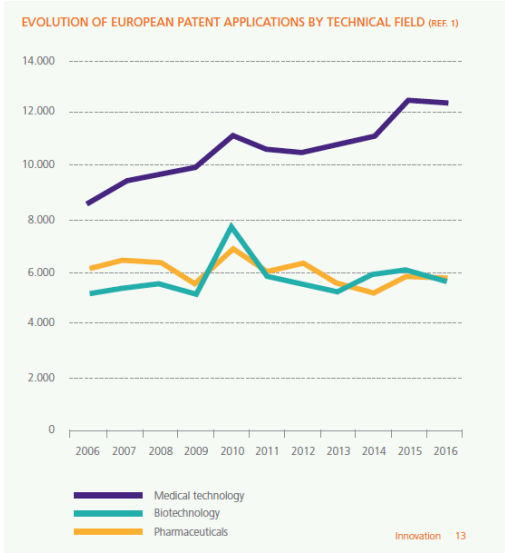
MEDICAL ROBOTICS AND BIONICS

A PUBLICATION OF
THE IEEE ROBOTICS AND AUTOMATION SOCIETY
THE IEEE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY

FEBRUARY 2019 VOLUME 1 NUMBER 1 ITMRBT (ISSN 2576-3202)

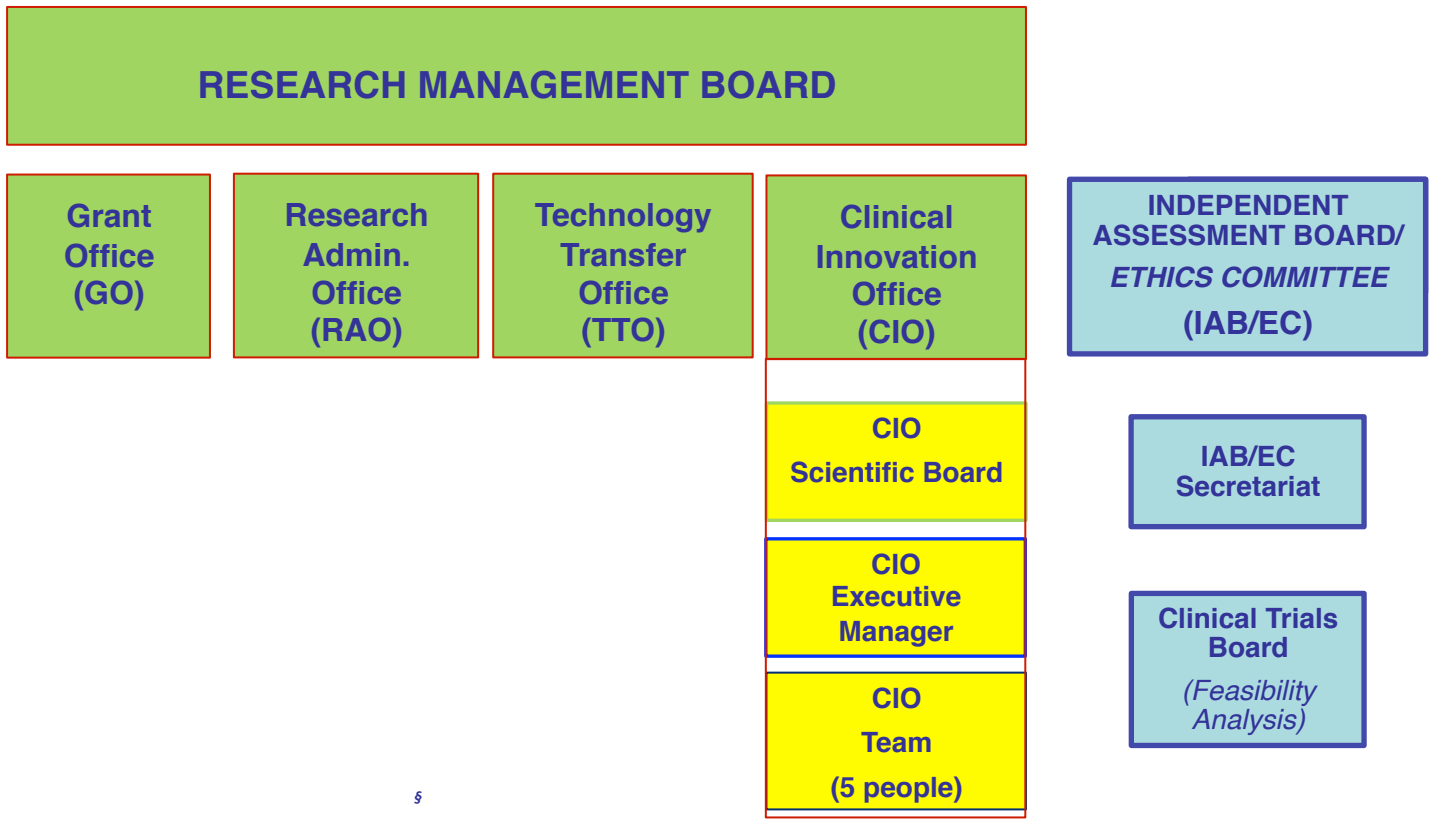
INAUGURAL ISSUE LINKED TO THE 7TH IEEE INTERNATIONAL CONFERENCE ON BIOMEDICAL ROBOTICS AND BIOMECHATRONICS (BIOROB2018)





The European Medical Technology Industry - in figures / 2018, MedTech Europe, www.medtecheurope.org

UCBM RESEARCH ORGANIZATION



§

Thank you!

Eugenio Guglielmelli
e.guglielmelli@unicampus.it

Prorector for Research
Founder, Research Unit of Biomedical Robotics and Biomicrosystems
Department of Engineering, UCBM

Member, Steering Committee of the Stakeholder Board,
Human Brain FET Flagship Project

Vice-President for Publication Activities
IEEE Robotics and Automation Society

Founding Editor-in-Chief
Springer Series on Biosystems and Biorobotics