Control of a team of micro-robots for non invasive medical applications

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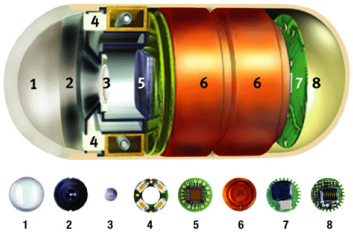
Summary

1. Introduction
2. Constraints
3. Proposals
4. Missions
5. Conclusions

1. Introduction

1.1. Existing meso-robots (centimetric)

OLYMPUS

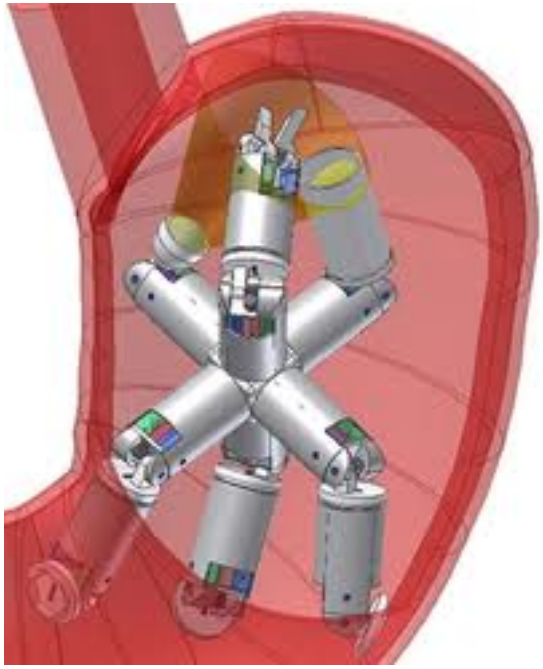


VECTOR

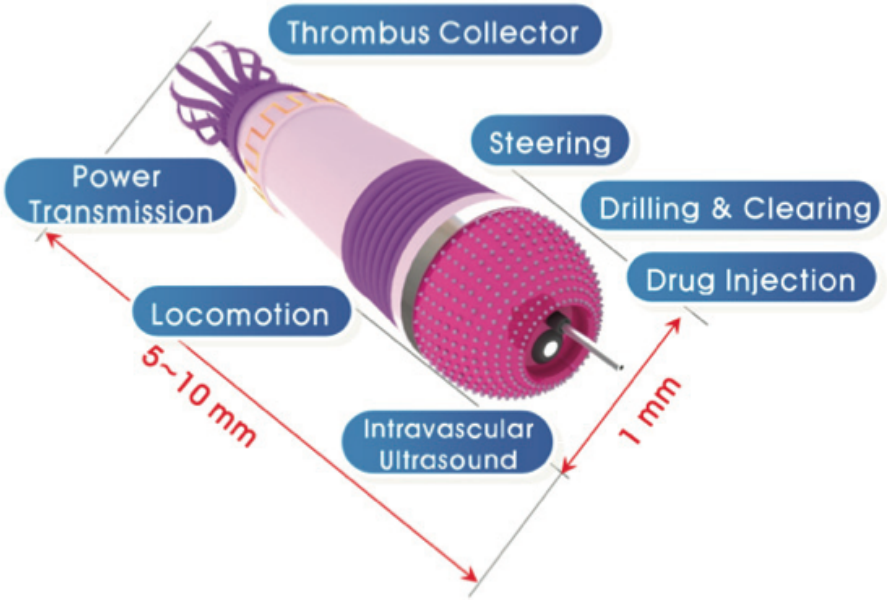
Figure 6. In the IDEAS (Integrated Diagnostics for Environmental and Analytical Systems) project's Laboratory in a Pill, a plastic shell encapsulates the device electronics. (image courtesy of the IDEAS team)

IDEAS

1.2. Projects of micro-robots (millimetric)

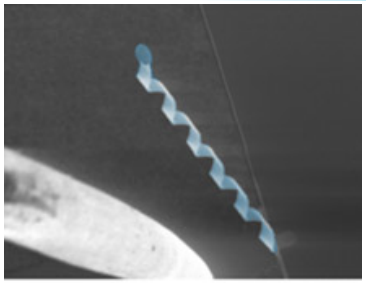


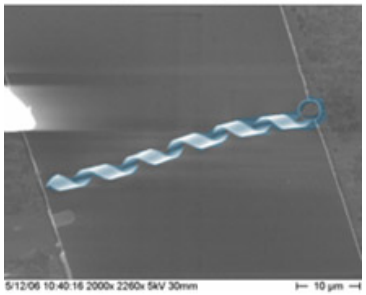
ARES
(Europeean project)

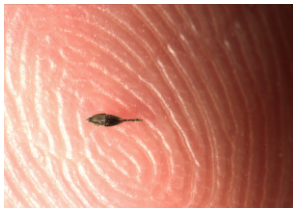


Microrobot for Intravascular Treatment
(Korea Inst. of Sci. & Technol., Seoul)

1.3. Research of nano-robots (micronic)







ETH Zurich

ETH Zurich

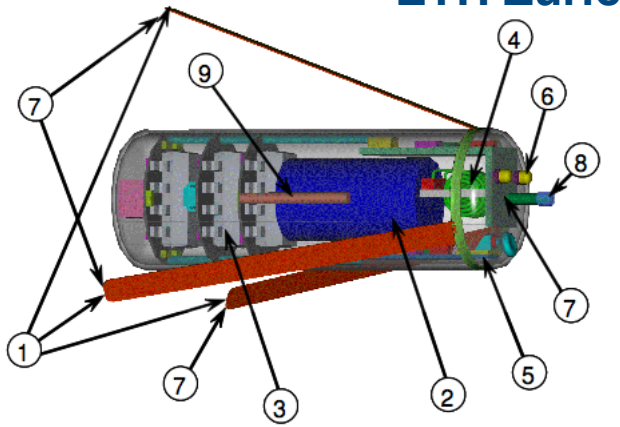
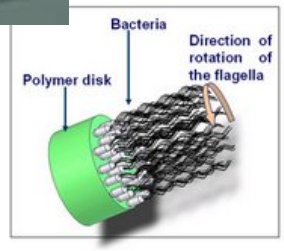
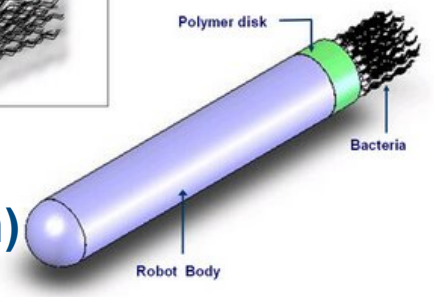


Fig. 10. Conceptual assembly of a swimming micro robot for neurosurgery. The components of the robot are: 1) Three swimming tails, 2) Power source (here 5 Renata ZA10 batteries in series), 3) Packaged IC for command control and communication, 4) Antenna, 5) Endoscopic Camera, 6) LEDs, 7) Force sensors, 8) Tool for intervention, 9) Localization sensor (here an Aurora magnetic tracker receiving coil.

Vi-Rob (Israël)





USA (Carnegie Mellon)

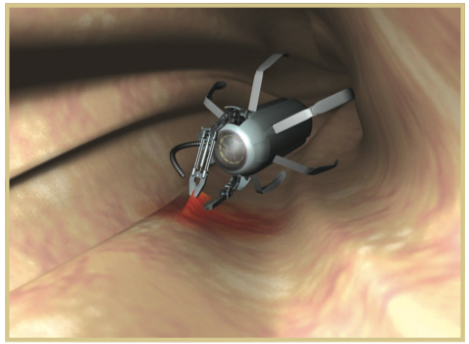
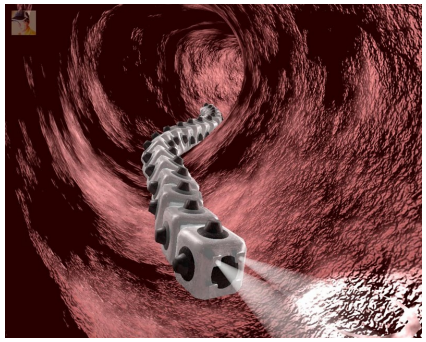


Figure 7. An artists' impression of the Vector (*Versatile Endoscopic Capsule for Gastrointestinal Tumor Recognition and Therapy*) capsule, which would use its imaging lens and mechanical arms to perform therapy. (Image courtesy of Mat A. Heide, Sintef)



(Korea Inst. of Sci. & Technol., Seoul)

2. Constraints

- **Bio-medical environment needs**
  - Non toxicity and non injury
  - Eliminability
  - Safety
  - Disposability (single use)

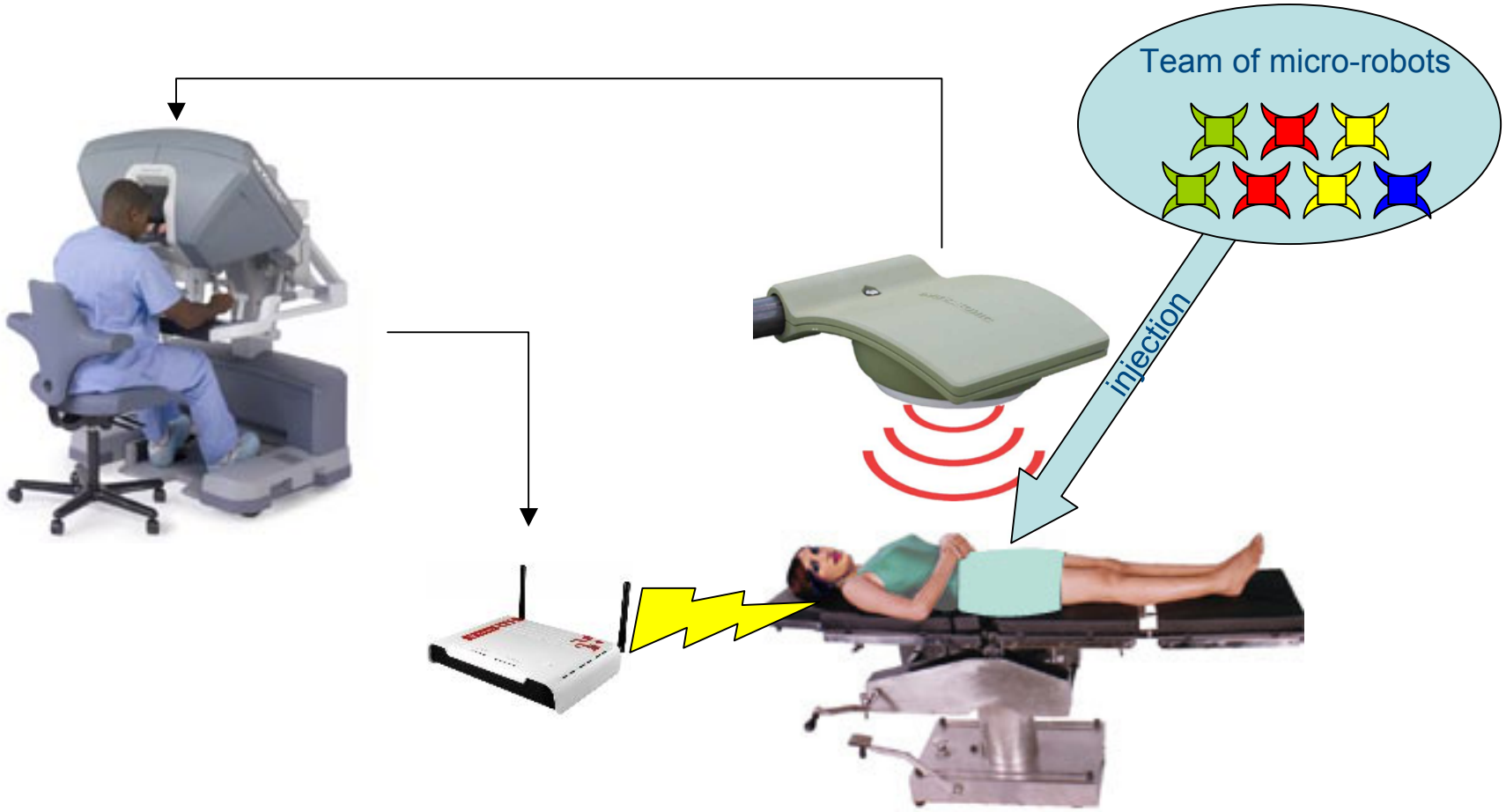
- **Safety needs**
  - monitoring and control of a mission allocated to a team

- **Microbotics and microworld constraints**
  - Specific physic of the micro-world

- **Embedded energy constraints**
  - Volume (and weight) of containers, quantity of energy, duration

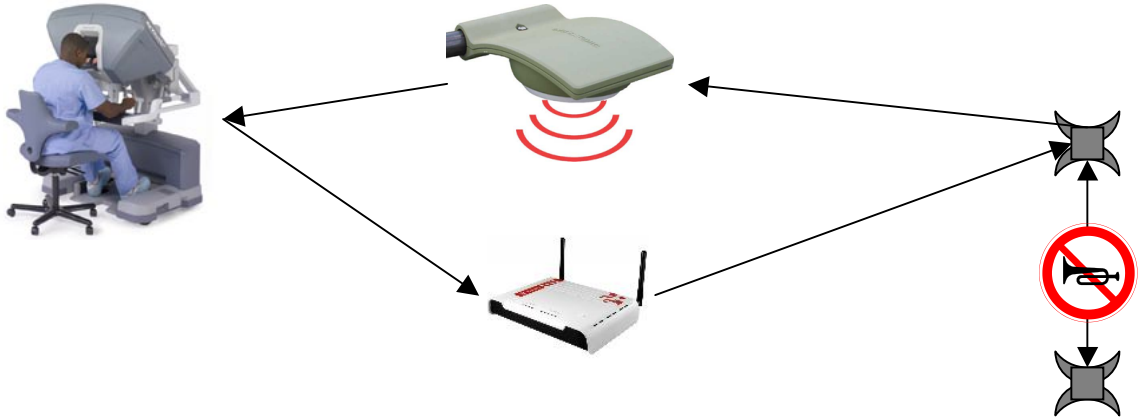
3. Proposal

3.1. Main description

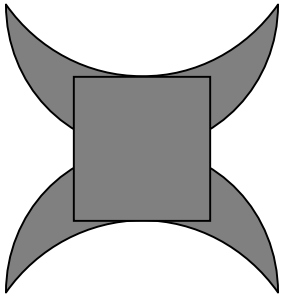


3.2. Design choices

- **Non communication between micro-robots (only broadcasting of informations)**



- **No autonomous move of the micro-robots (use of the body fluidic moves or external fields)**



Sensors
- Main controller signals listening
- Environment sensors

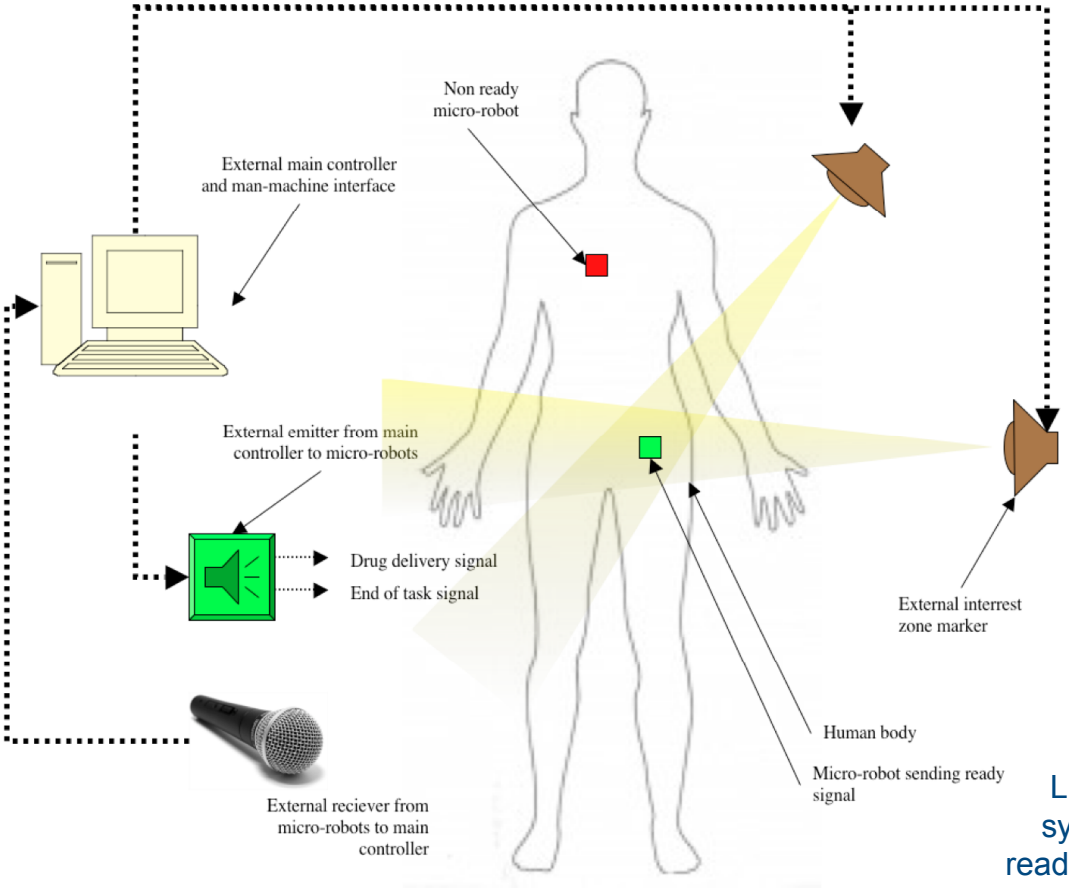
Actuators
- Single ready signal sender
- One or two digital actuator

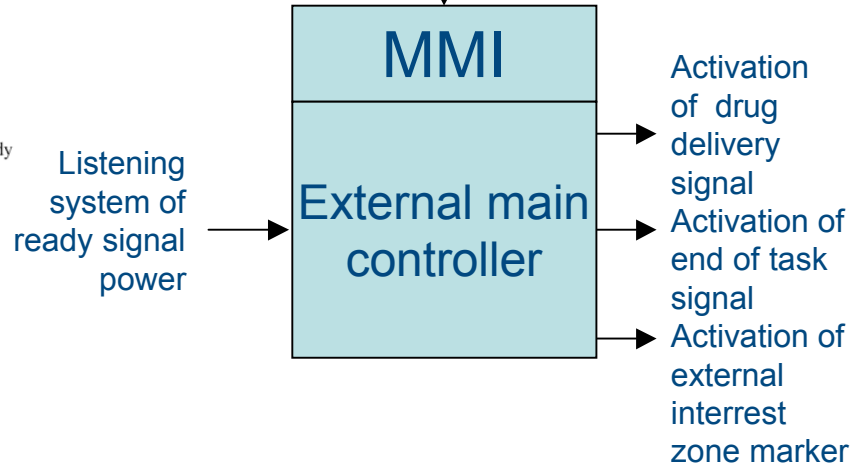
3.3. Principles

- **Minimalist micro-devices**
- **Mass effect to accomplish a mission**
- **Only the number of ready units can be evaluated (no identification of the units)**
- **The lost of some units is allowed**
- **The elimination of every unit at the end of the mission is required**

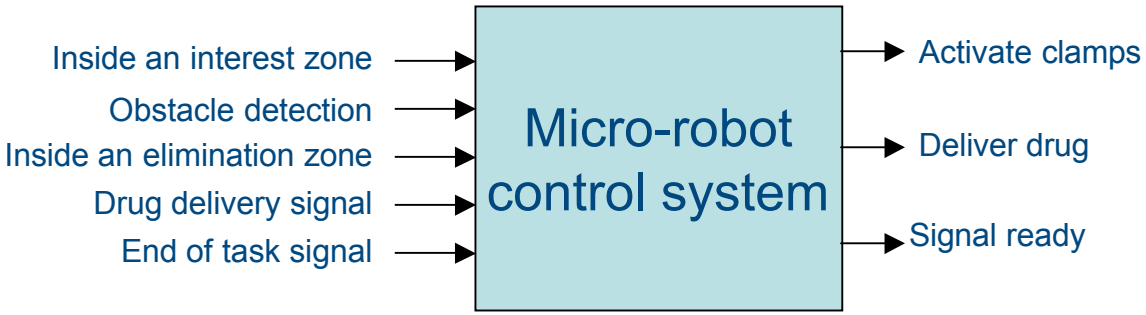
4. Mission example : drug-delivery

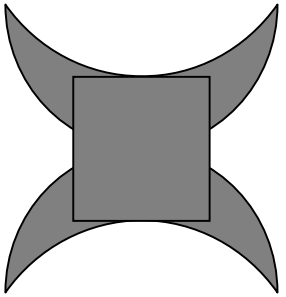
Drug-delivery external devices



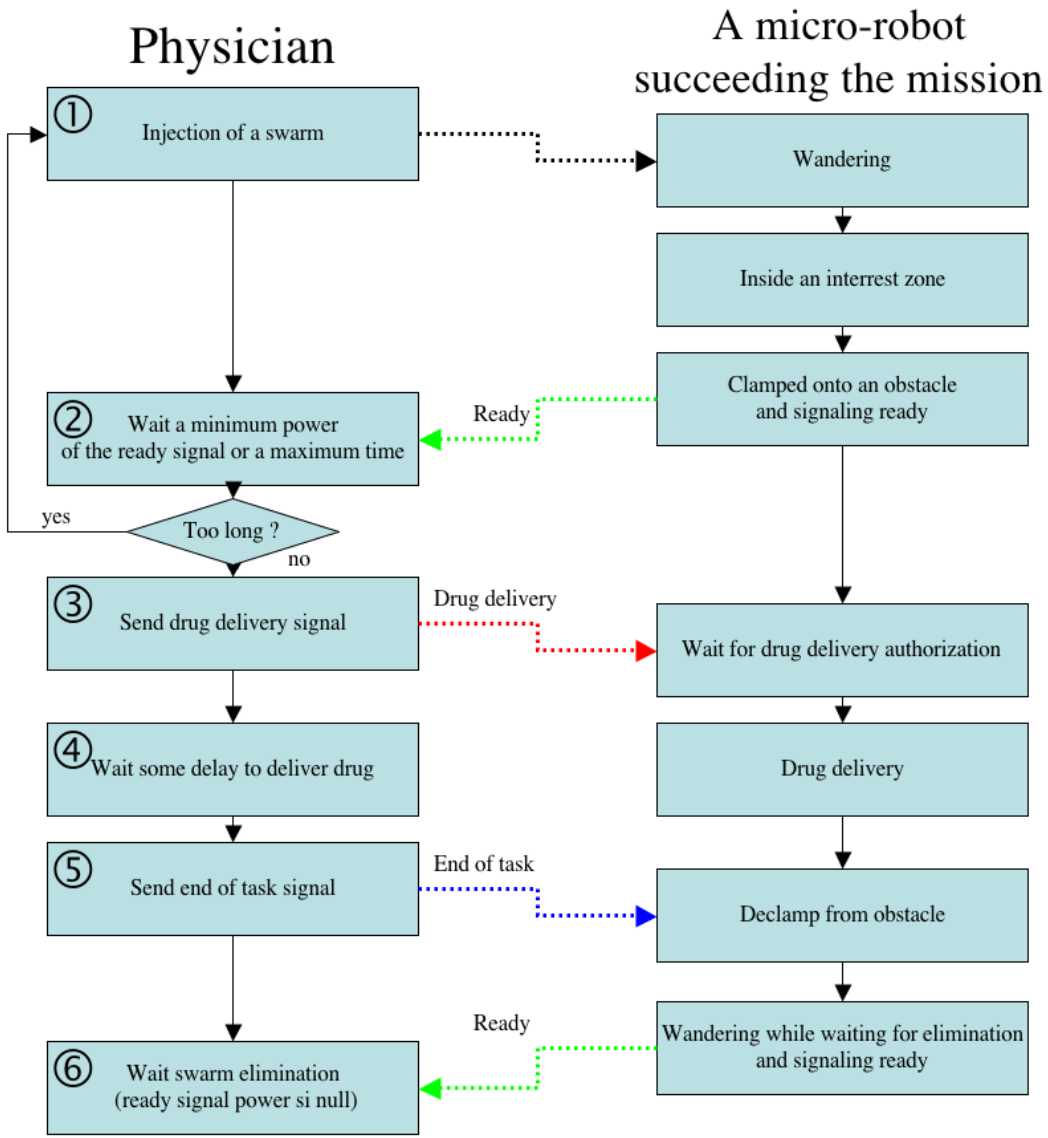


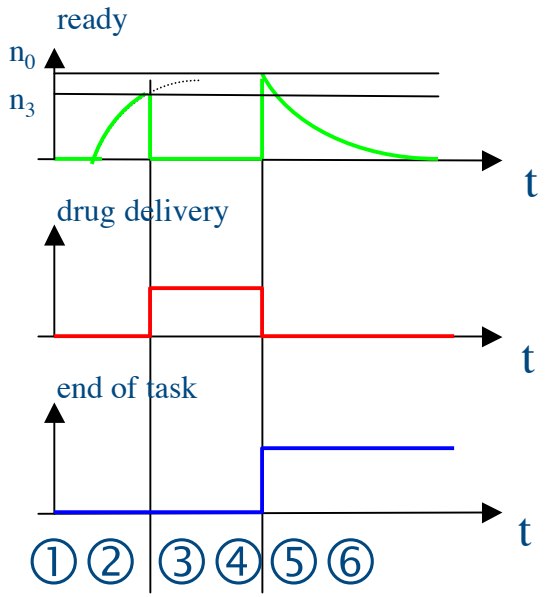
Drug delivery : micro-robot devices



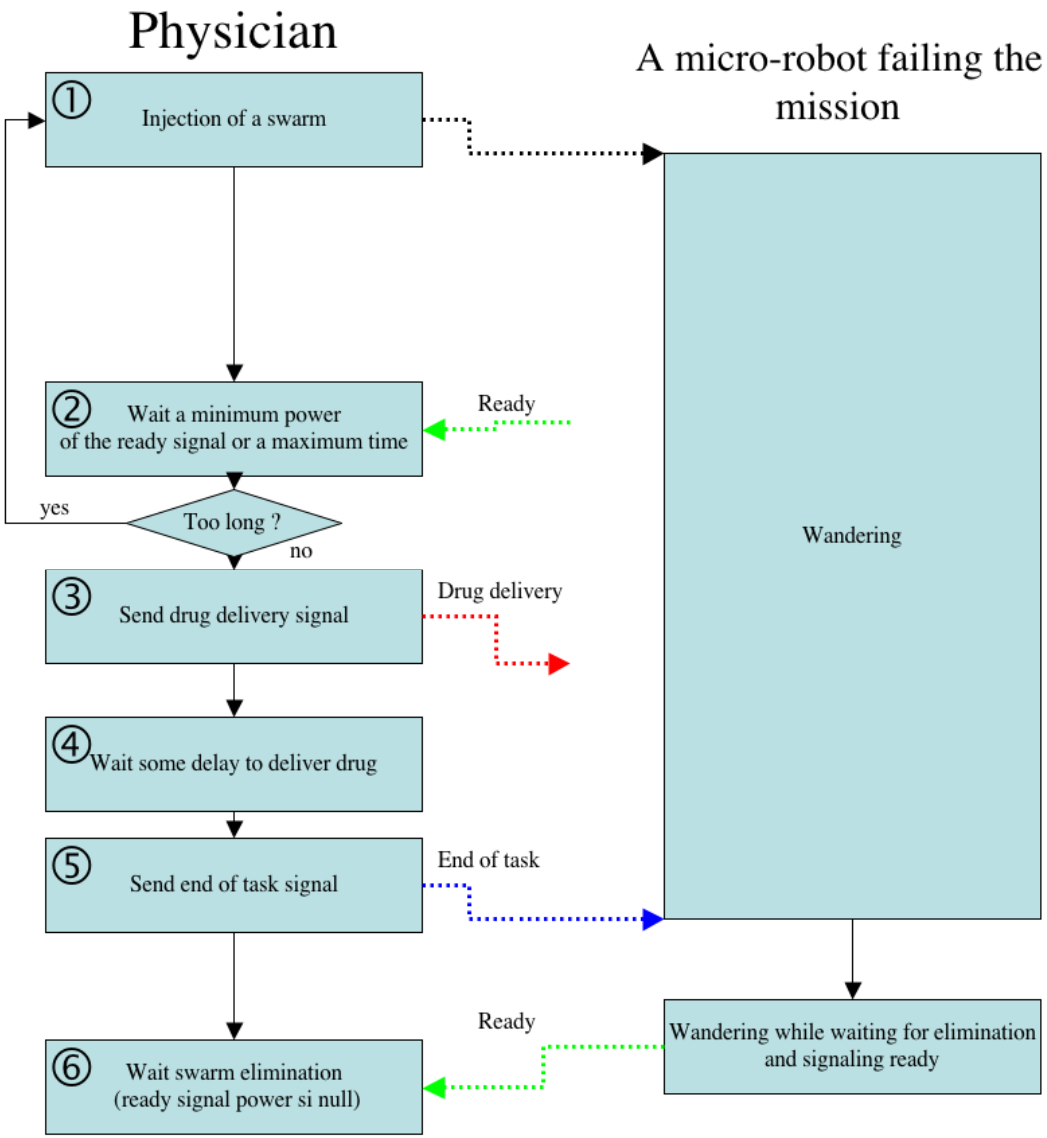


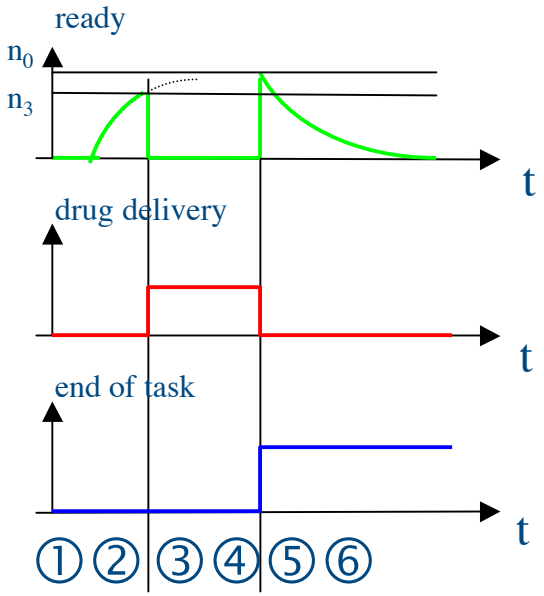
Mission main steps



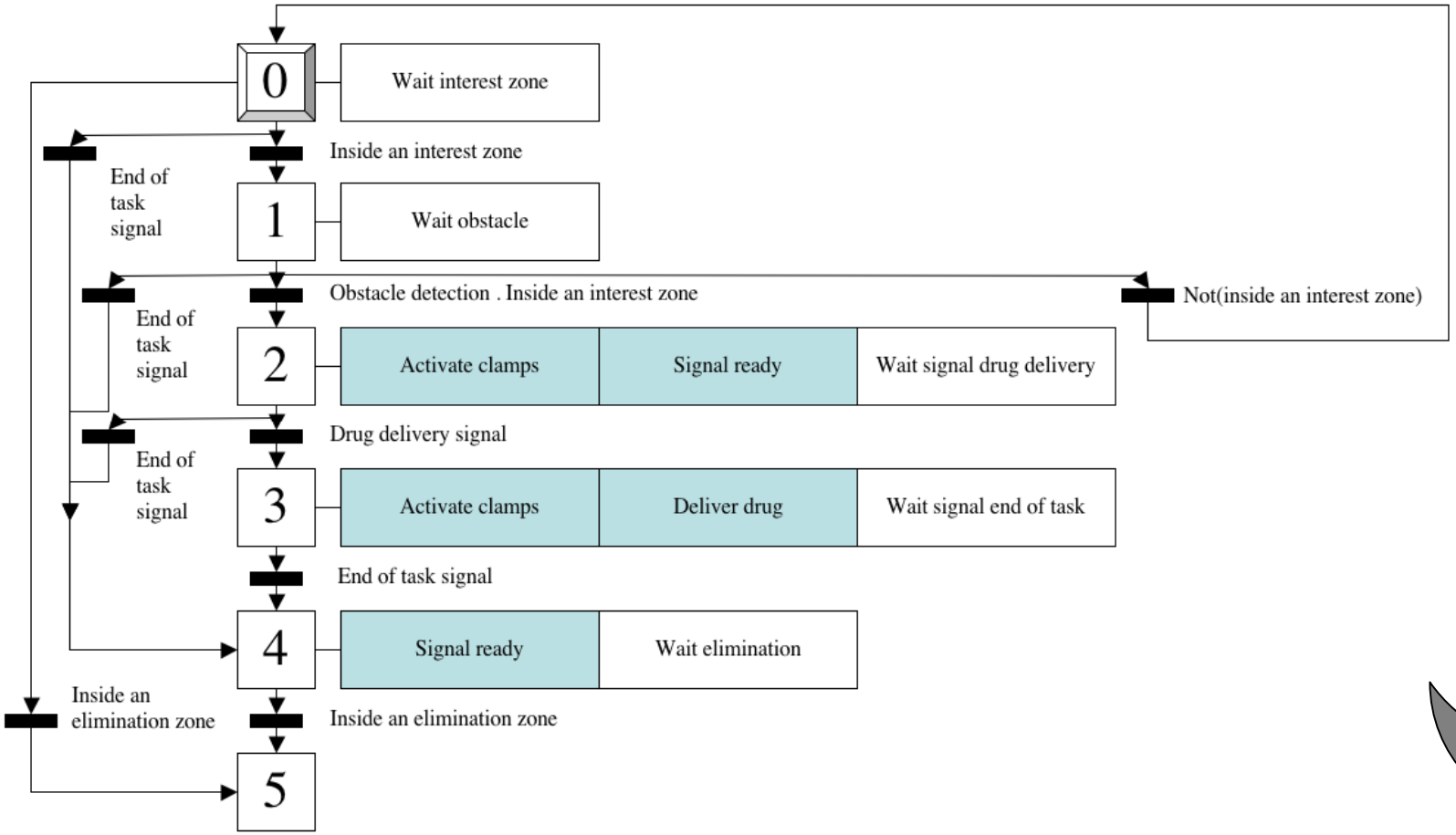


Mission main steps

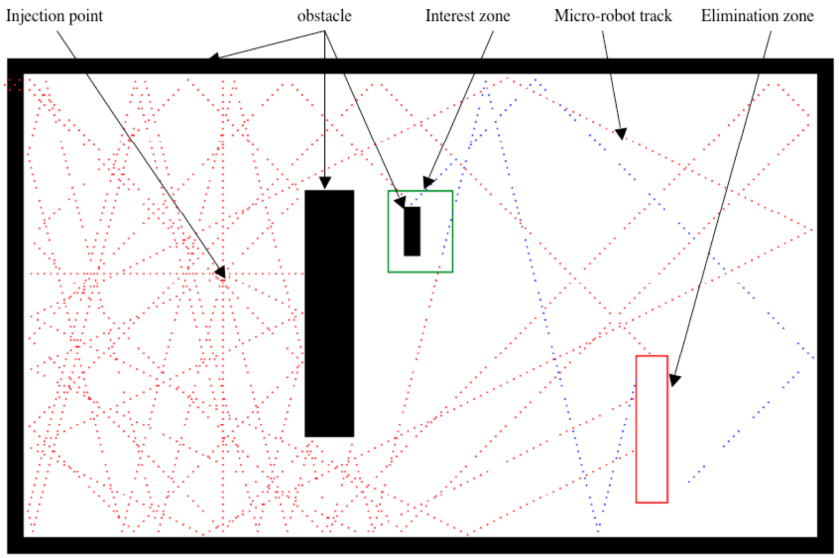




Micro-robot control structure program



Experiments and results

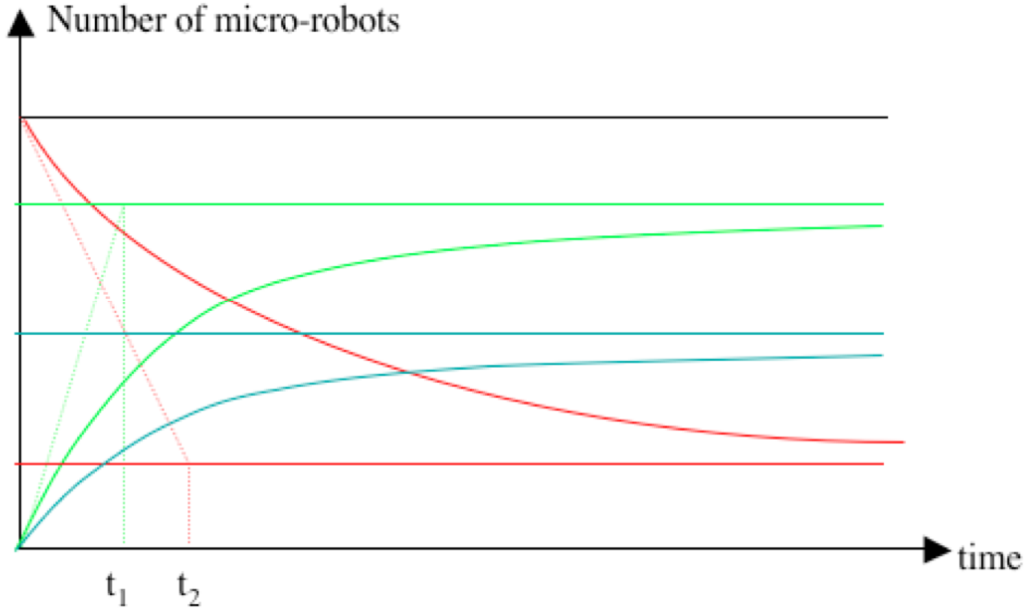


Number of micro-robots that reach the target, without elimination consideration

Number of micro-robots still wandering when including an elimination zone, without target consideration

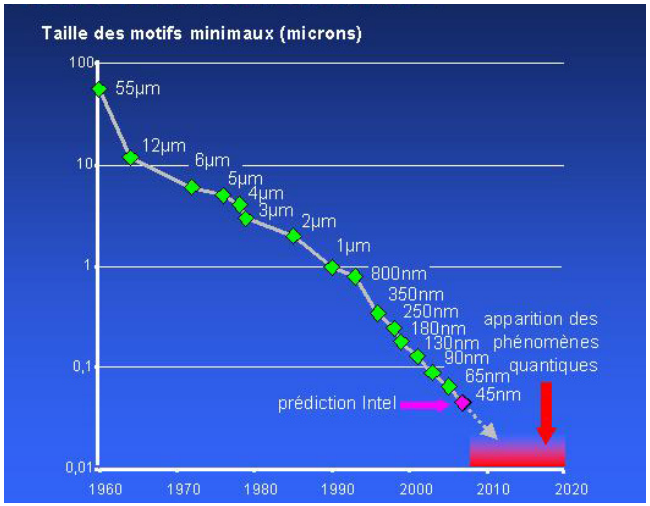
Number of micro-robots that reach the target, when considering an elimination zone

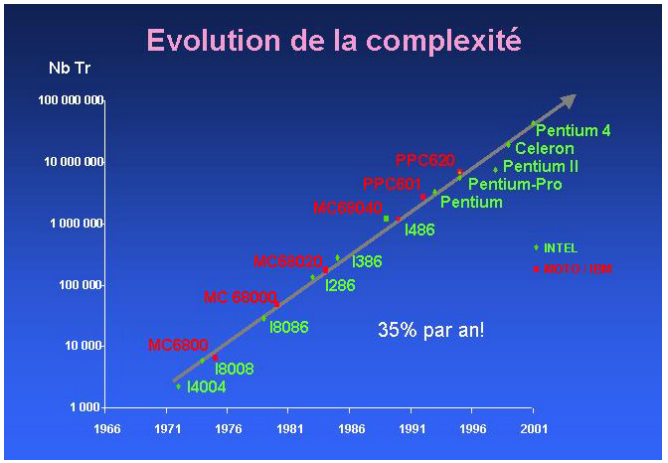
$N_2 \neq 0$!!



Estimation

- **Present densities :**
  - 1994 Intel Pentium 1994 ⇒ 3 millions de transistors
  - 1997 Pentium II 1997 ⇒ 5 millions on 3 cm^2
  - 1997 AMD processeur K6 ⇒ 8,8 millions on 1,7 cm^2
  - 1 component by 50 nm (2000 maximum smoothness) ; today 25nm
  - Then, we assume 10^6 transistors/cm^2 ⇒ 10^3 transistors / μm^2
- **Needs :**
  - Realization of a micro-robot CPU onto 1 μm^2
  - 2 transistors by NAND gate (universal gate)
  - 1 G7 step : 2 « and » + 1 « or » 2 « not» ⇒ 11 NAND ⇒ 22 transistors
  - 1 G7 transition including 5 inputs ⇒ 5 « not », 5 « or including 5 inputs » ⇒ 25 NAND ⇒ 30 transistors
  - 1 output : 1 « or including 5 inputs » ⇒ 15 NAND ⇒ 30 transistors
  - N steps + 1,5 N transitions (5 inputs) + 3 outputs by 1000 transistors
    - ⇒ N*22+1,5*N*30+3*30=1000
- **Then N = (1000-90)/(22+1,5*30) = 13 steps on 1 μm^2 CPU**





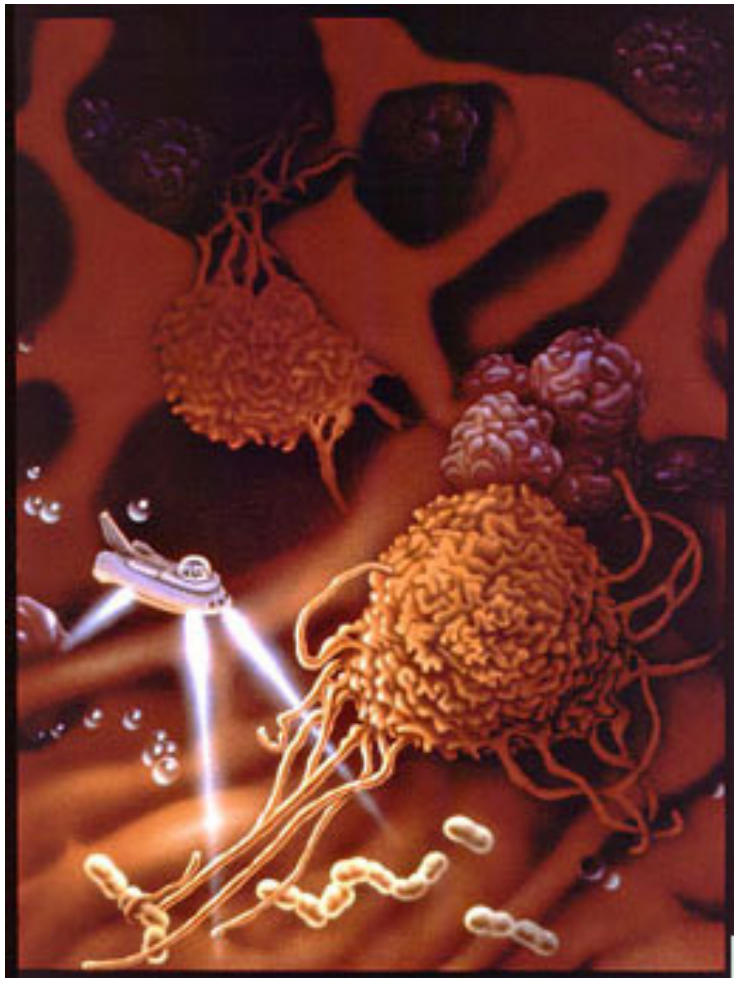
5. Conclusions

5.1. Results

- **Proposition of a kind of smart medicine that only acts where and when it is needed (under physician acknowledgment)**
- **Configurable to many kind of missions**
- **Today, such micro-robots do not exist. Only programs run into a simulation program**
- **Problem of complete elimination of the team**

5.2. Further works and perspectives

- **Bring improvements to the simulator**
- **Imagine some other missions. May be, this team may be more efficient if it is an heterogeneous one, with some specialized units**
- **Realize a true team and perform real experiments !**



Movie illustration of the movie « Fantastic voyage »

Thank you for your attention…