Robot Research Initiative

ROBOT RESEARCH INITIATIVE
CHONNAM NATIONAL UNIVERSITY

Micro-Robots in Medical Applications

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Contents

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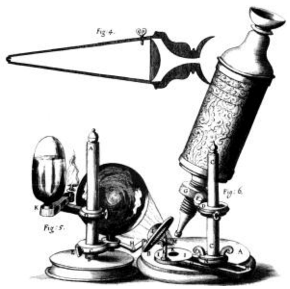
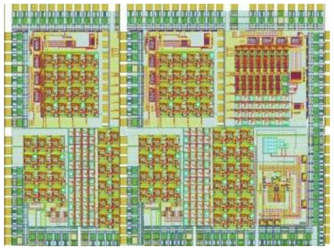
History of Micro-robots



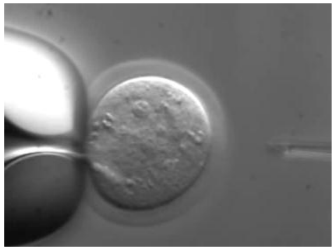
1600's: Optical microscope

1900's: Manipulation of small objects (magnetic, electrical, optical)



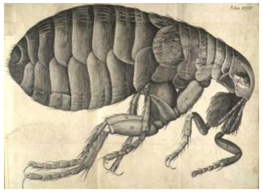
1950's: Integrated circuits

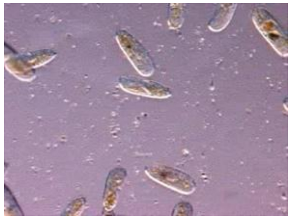
1982: Silicon as mechanical material



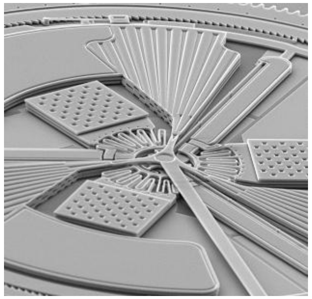
1998: Manipulation of single cells

1850: Micro-assembly in watch industry

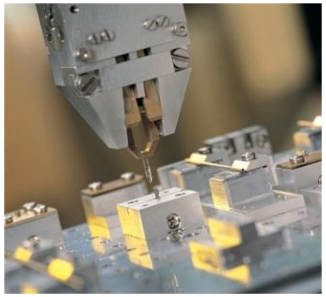




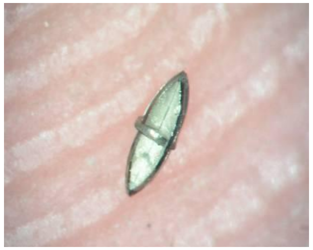
1930, 1952, 1973: Micro-organisms



1980-90's: MEMS research



1995: Micromanipulation/ Micro-assembly



2003: Biomedical micro-robots

Introduction – Micro-robot technology

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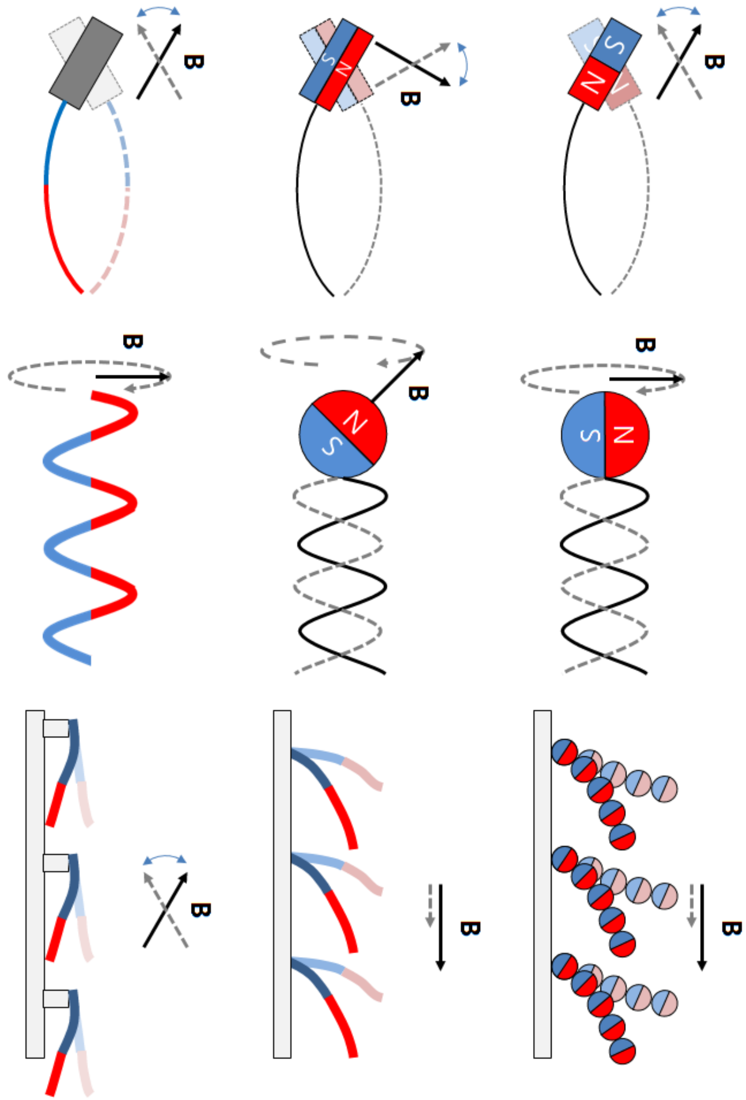
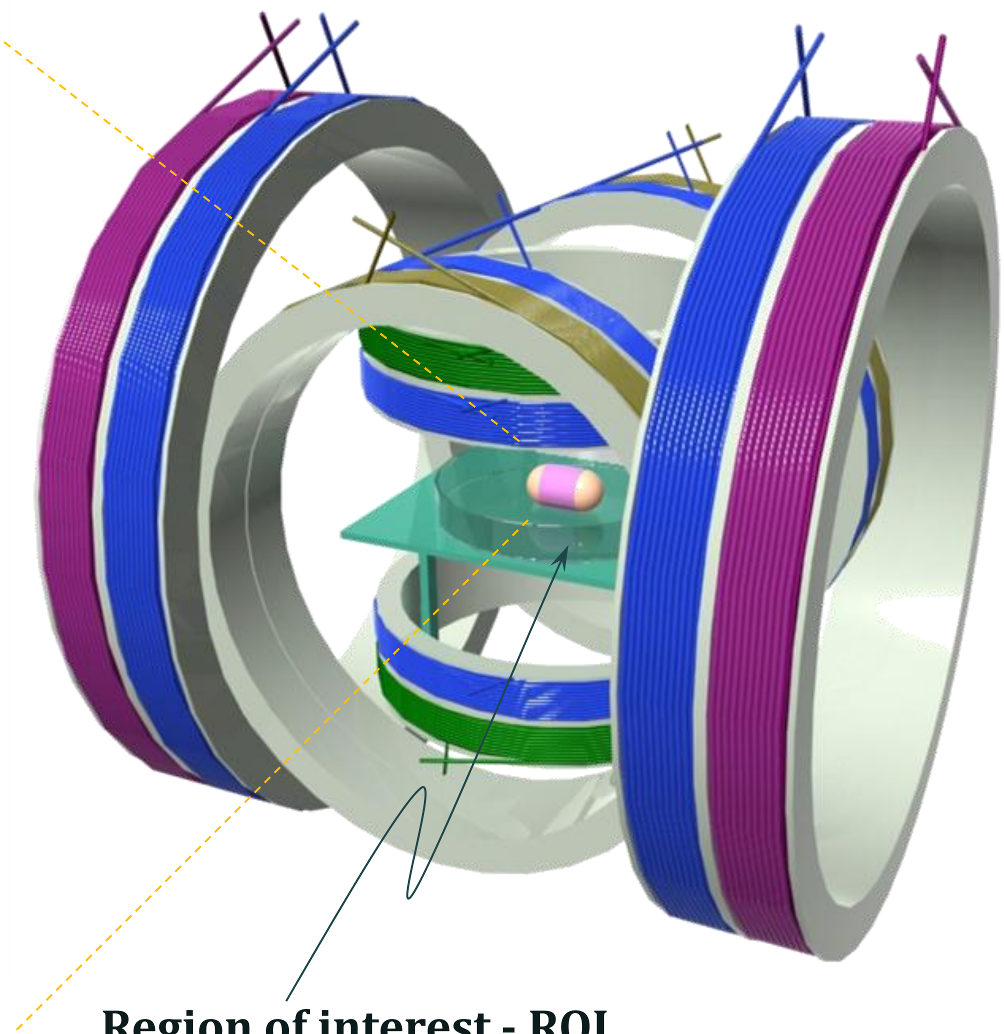
Micro robot - magnetic



Electromagnetic actuator - EMA



Resonant impact force

http://www.iris.ethz.ch/

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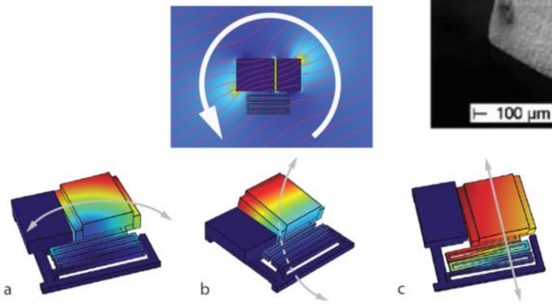
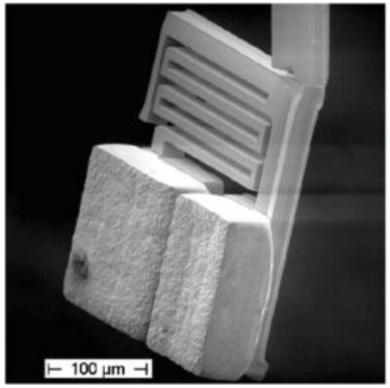
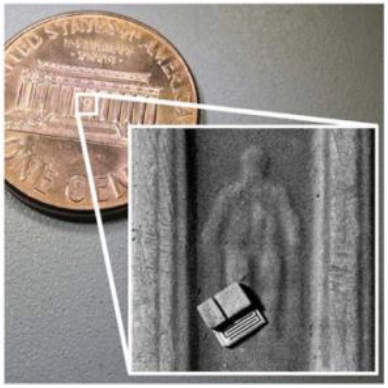
▪ SOA of Cell Manipulation using Electromagnetic Field

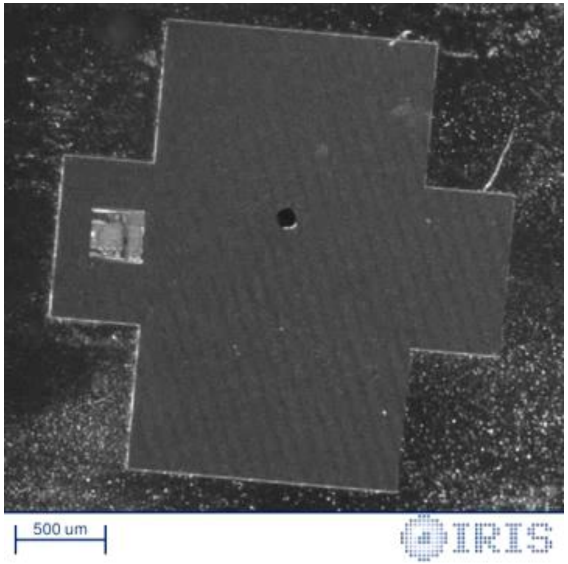
B. J. Nelson (Applied Physics Letters, 2008)

- Wireless resonant magnetic micro-actuator
- Microrobot configuration : Nickel attractor, Swing mass (MEMS Technique)
- 2 pair of Helmholtz coil Moving the two-dimensional plane
- Drive mechanism: Resonant impact force using linear motion







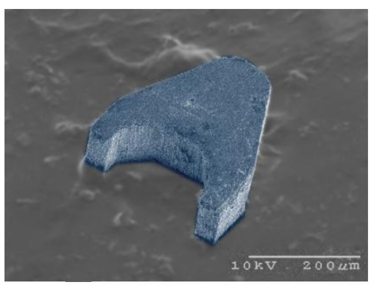


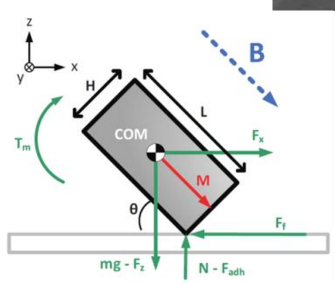
Gradient magnetic field

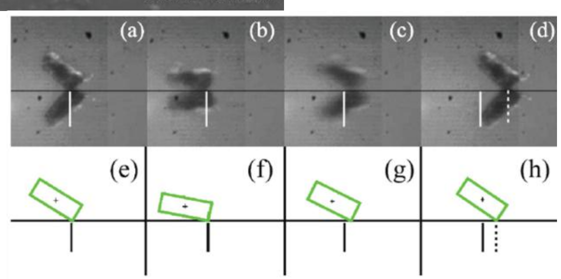
▪ SOA of Cell Manipulation using Electromagnetic Field

M. Sitti (The International Journal of Robotics Research, 2009)

- Driven by an external magnetic field Untethered microrobot
- Micro-robot configuration : Permanent magnets (laser cutting)
- 3 pair Helmholtz coil Moving the two-dimensional plane
- The drive mechanism: Stick–slip motion using linear motion







Rotational magnetic field

http://www.iris.ethz.ch/

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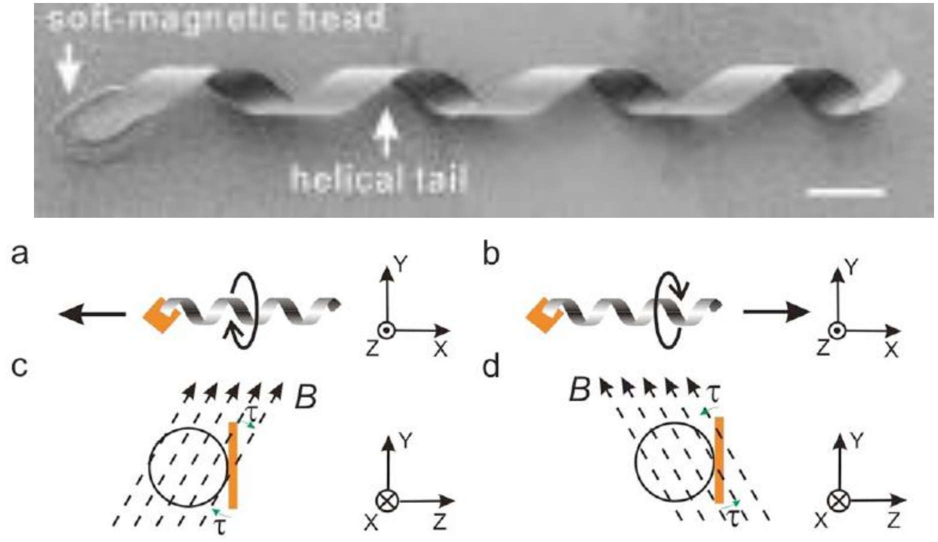
▪ SOA of Cell Manipulation using Electromagnetic Field

B. J. Nelson (Applied Physics Letters, 2009)

- Artificial bacterial flagella
- Micro-robot configuration: Helical tail, soft magnetic head (MEMS Technique)
- 3pair of Helmholtz coil are using to moving in the three-dimensional space
- Drive mechanism: Rotational magnetic field uses linear motion



Magnetic composite body

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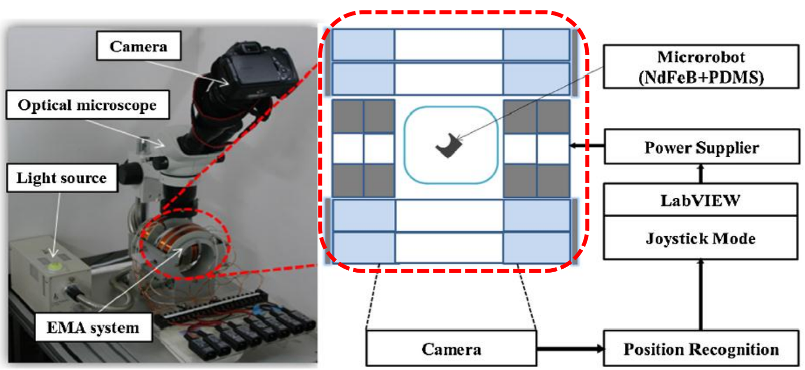
▪ SOA of Cell Manipulation using Electromagnetic Field

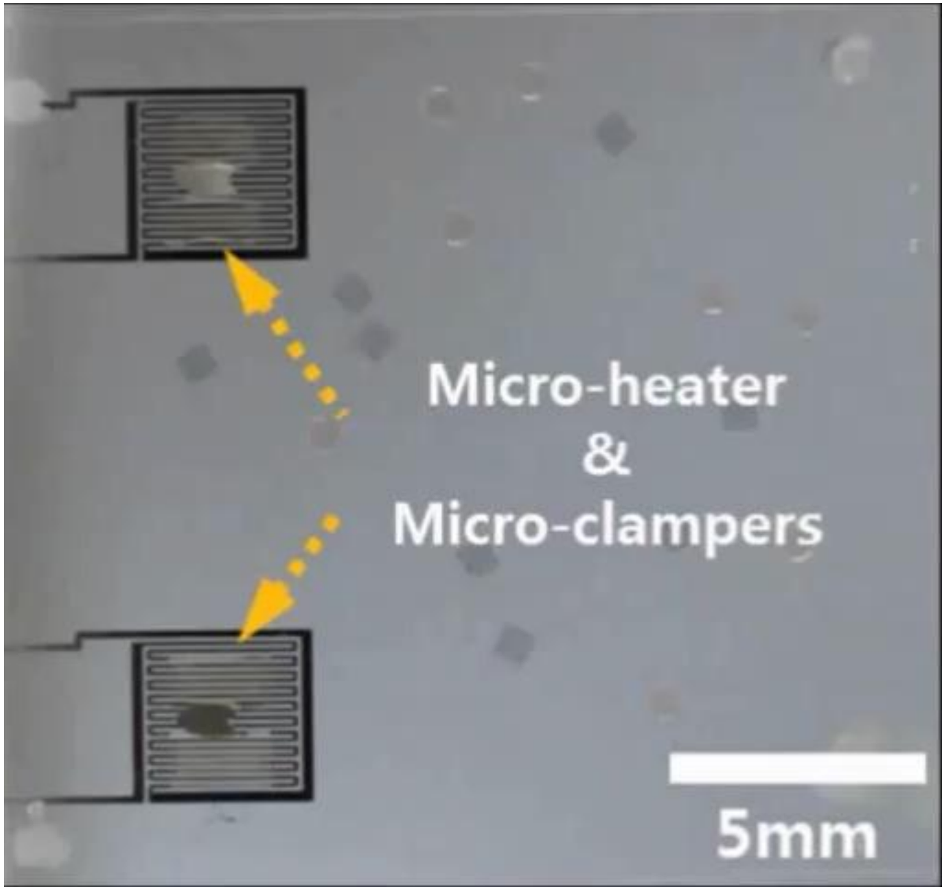
S. Park (Mechatronics, 2013)

- Microrobot Configuration: Magnetic composite body Micro-molding technique
- 2 pair of Helmholtz coil and Maxwell coil uses to move 2 dimensional surface
- Drive mechanism: Magnetic torque & force using linear motion



Manipulation using a multiple micro-robot system

Manipulation of Heterogeneous Micro-particles



Multiple micro-particles manipulation

S. Park (BioRob, IEEE, 2016)

- **Experimental methods**

Two optional powered micro- robots capable Micro-robot: tip : U, V shape

Block : 8 blue square, 8 red disk

- Lithography uses process

A number of the independent operation of the micro-robot Through micro- particles 2-D assembly

Thermally Responsive Micro-clamper

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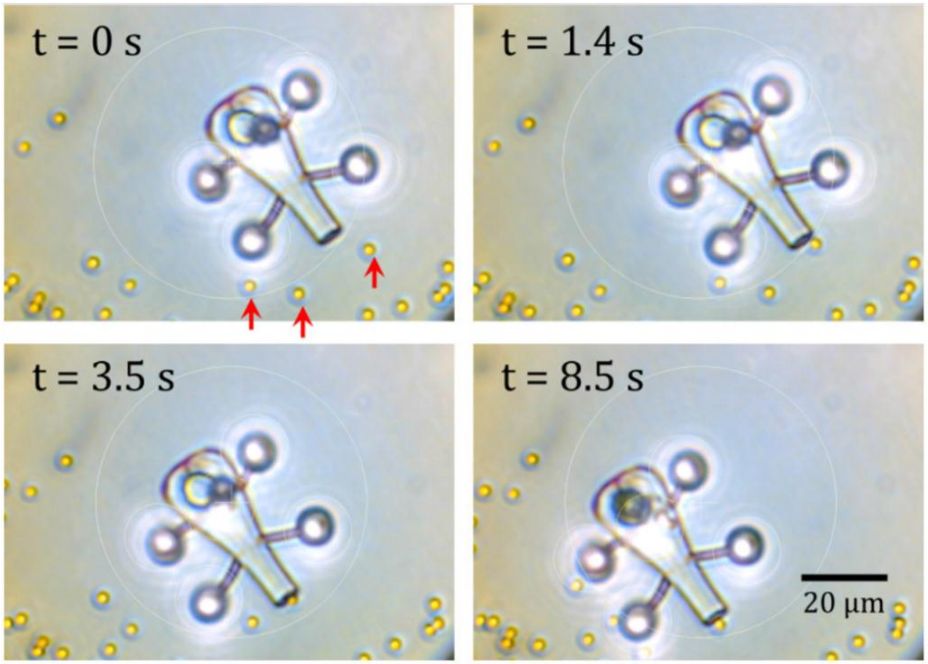
Medical therapies by micro-robot

Light-driven micro-robots

Light-actuated microrobots for biomedical science



1μm-diameter polystyrene beads are loaded inside a micro-robot.

Mask is fabricated on top of the structure to secure exposure of only certain regions by metal-vapor deposition.

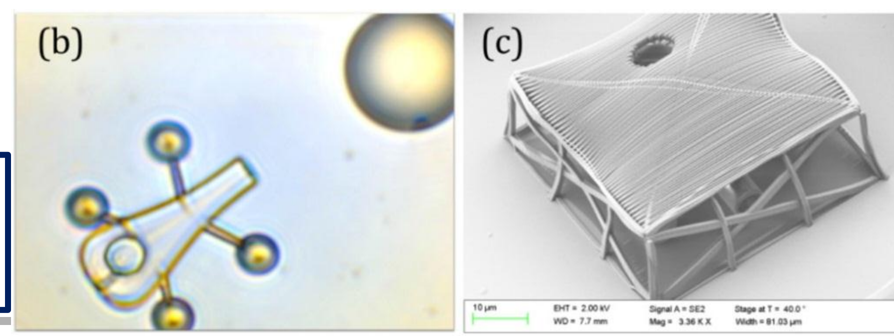
Glückstad, Lasers & Sources, 2017)

- **Experimental methods**

Optical forces are non-invasive and can operate through sealed and sterile biological chambers

Metal-vapor deposition of titanium adhesion and a gold layers (of 1 and 5nm thickness) as a circular disk inside the body of each light robot.

these light robots is practically transparent to the trapping beam wavelength and thus generates very little heat.



Applications in the Eye

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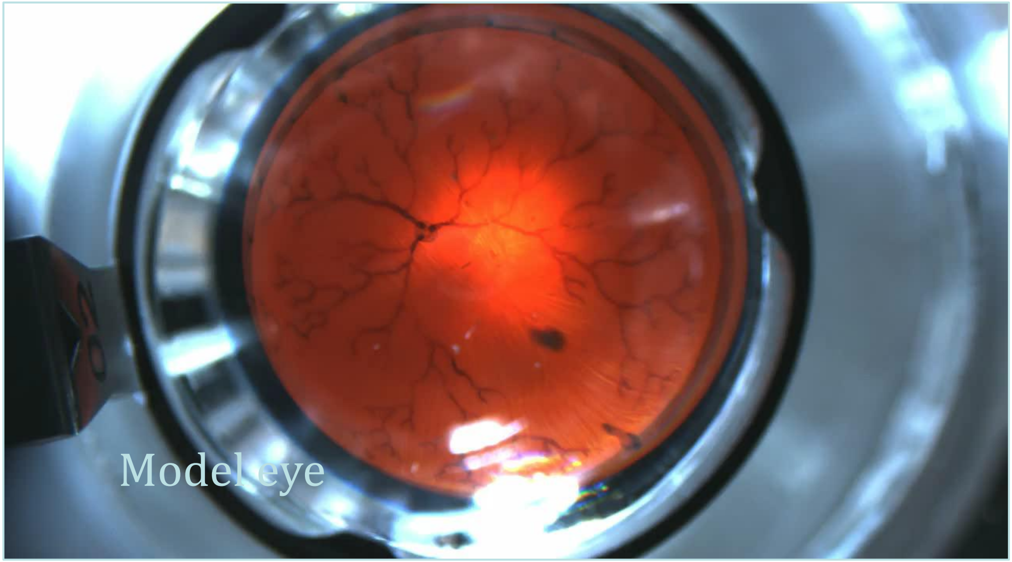
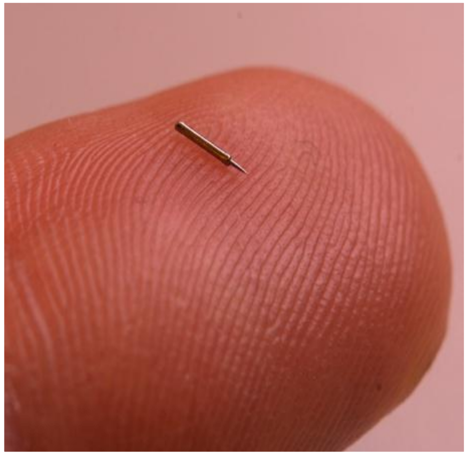
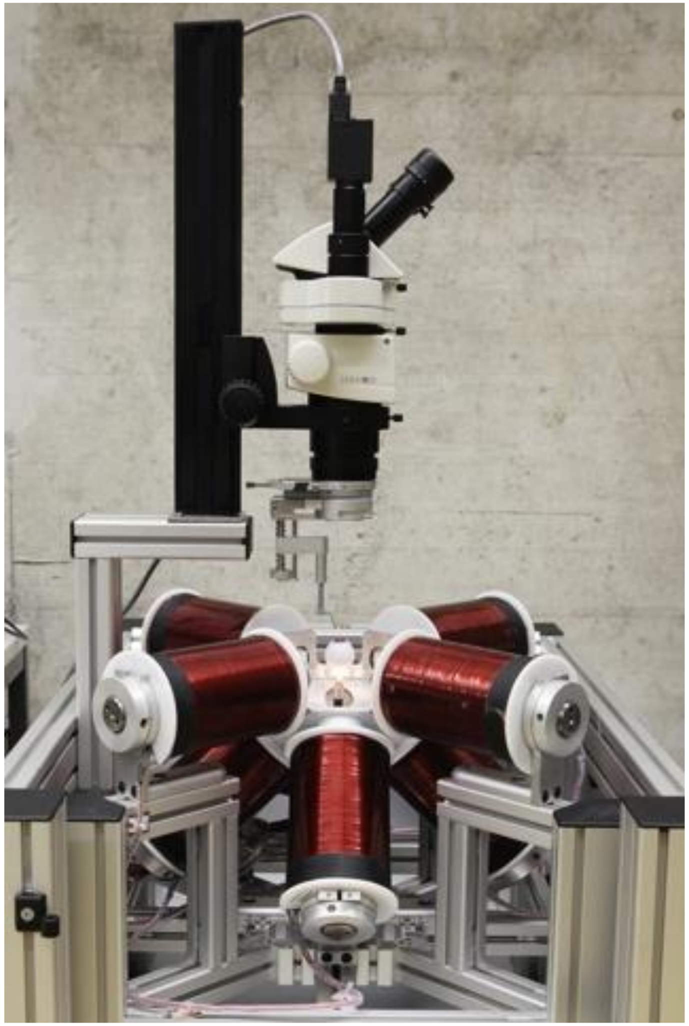
Experiments in the laboratory

IRIS
Institute of Robotics and Intelligent Systems







“Bacteria swim by rotating their flagella filaments” (1973, Berg)

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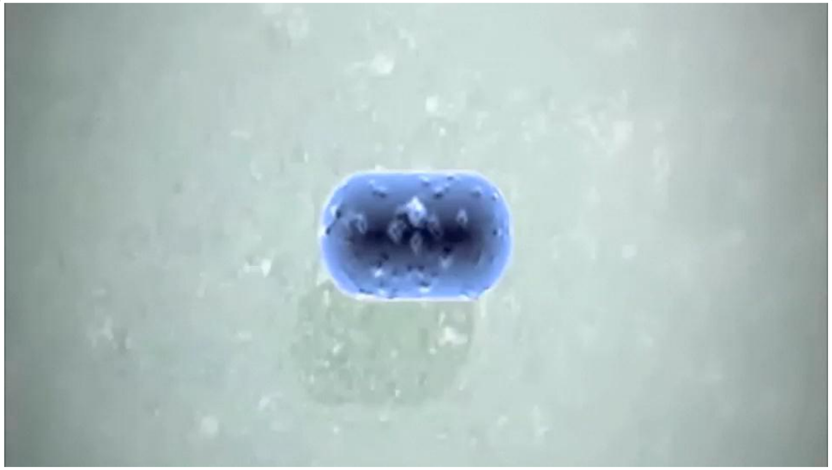
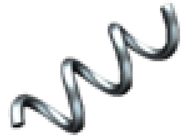
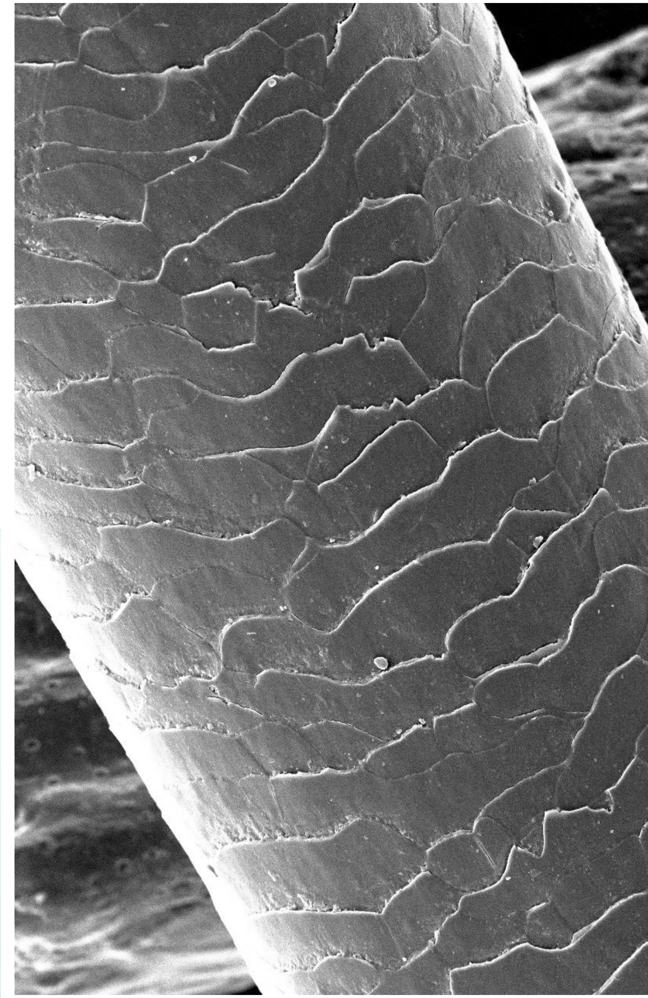


Micro-robot



Red cell: 8µ



Artificial Bacterial Flagella

50 µm


GUINNESS WORLD RECORDS

CERTIFICATE

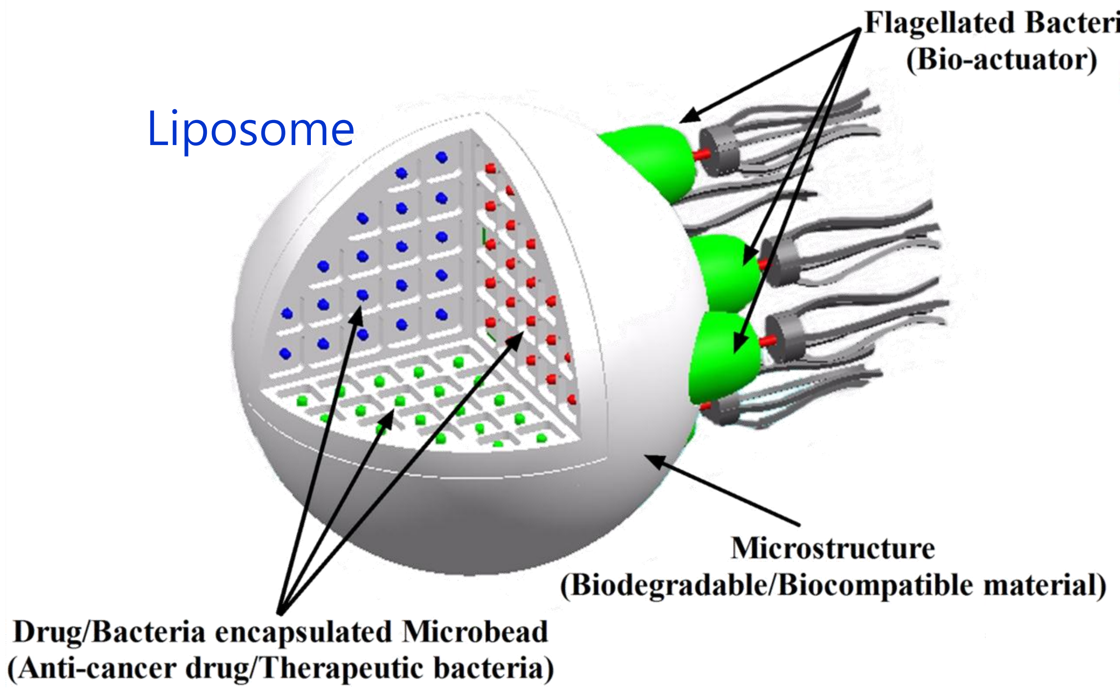
The smallest robotic medical device is a micro-robot, measuring 60 µm in length. It was created by scientists at Zurich's Federal Institute of Technology (Switzerland) in April 2009

GUINNESS WORLD RECORDS

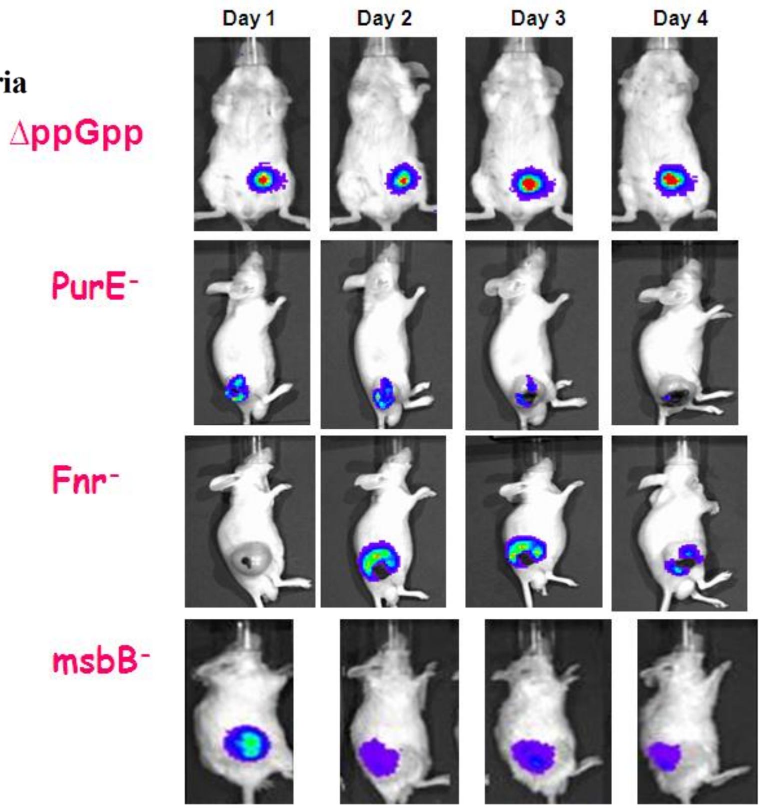
IRIS

Institute of Robotics and Intelligent Systems

Active targeting therapeutic bacteria-based micro-robot Using liposomes



Concept of bacteria-based microrobot



nonpathogenic/attenuated bacterial strain

mm Robot Capsule Endoscope Robot (active)

Endoscope

- Pain and infection

Passive capsule endoscope

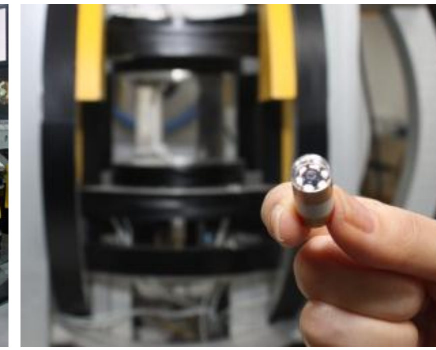
- Small intestine diagnosis only
- Time required 24 hours

Active capsule endoscope

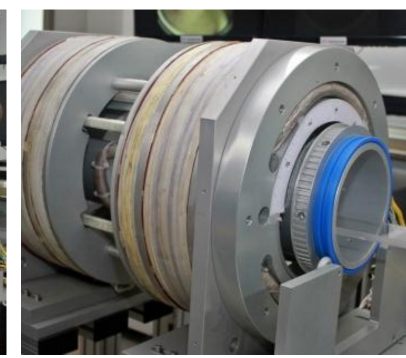
- Pre-digestive target
- Diagnosis and treatment function
- Time required 20 minutes

Active capsule endoscope

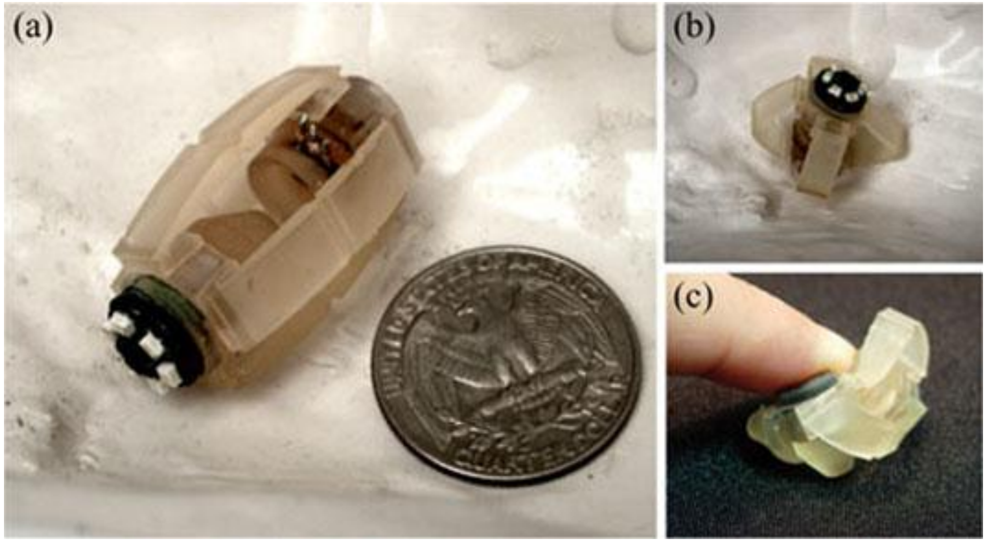
Prototype I

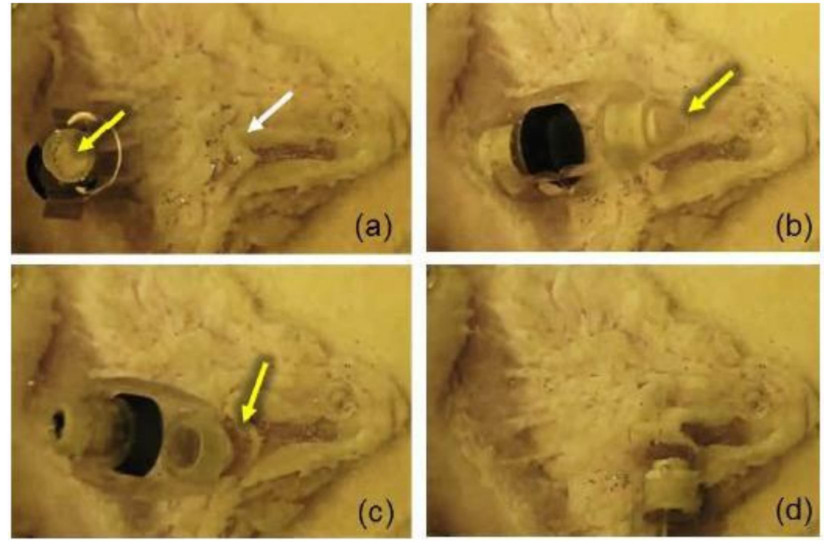


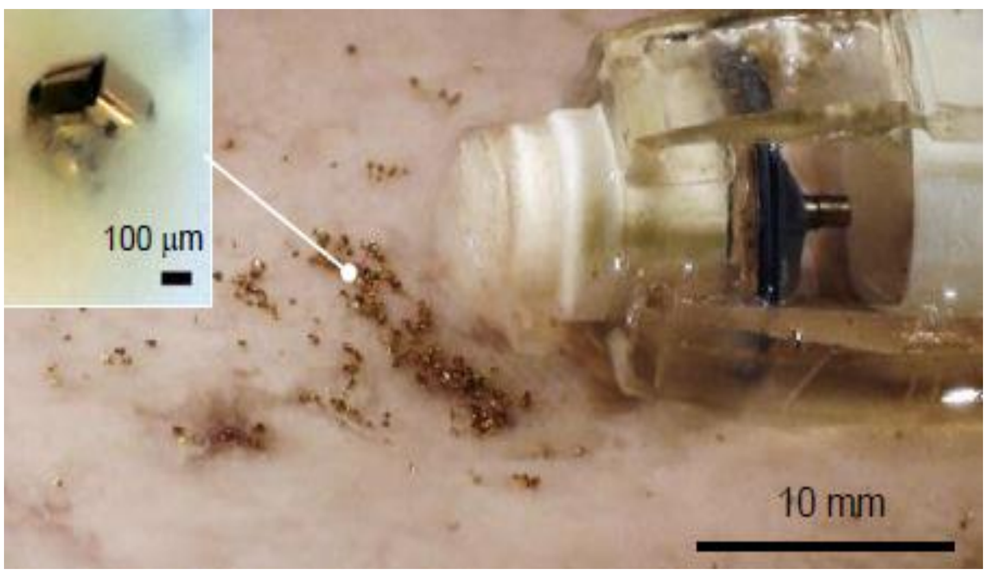
Prototype II



Magnetic Capsule Endoscope





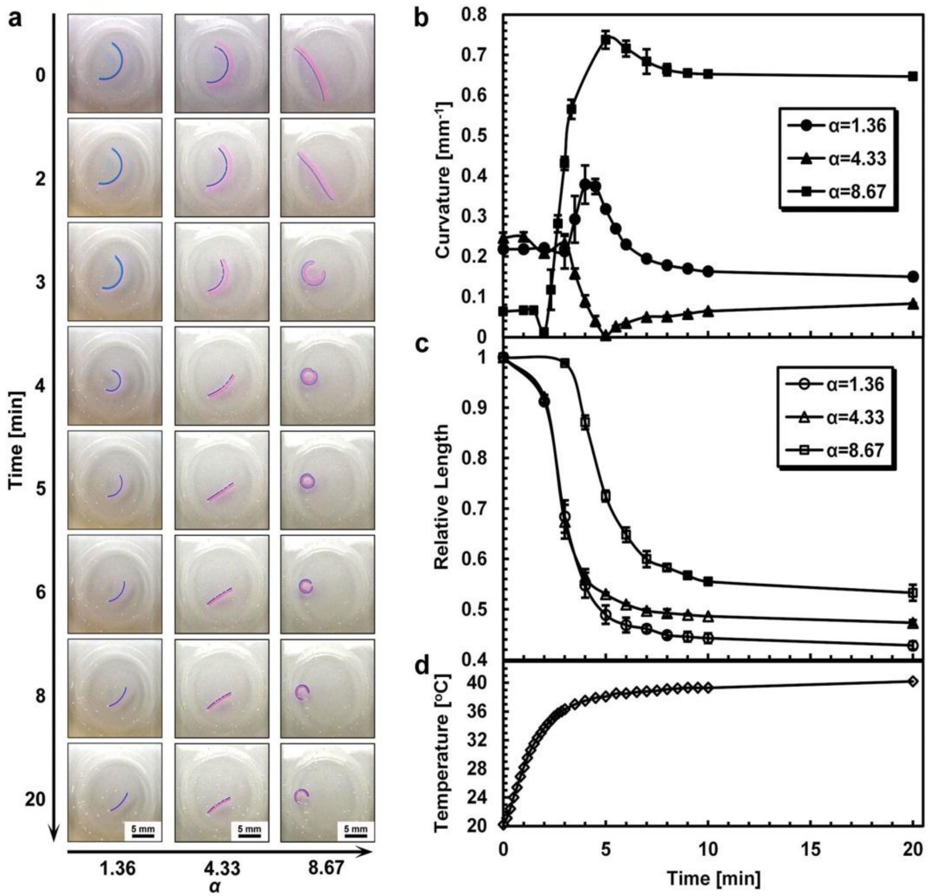


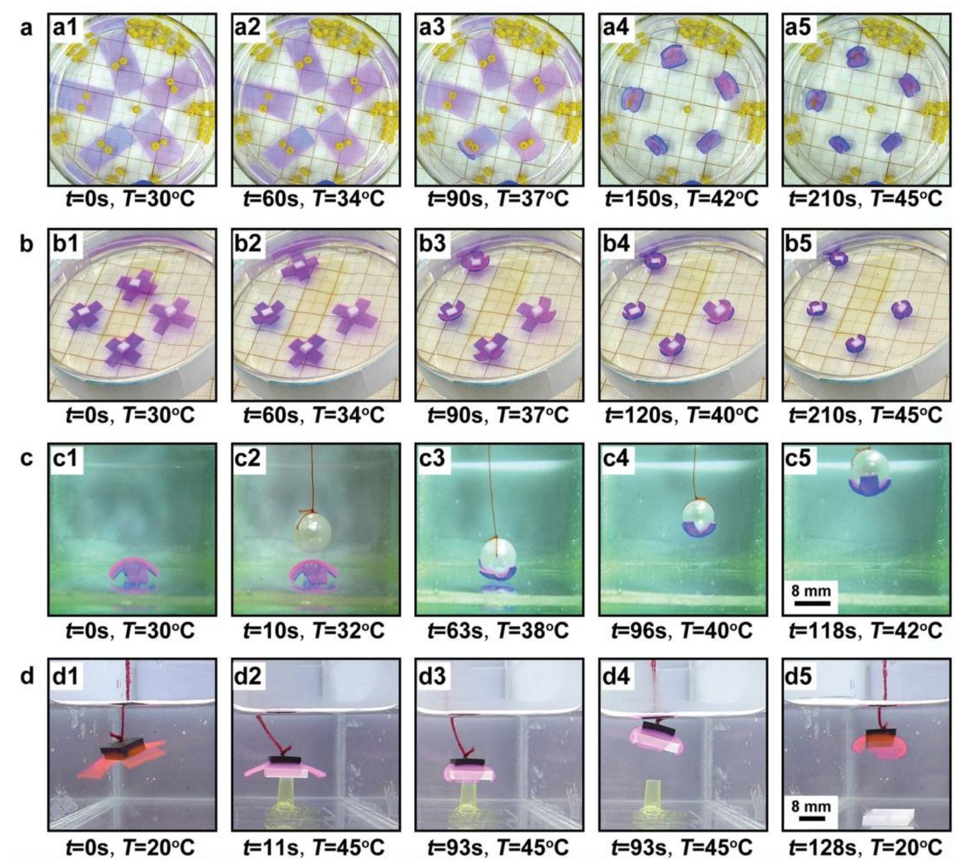
S. Yim and M. Sitti, "Design and rolling locomotion of a magnetically actuated soft capsule endoscope," IEEE Trans. Robotics, vol. 28, no. 1, pp. 183–194, 2012.

Bending and elastic properties

Poly(N -isopropylacrylamide)-clay (PNIPAM-clay) nanocomposite (NC) hydrogels with both excellent responsive bending and elastic properties are developed as temperature-controlled manipulators.

University Chengdu , Sichuan 610065 , P. R. China
Adv. Funct. Mater. **2015**, *25*, 2980–2991





3D Locomotion with polymer material

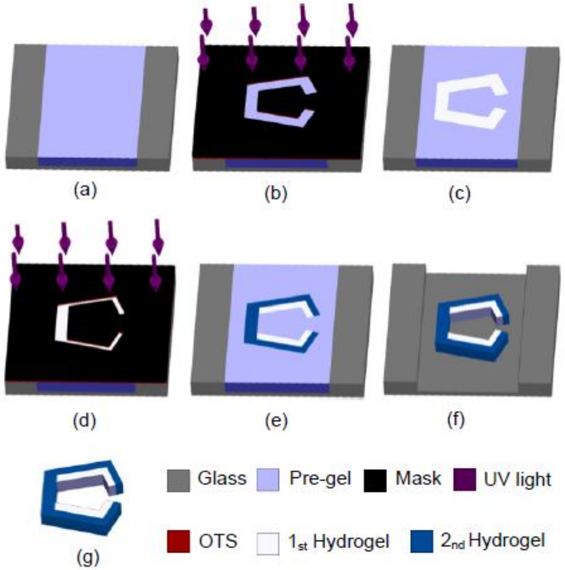
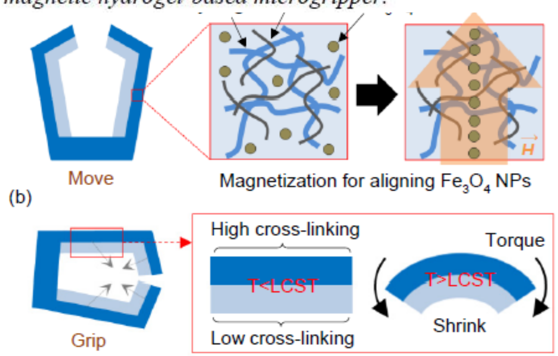
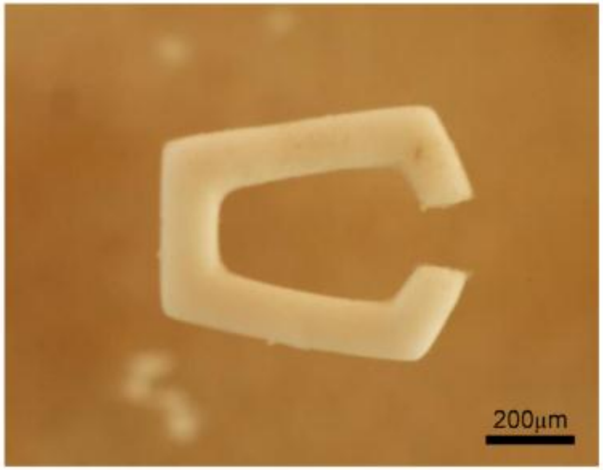
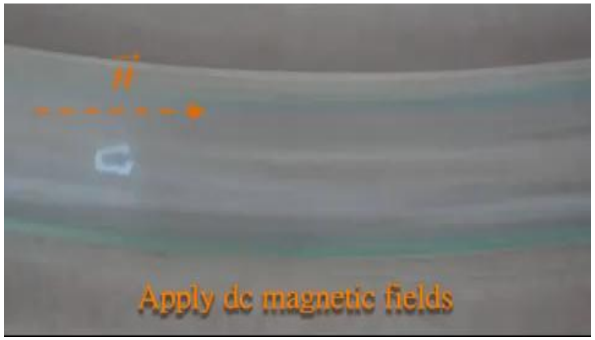
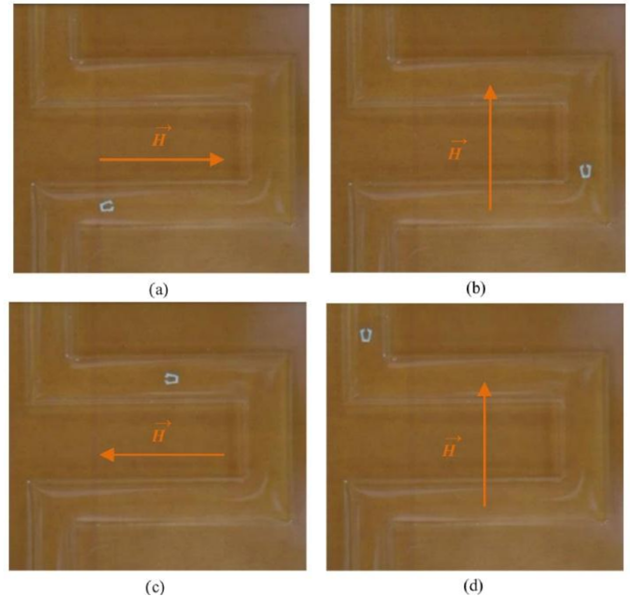


Figure 3: The fabrication processes of the proposed magnetic hydrogel-based microgripper.

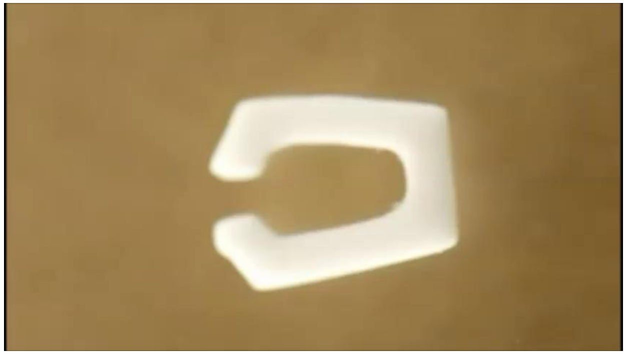








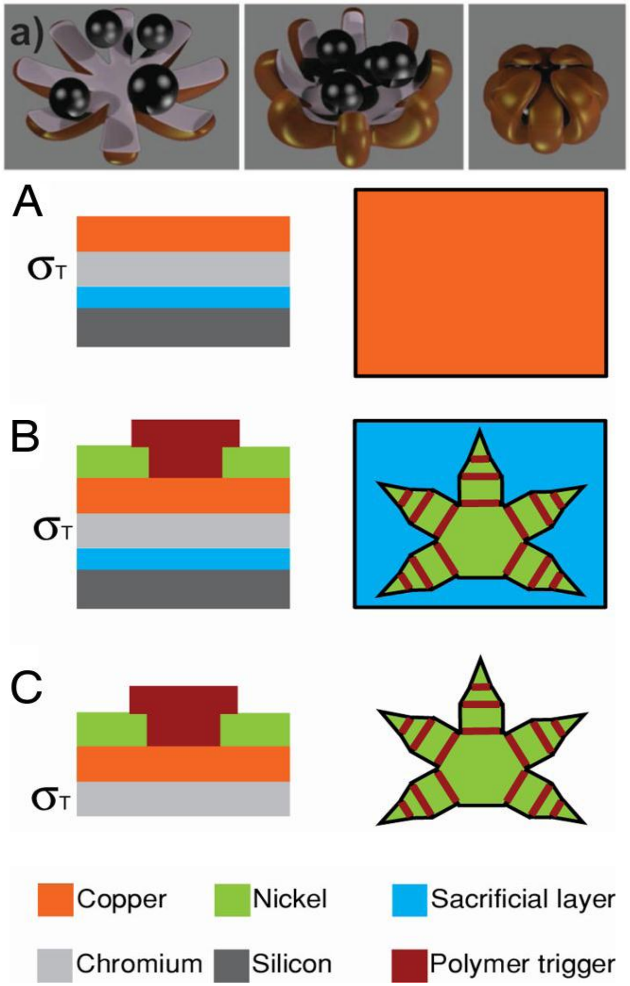
Temperature controller:
Alternating magnetic field (AMF)

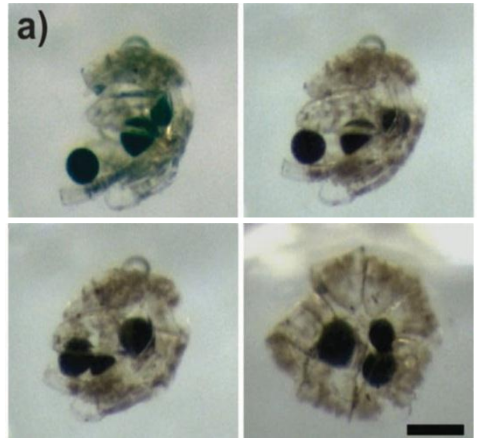


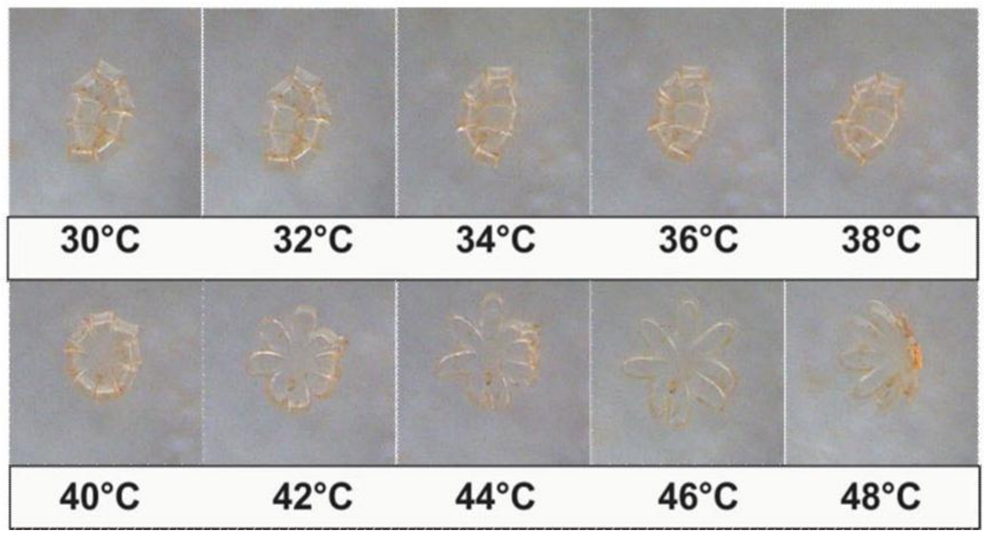
J.C. Kuo, S.W. Tung, and Y.J. Yang, "A hydrogel-based intravascular micro-gripper manipulated using magnetic field," The International Conference on Solid-State Sensors, Actuators and Microsystems, 2013, National Taiwan University, TAIWAN.

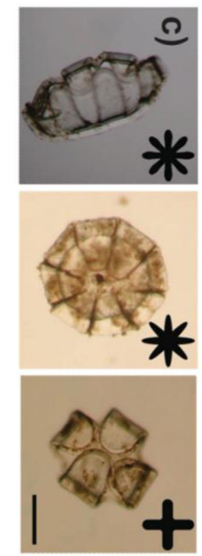
3D Locomotion and folding

Temperature controller: Near-infrared light (NFR)



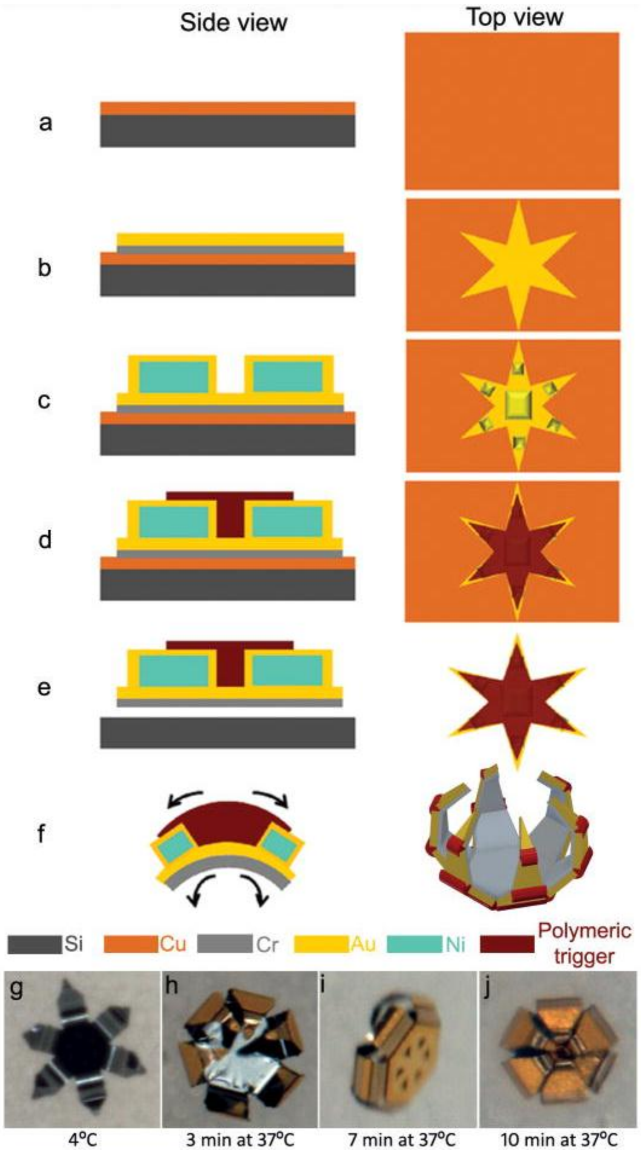






S. Fusco, M. S. Sakar, S. Kennedy, C. Peters, R. Bottani, F. Starsich, A. Mao, G. A. Sotiriou, S. Pané, S. E. Pratsinis, D. Mooney, B. J. Nelson, "An Integrated Microrobotic Platform for On-Demand, Targeted Therapeutic Interventions," Advanced Material, 2014, ETH Zurich , Zurich, Switzerland.

Self-folding devices with biopsy capability



SELF-FOLDING THERMO-MAGNETICALLY RESPONSIVE SOFT MICROGRIPPERS

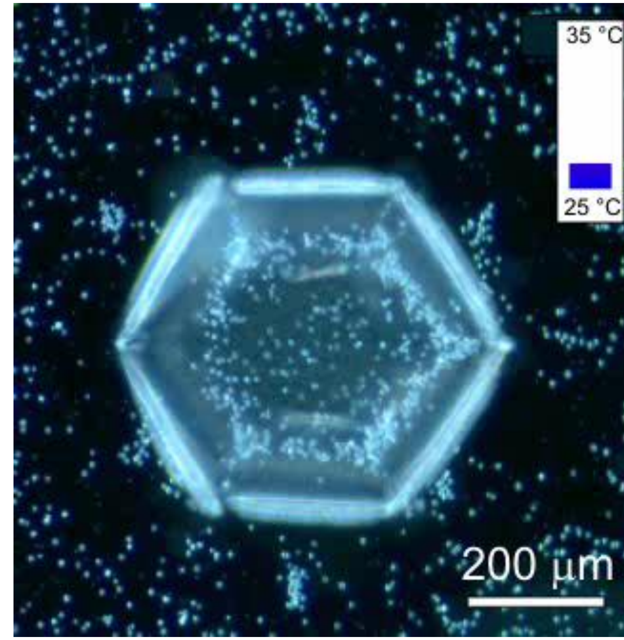
The Johns Hopkins University in Baltimore, MD, a team working in a new area called soft robotics is developing tiny, self-folding devices that could one day be used to perform biopsies or precisely deliver drugs inside living tissue.

Source: http://www.medicalnewstoday.com/articles/289078.php

ACS Appl Mater Interfaces 2015 Feb 28

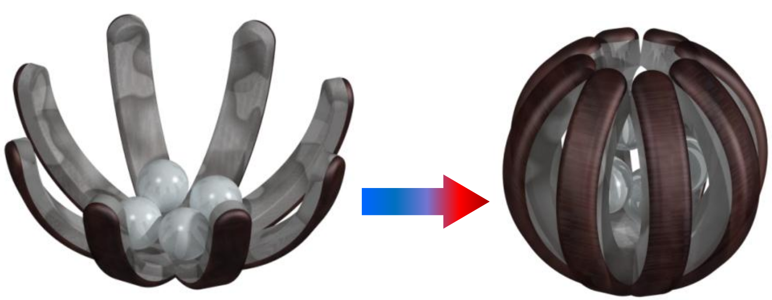
Drug-load Bead Trap with Electromagnetically actuated ability

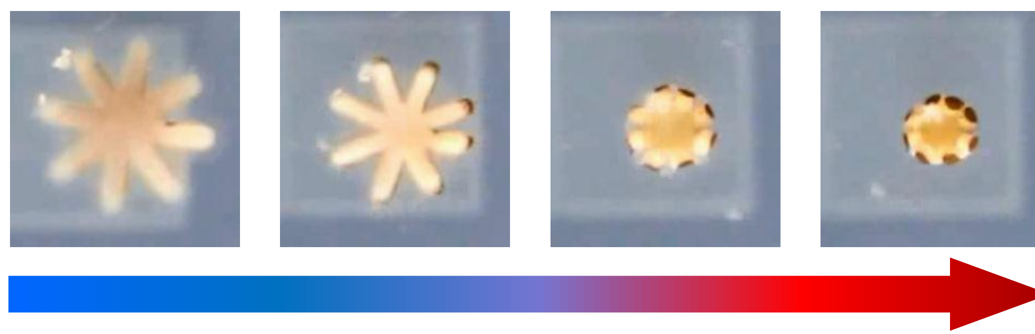
Programmable Self-folding Micro-robot with Electromagnetically Actuated Ability



Self-folding Micro-robot
- Bilayer (NIPPAM, PEG-DA)
- Shape change with temperature

Application
- Tissue engineering
- Micro-particle assembly
- Drug & cell delivery





Reference temperature = 33℃

3D Locomotion System with HC and MC

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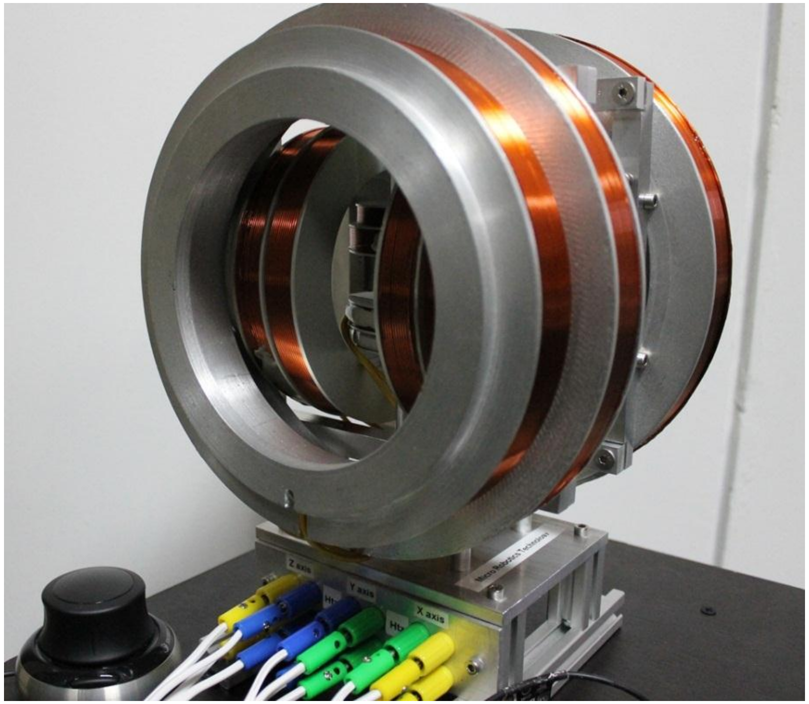
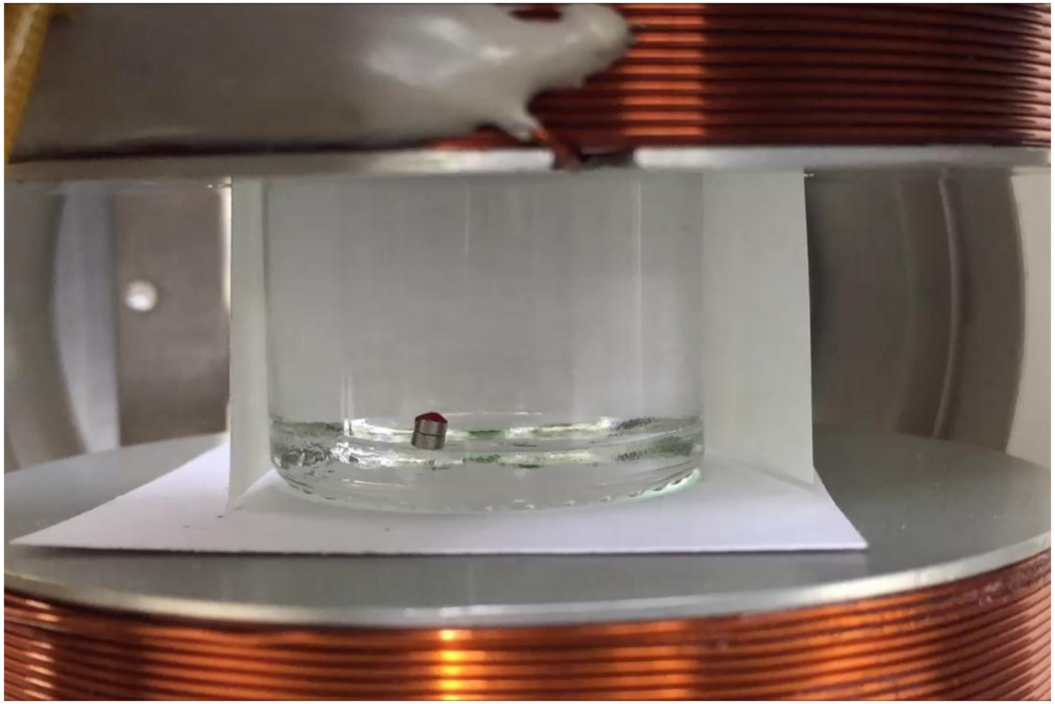
- 3D EMA system with 2-pair Helmholtz and Maxwell coils on each axis.
  - Composition: 3D Fixed HC, MC.
  - Characteristic: 3D driving and alignment direction
  - Advantage: HC and MC are suitable for 6DOF for rotation and pulling.



Local EMA manufactured system



Nueva Granada Military University of Colombia

2D Autonomous motion with HC and MC

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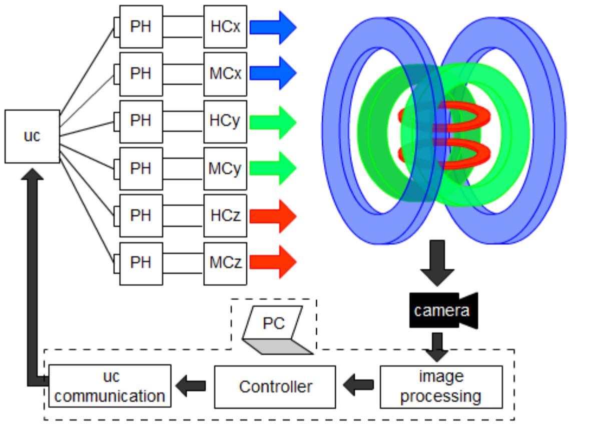
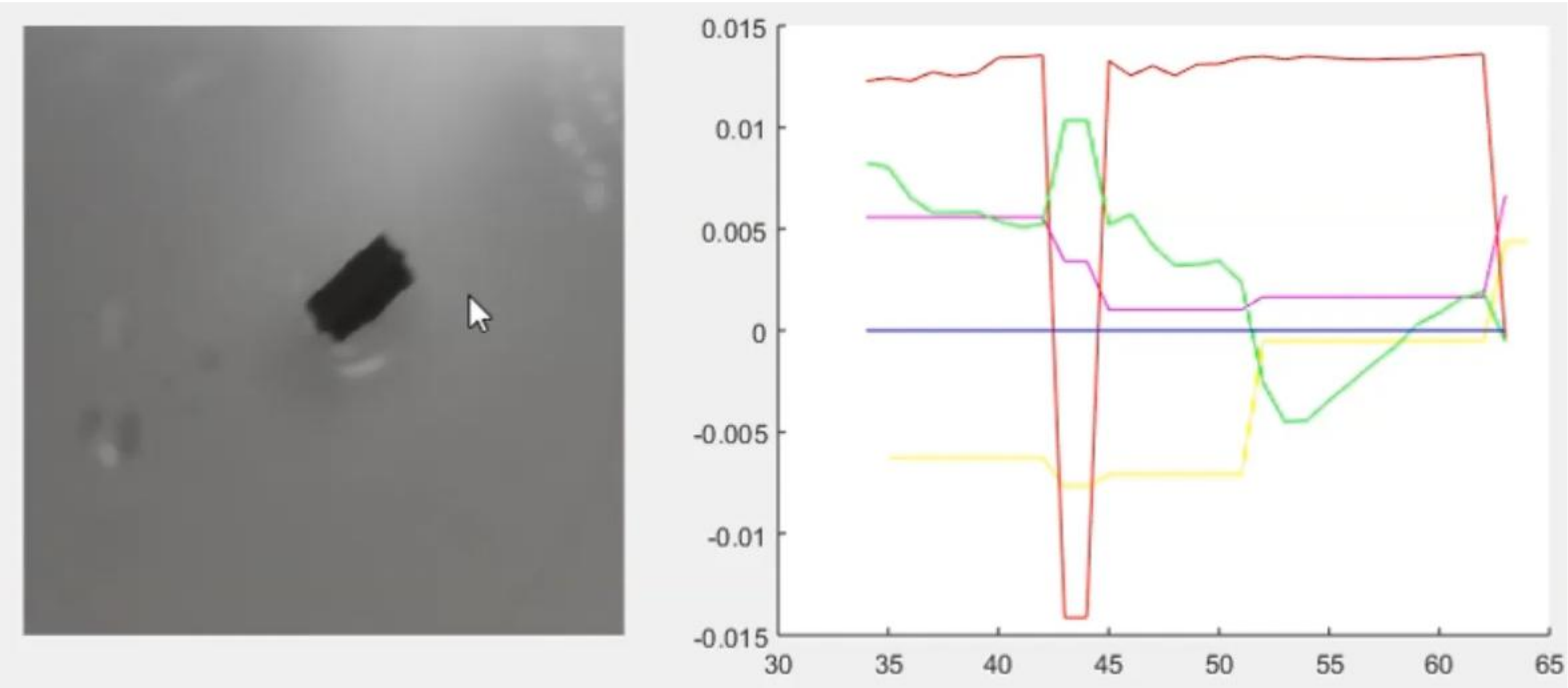
Autonomous control of
Micro-robot



3D EMA system with 2-pair Helmholtz and Maxwell coils on each axis.



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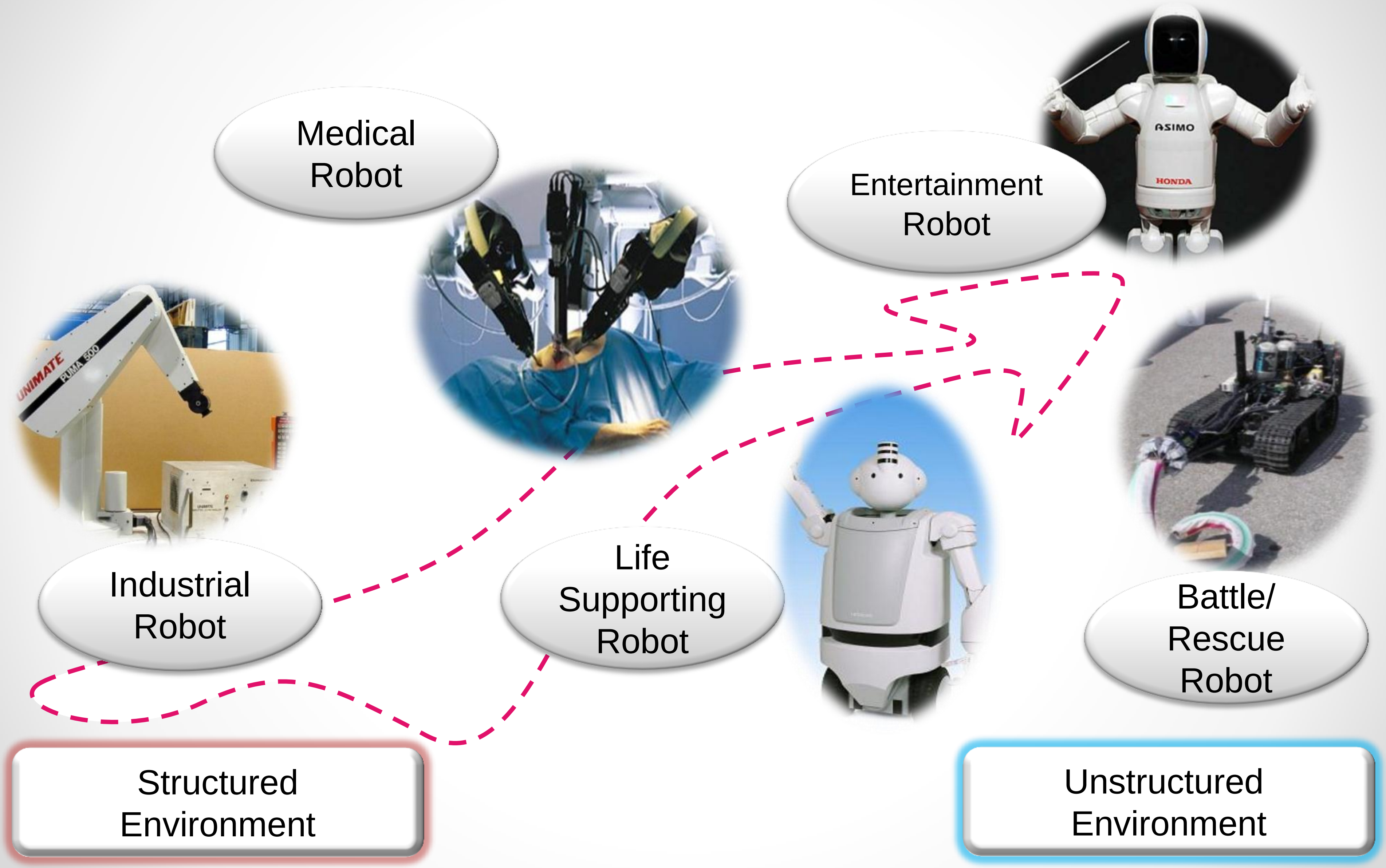
Macro-Surgical Robots

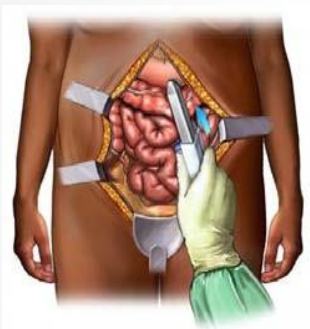
and Devices

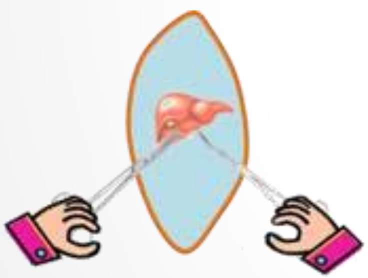
Tendency of Robotic Systems



Development of Surgical Robotics and Devices

Open Surgery





Open Space

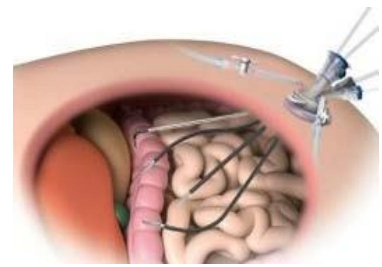
MIS

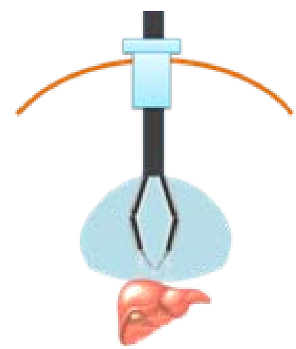
Minimally Invasive Surgery

Enough Space

SILS

Single Incision Laparoscopic Surgery

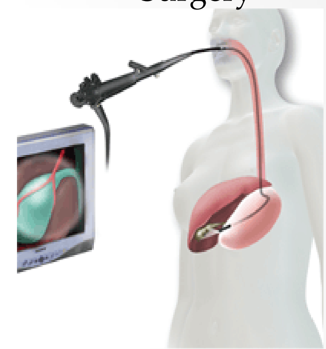


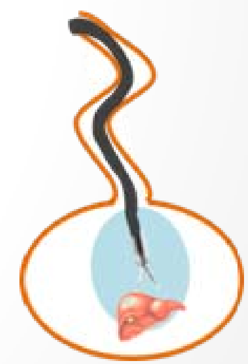


Extended Space

NOTES

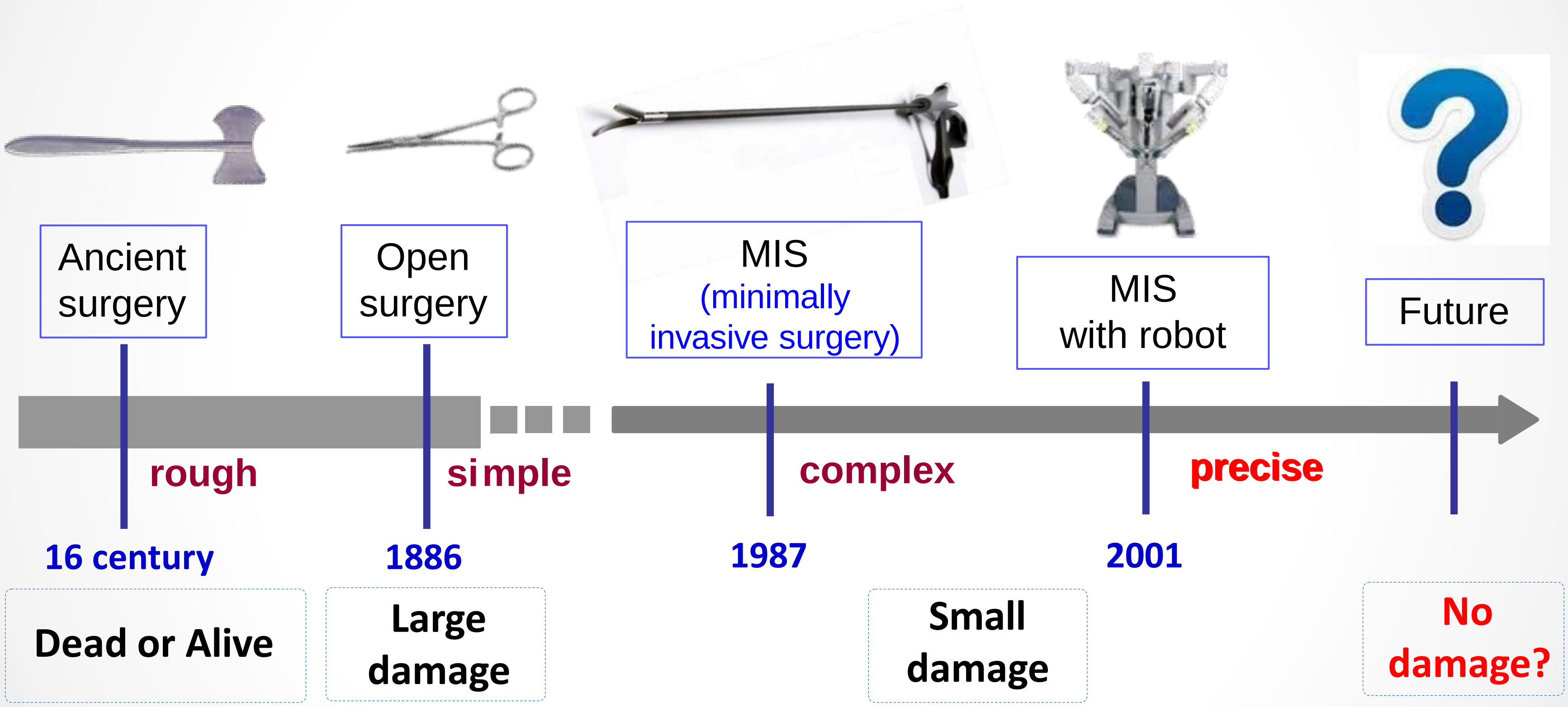
Natural Orifice Transluminal Endoscopic Surgery



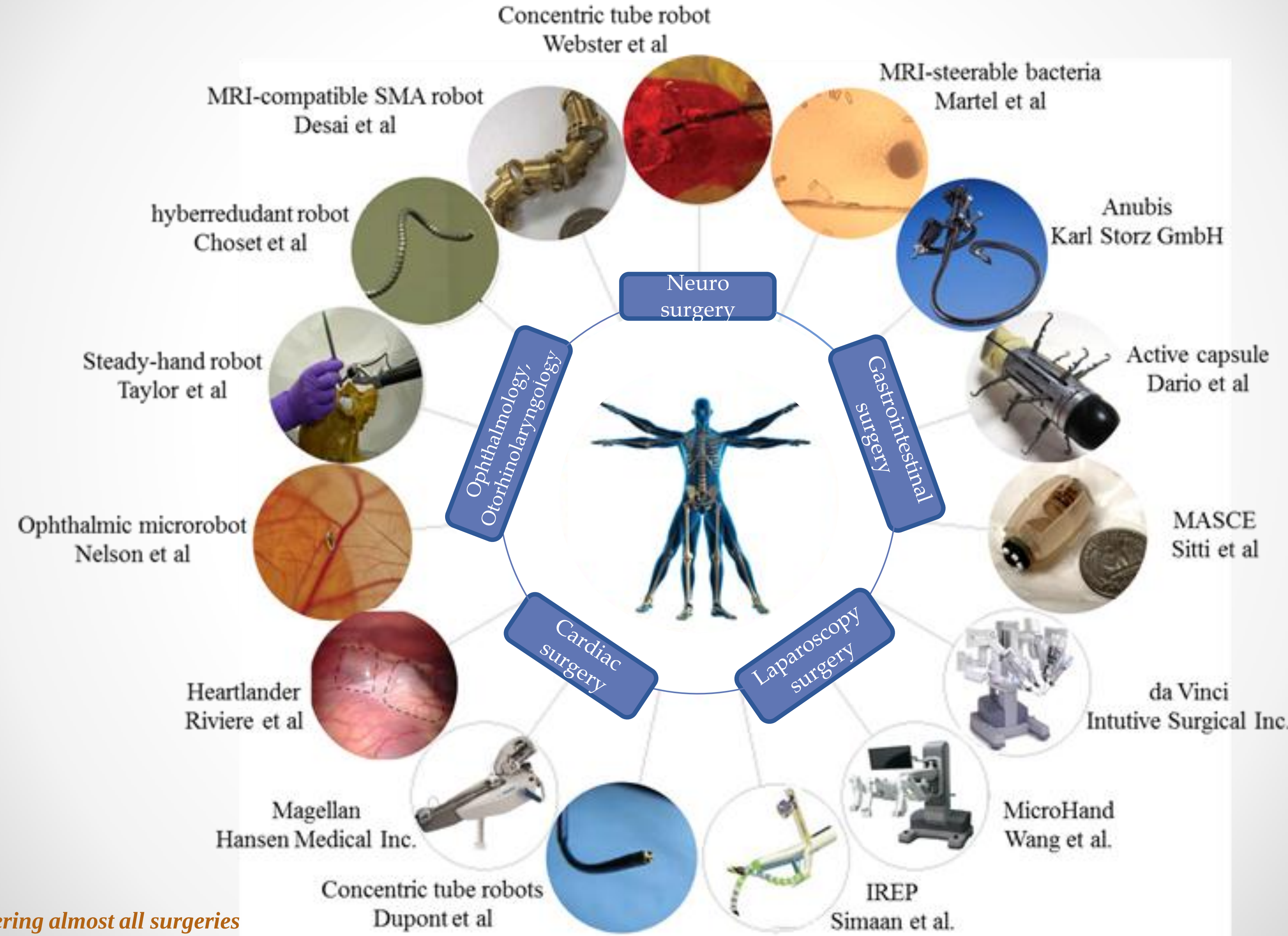


Curved Space

Development of Surgical Robotics and Devices



Development of Surgical Robotics and Devices

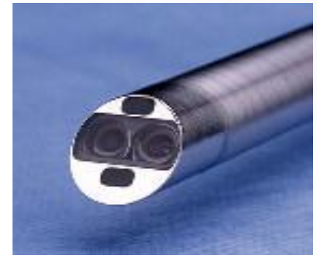


Covering almost all surgeries

Da Vinci System – Laparoscopic Surgery Robot

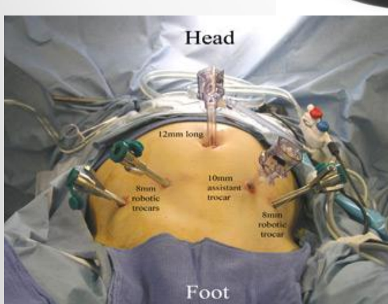
Master Console

InSite High Resolution
3D Endoscope



Surgical Arm Cart

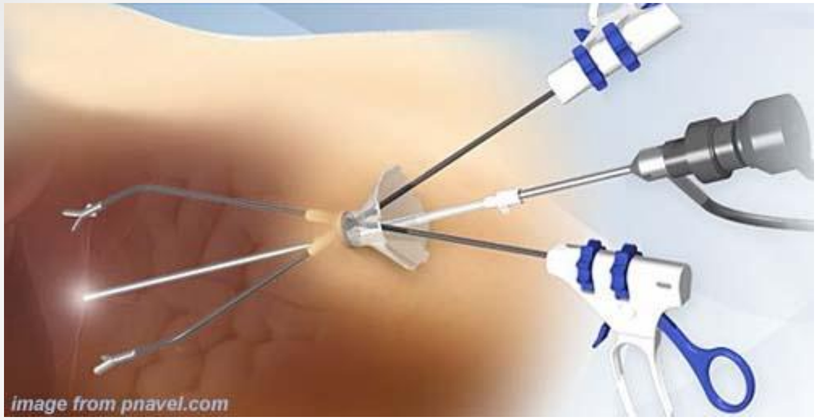
Surgeon Console

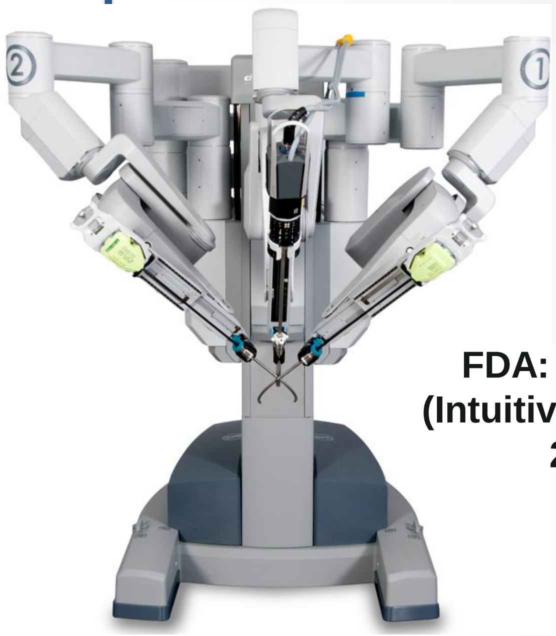


EndoWrist Instruments

Minimally Invasive Surgery (MIS) :

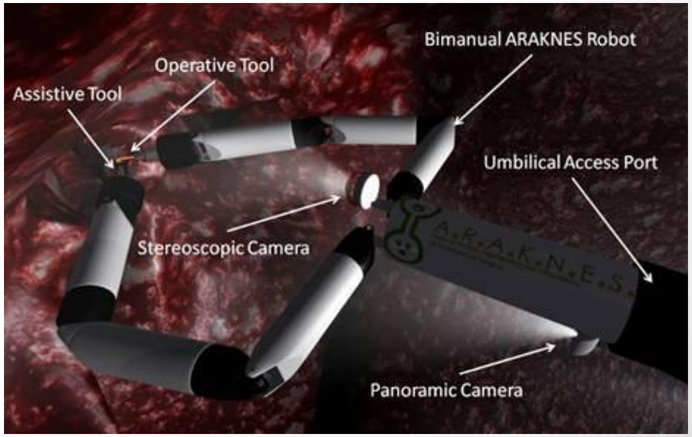
Single Port Laparoscopic Robot





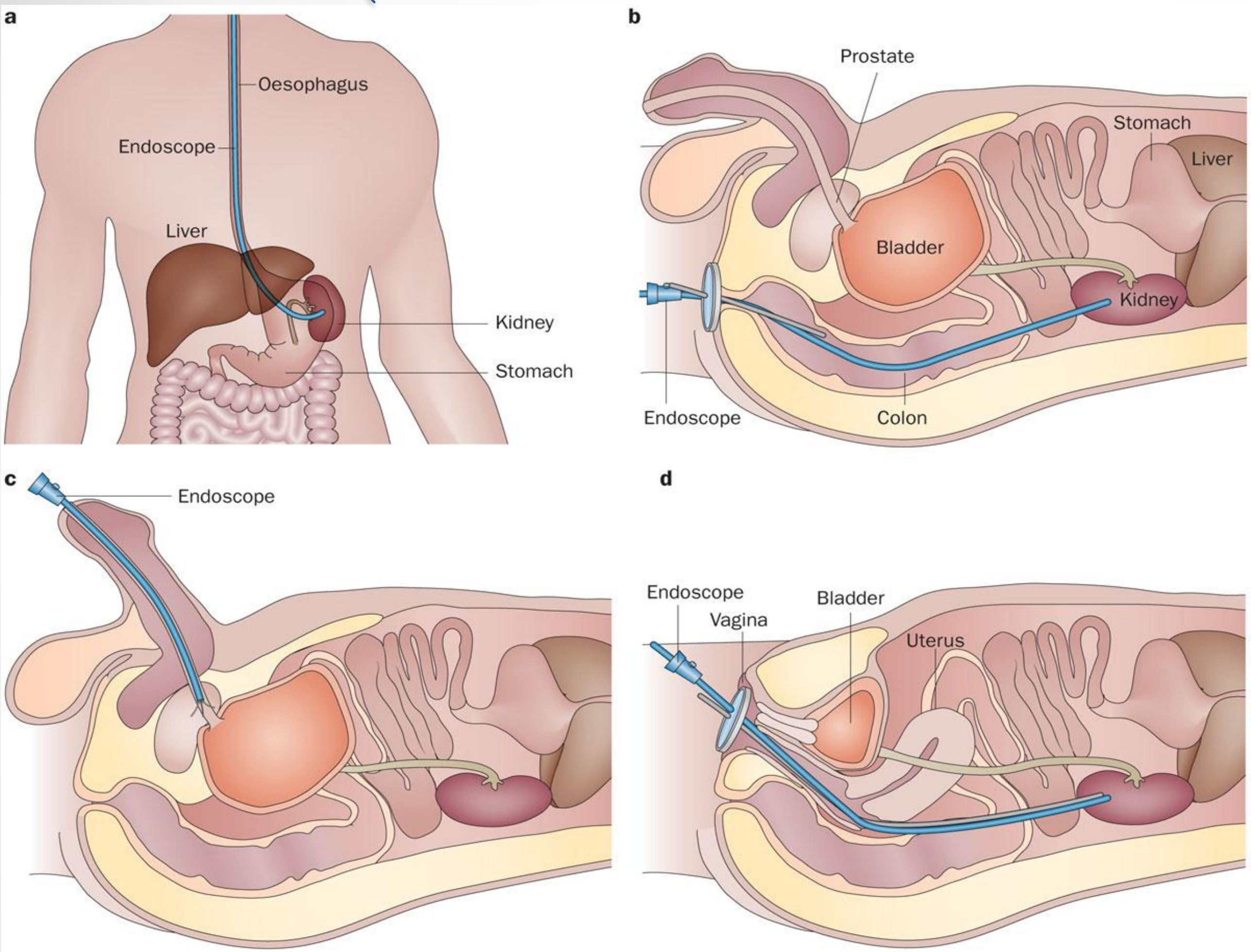
FDA: Da Vinci (Intuitive Surgical), 2011

SPIDER (TransEnterix)

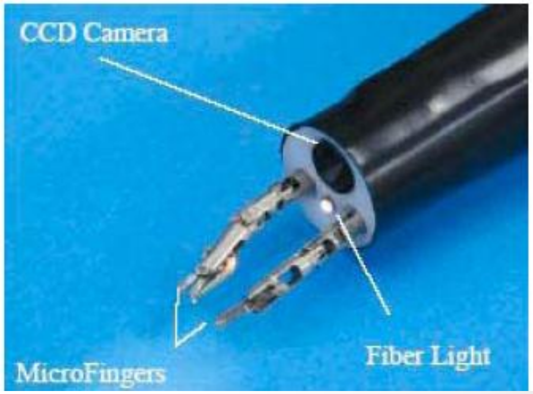


ARAKNES (Scuola Superiore Sant'Anna)

NOTES? (Natural Orifice Transluminal Endoscopic Surgery)

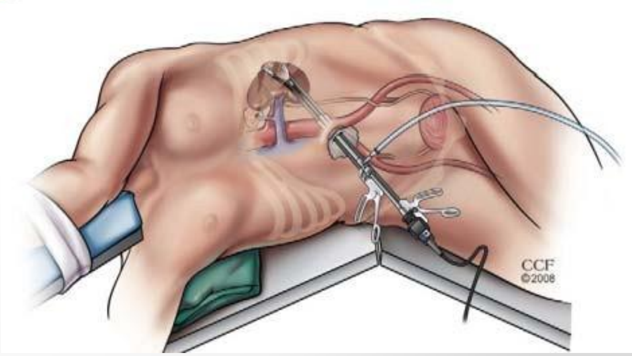


(Hitachi) 2000



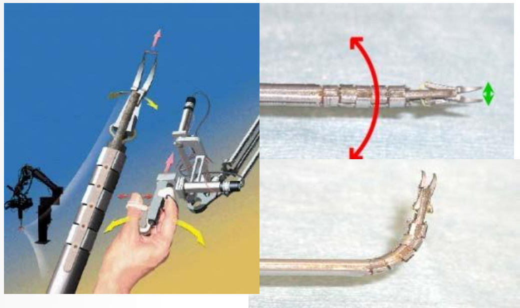
(Nagoya Univ) 2004

Tyson, M. D. & Humphreys, M. R. (2014) Urological applications of natural orifice transluminal endoscopic surgery (NOTES); *Nat. Rev. Urol.* doi:10.1038/nrurol.2014.96



Development of Surgical Robotics and Devices

MM-1 Tokyo University, Japan

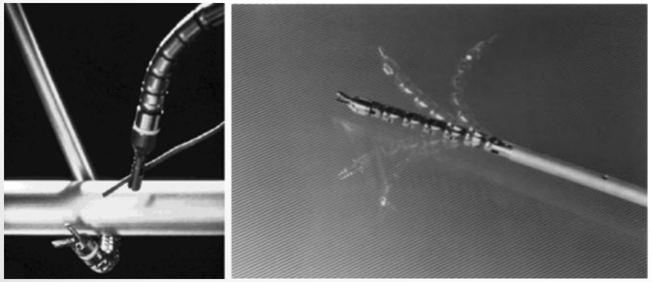


- **Diameter：** **5 mm**
- **DOF：** **6**

Cardioarm Cardiorobotics and Carnegie Mellon University, USA

- **Diameter：** **10mm**
- **DOF：** **snake-like**

ARTEMIS Karlsruhe Research Centre, Germany

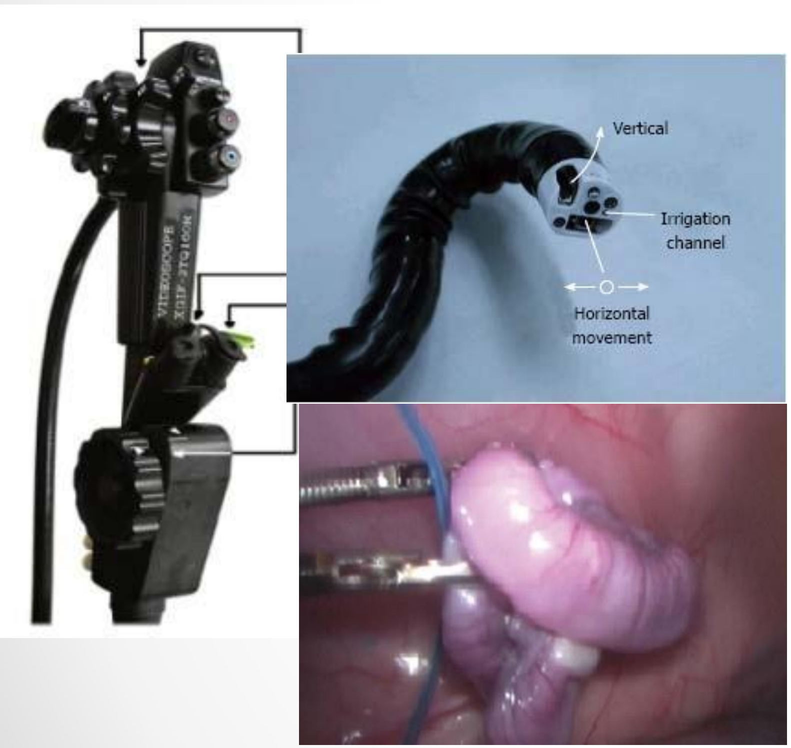


- **DOF：** **6**
- **Diameter：** **10mm**

Development of Surgical Robotics and Devices

NOTES/R-scope

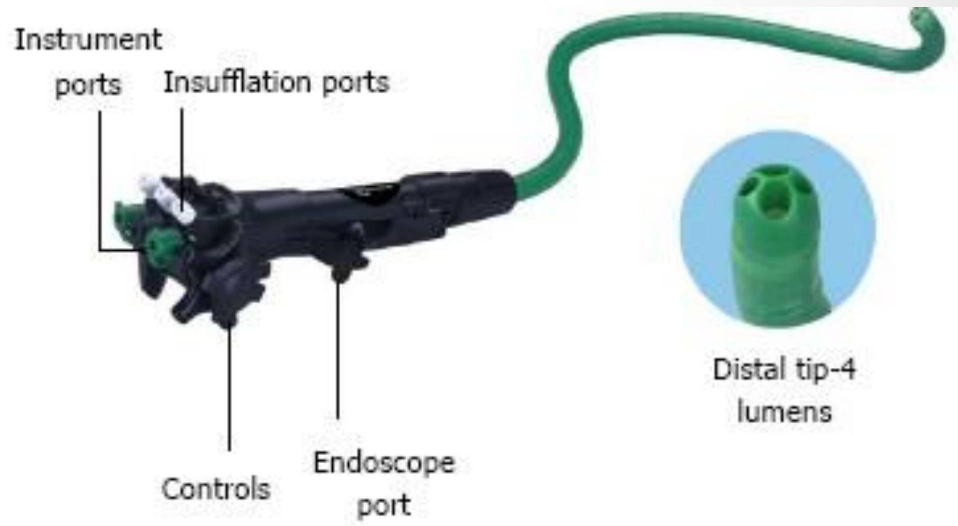
Penn State Hershey Medical Center, Hershey, Pennsylvania, USA.



- **Operation:** **Manual**
- **Size:** **130cmx11.7mm**

TransPortTM

USGI Medical, San Capistrano, CA



- **Operation:** **Manual**
- **Size:** **110cmx18mm**
- **Channel:** **4 (7mm,6mm,4mm,4mm）**

Development of Surgical Robotics and Devices

Cardioarm

**Cardiorobotics and Carne
gie Mellon University**

- **Diameter:** **10mm**
- **DOF:** **Snake-like**

DDES

Boston Scientific Inc. USA

- **Channel：3个(6mm,
4mm,4mm) Size：16**
- **x22mm； Length：**
- **55cm**

Development of Surgical Robotics and Devices

MicroHand System for MIS

Tele-surgery

Companion RP-6 robot (InTouch Health, Goleta, CA, USA), 2002

Healthcare through a "Remote Presence" Robot, RP-6: the doctor is projected to another location where the patient is located

RP-7 robot (InTouch Health, Goleta, CA, USA)

Tele-surgery

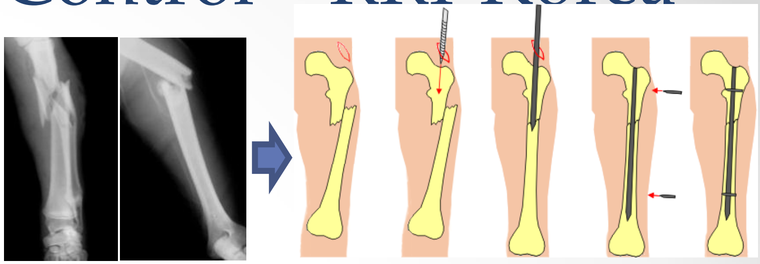
- **Applications:**
  - Patient in remote or non accessible locations
  - Tele-mentoring for education and training
  - Telesurgery in the battlefield
  - Telesurgery in space
    - Several projects: ROTEX & ROKVISS projects (DLR), SRI M7 robot,…

DARPA Project (BioRobotics Lab., Washington Univ., Seattle, US)

M7 robot (SRI , Stanford, USA): micro-gravity experiment in the NASA C-9 airborne parabolic lab.

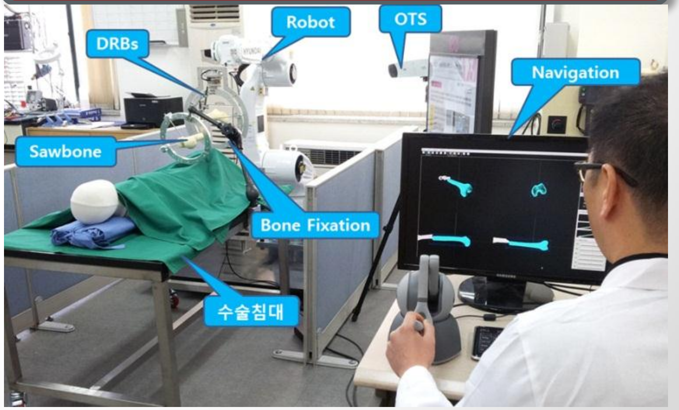
Joint Surgery Robot Intelligence Control – RRI-Korea

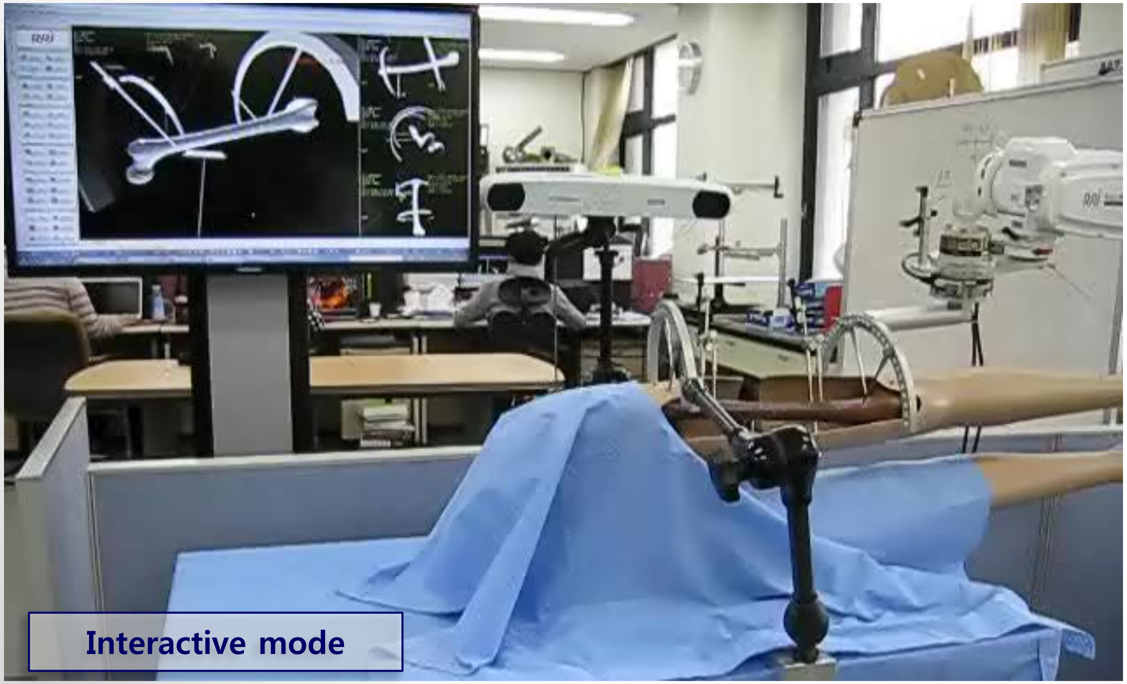
- Core haptic technology and remote control technology
- Master-slave remote control technology
- Force echo technique of two-way remote control
- **F/T** Sensor based force echo technology and safety control
- Direct intervention of physician
- Restriction of robot movement



Interactive mode

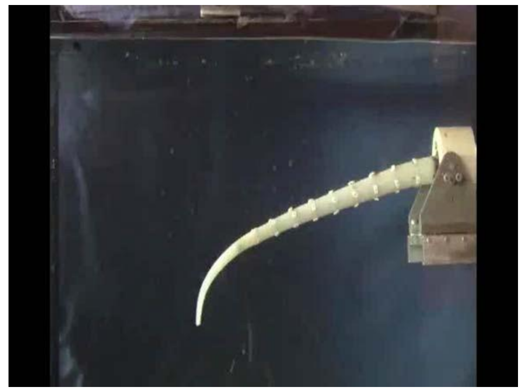
Remote mode





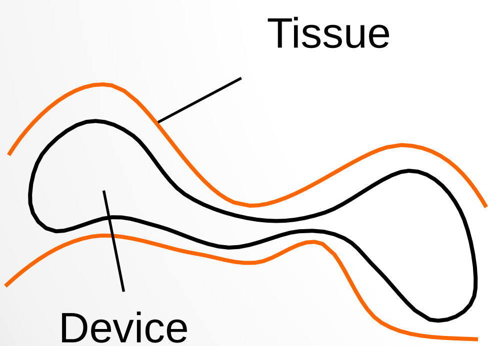
Future of Surgical Robotics and Devices

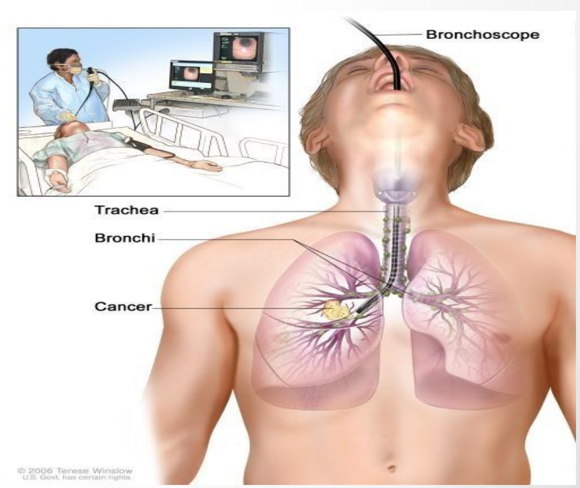
Jamming gripper



Stiff-Flop

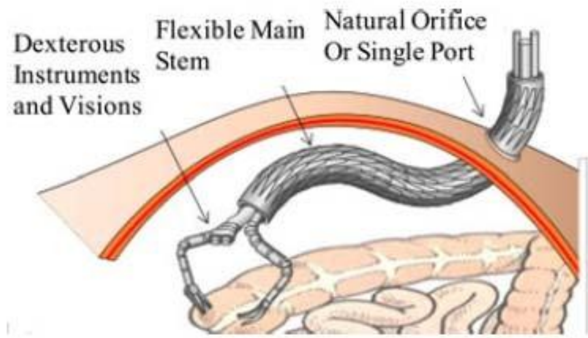
ANUBIS





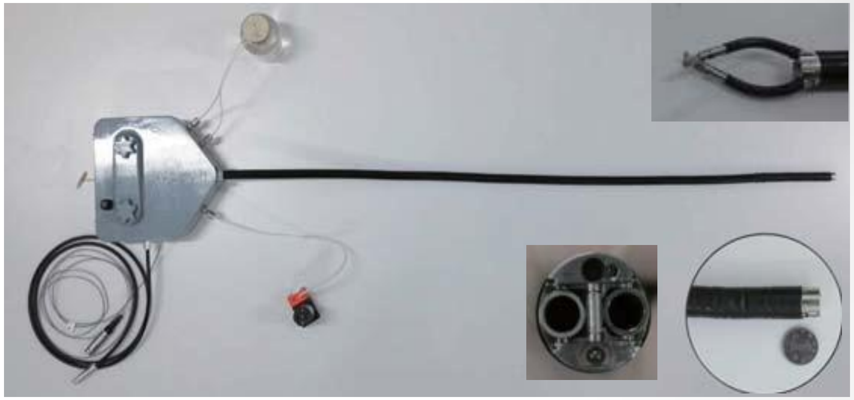
Future of Surgical Robotics and Devices

Layer Jamming Mechanism
the Samsung Advanced Institute of Technology， Korea



- **Diameter：** **22mm**
- **Force：** **2N**

FlexHand Tianjin University



Future of Surgical Robotics and Devices

Sensors in surgical devices

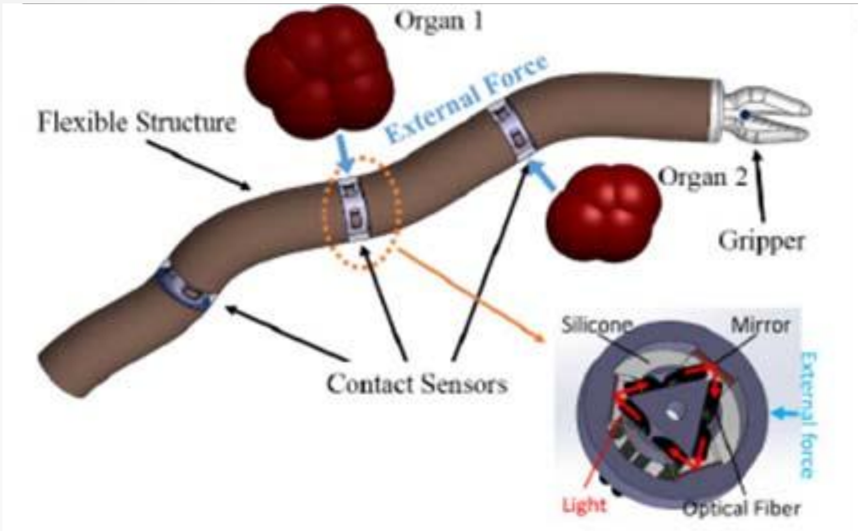
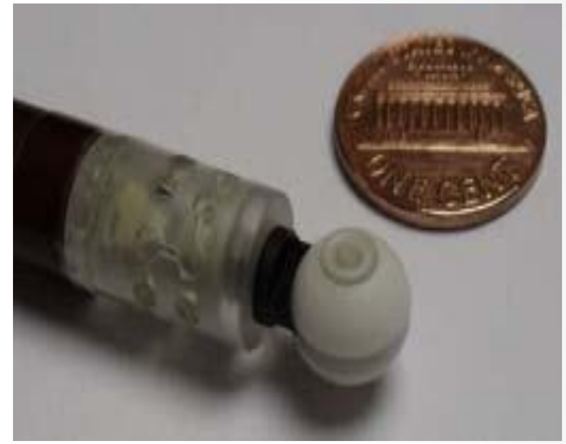
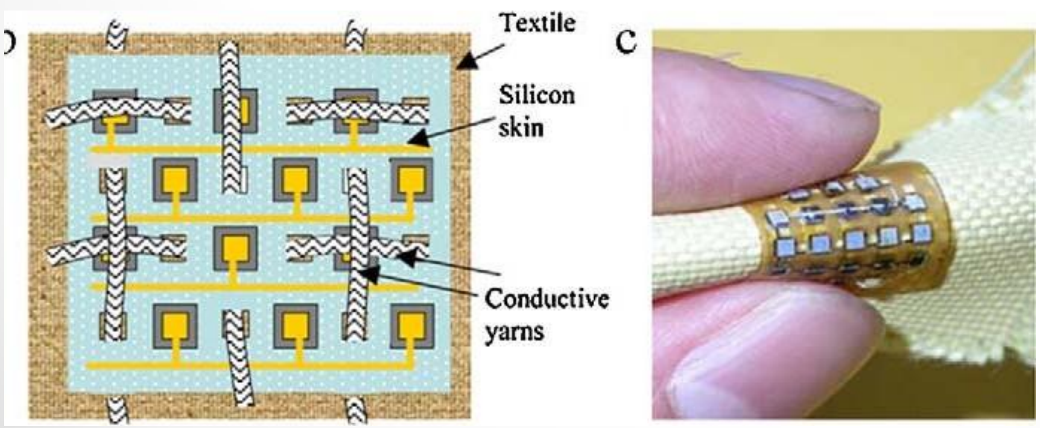


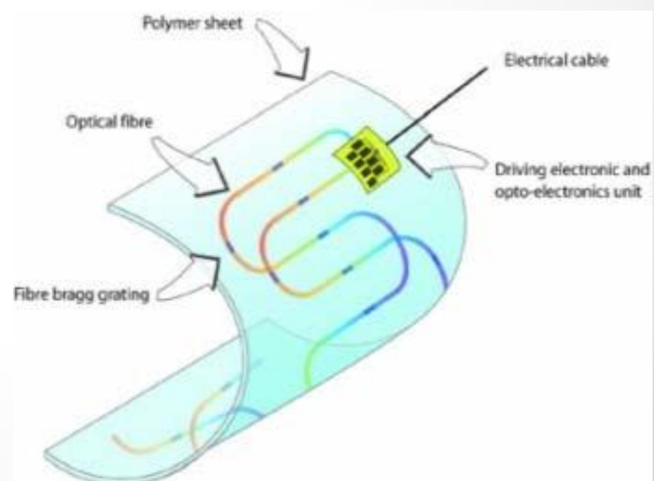
Fig. 1. Envisaged use of the contact sensor for a flexible robotic arm



Haptic Sensors
（Liu 2012）



Flexible Sensors



Sources:

http://internetmedicine.com/robotics-lecture/

Robot Research Initiative, **Chonnam National University**
Jong-Oh Park, Sukho Park, Seong Young Ko, Ph.D Professors

Shuxin Wang
Tianjin University