# Coordination and Computation in distributed intelligent MEMS

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1: UFC/FEMTO-ST, 2: PolyU, 3: IRISA, 4: UFC

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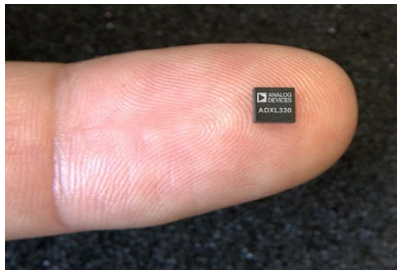
# Introduction

- Microtechnology is now a mature technology
- MEMS can be produced by thousands units
- Applications:
  - What for?

Accelerometers



STMicro LIS331DLH

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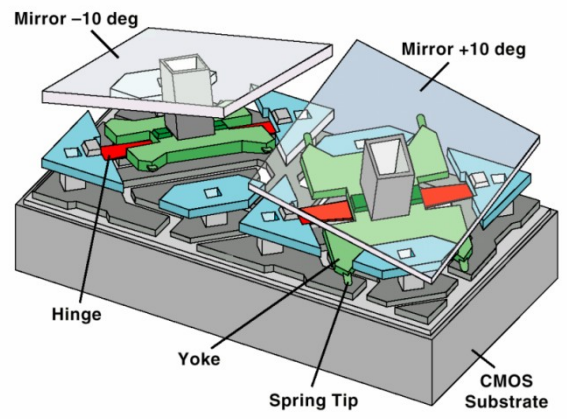
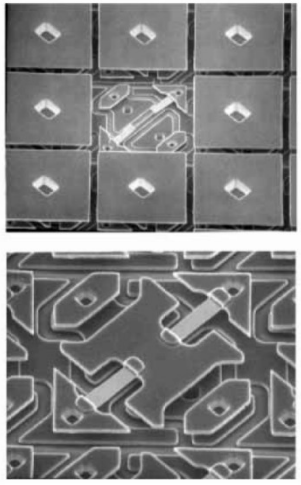
Digital Micromirror Device



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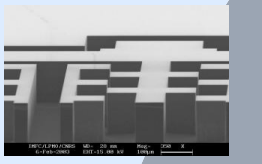
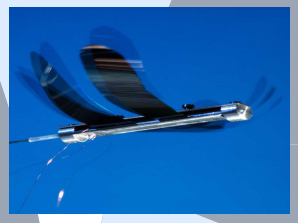
# Introduction





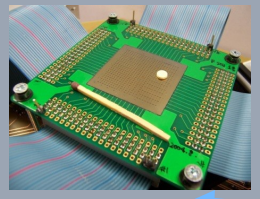
**Silmach Dragonfly**

Simple MEMS

+ External PC

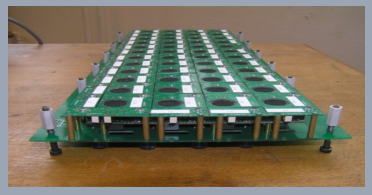
Remote (centrelized) intelligence MEMS

+ FPGA



**Smart Surface**

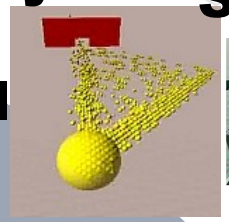
Integrated intelligence MEMS



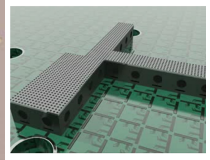
**Accoustic impedance control**

Static Distributed MEMS

+ Distributed intelligence



**Claytronics**



**Smart Blocks**

Mobile Distributed MEMS

+ Dynamic network topology

video

# Scientific objectives

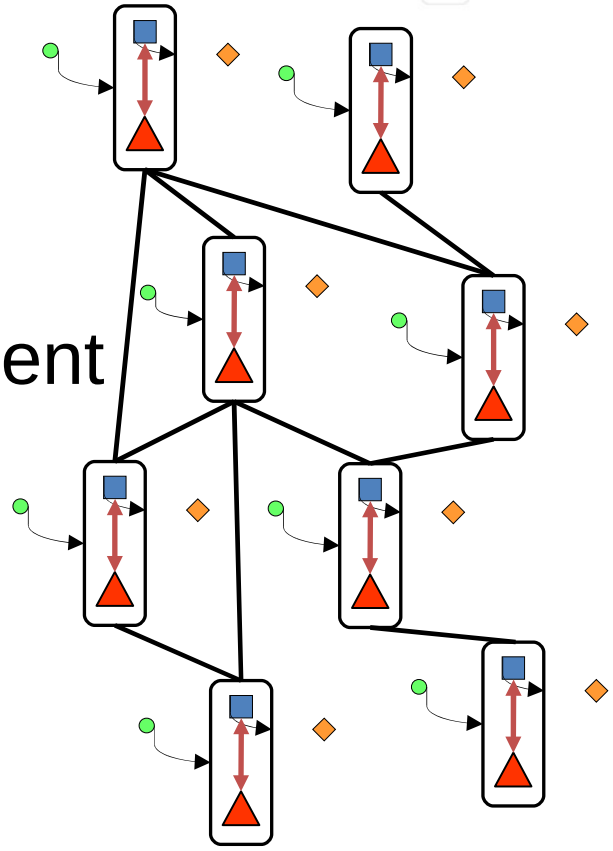
- Four mains scientific challenges ...

# Scientific objectives

- Scalable and fault-tolerant distributed programming
  - Challenge: Propose a programming model which can scale up to millions of MEMS units

# Programming model

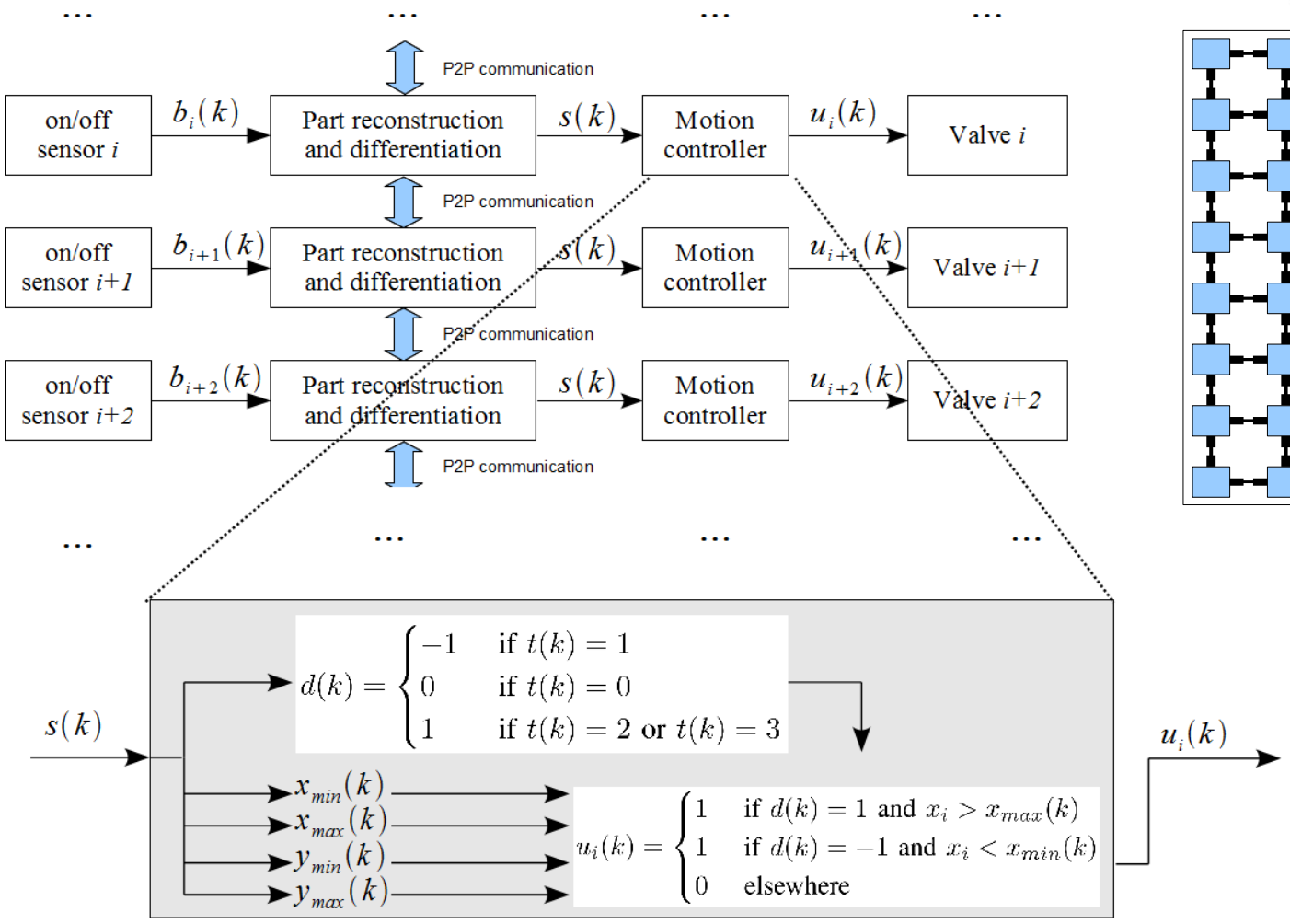
- Expected properties:
  - Scalable
  - Fault-tolerant
  - Allowing real-time features
  - Embedded in resource constraint environment
- Meld as a basis
  - Adding real-time features
  - Unit synchronization

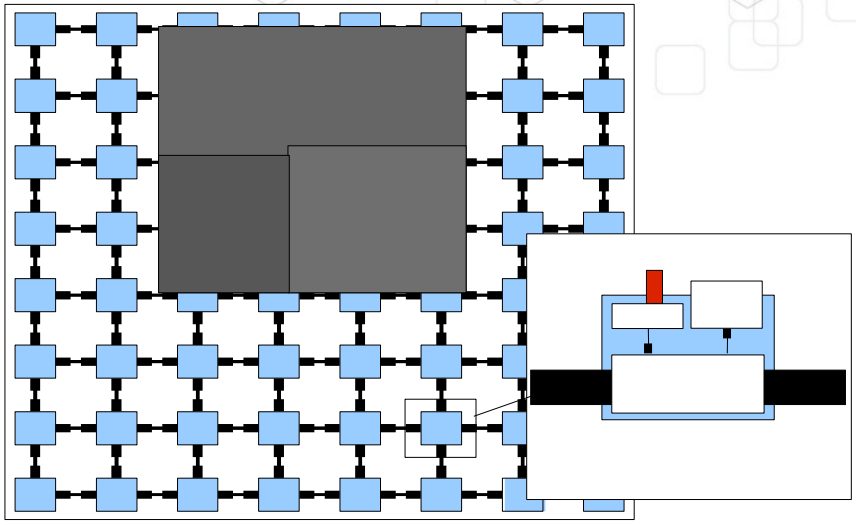


# Scientific objectives

- Scalable and fault-tolerant distributed programming
  - Challenge: Propose a programming model which can scale up to millions of MEMS units
- Integration of fully distributed computing and control
  - Challenge: Co-design between distributed computing and control to manage sensors/actuators.

# Distributed actuation: principles

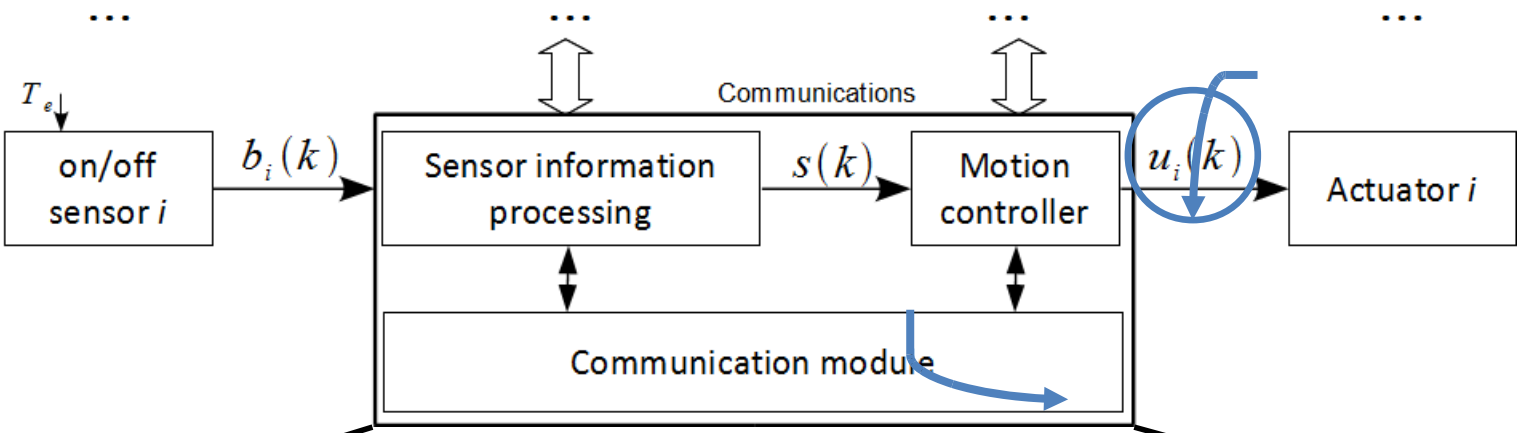


In K. Boutoustous, G. J. Laurent, E. Dedu, L. Matignon, J. Bourgeois, and N. Le Fort-Piat. Distributed control architecture for smart surfaces. In *IEEE/RSJ IROS*, pages 2018–2024, Taipei, Taiwan, October 2010. IEEE.

# Distributed actuation: performance

- Very dependent on the programming model
- Can estimate local processing times (WCET : Worst Case Execution Time)




$$\left( \sum_{n=1}^{NbB(P)} \left( \sum_{b=1}^{Nb(p_{seq})} C_g.NE_b \sum_{i=1}^{n} C_i.T_m(S_i).NI_b(S_i) \right) + \sum_{n=1}^{NbC(P)} T_{c(n,m)} + T_{s(n,m)} \right)$$

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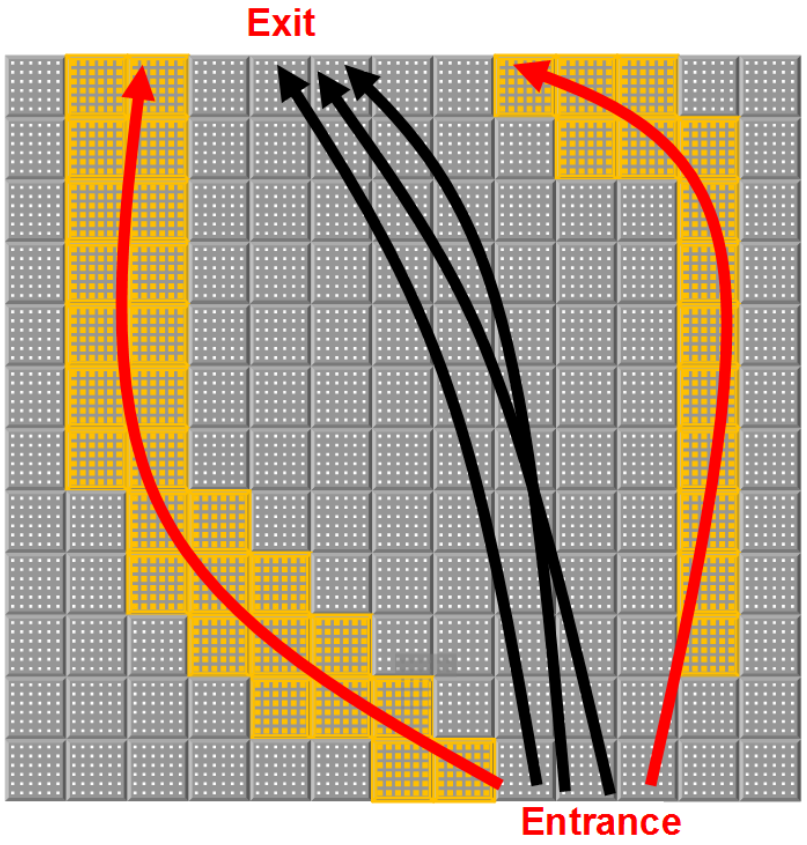
- Fault detection
  - What are the possible faults, how to detect them, what do we require to do so

# Failure localization

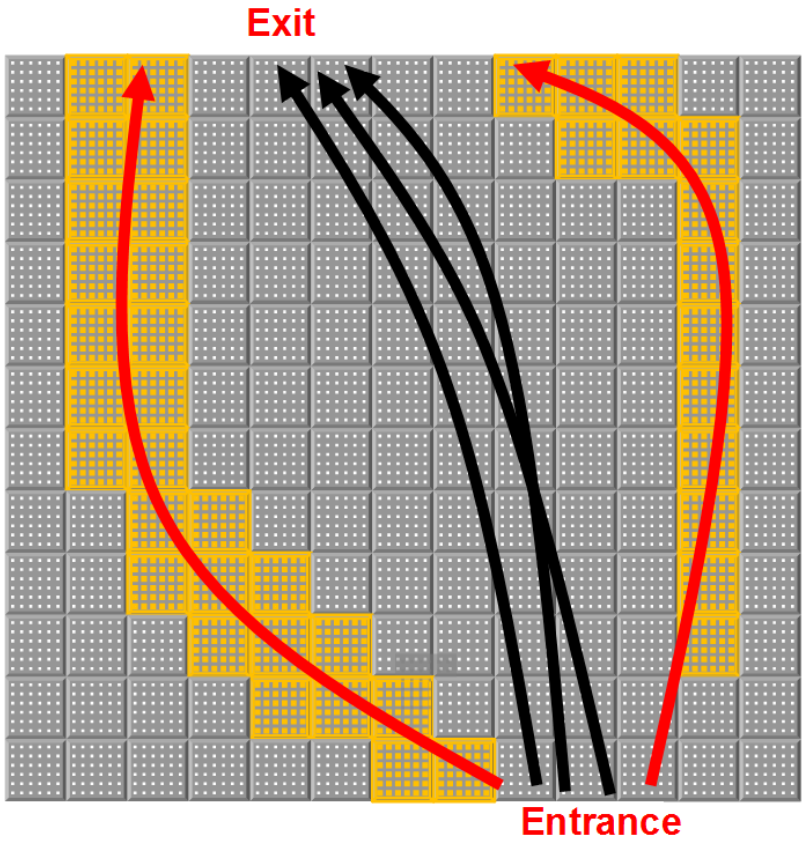
- MEMS actuators are prone tc failure
- Detecting failures by analyzing misbehaviors
- Localizing faulty actuators
- Need for a distributed consensus algorithm



# Failure localization

- Leads to the « fault detector » concept : a high level service able to detect incorrect situations

- Steps :
  - Define the level of details and the « trustworthyness » of thoses detectors ir our context.
  - Define the formal synchronism requirements of thoses detectors
  - Implement the detectors in a distributed way



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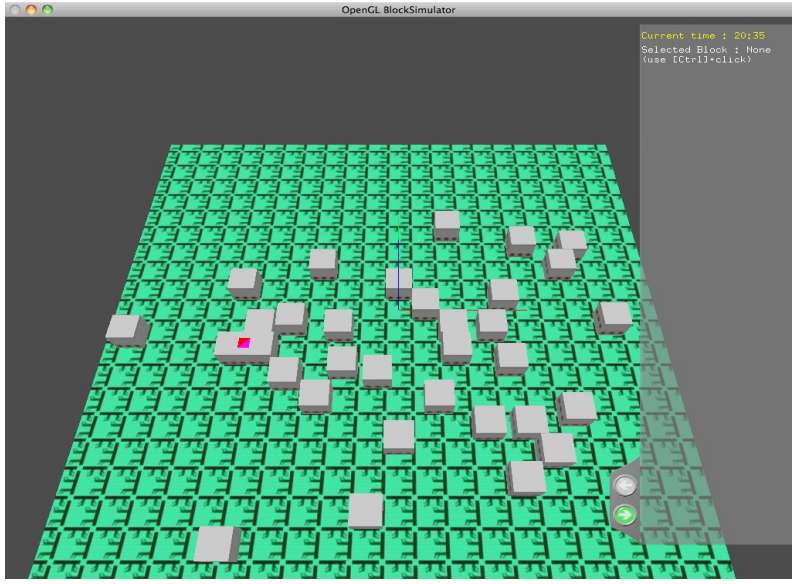
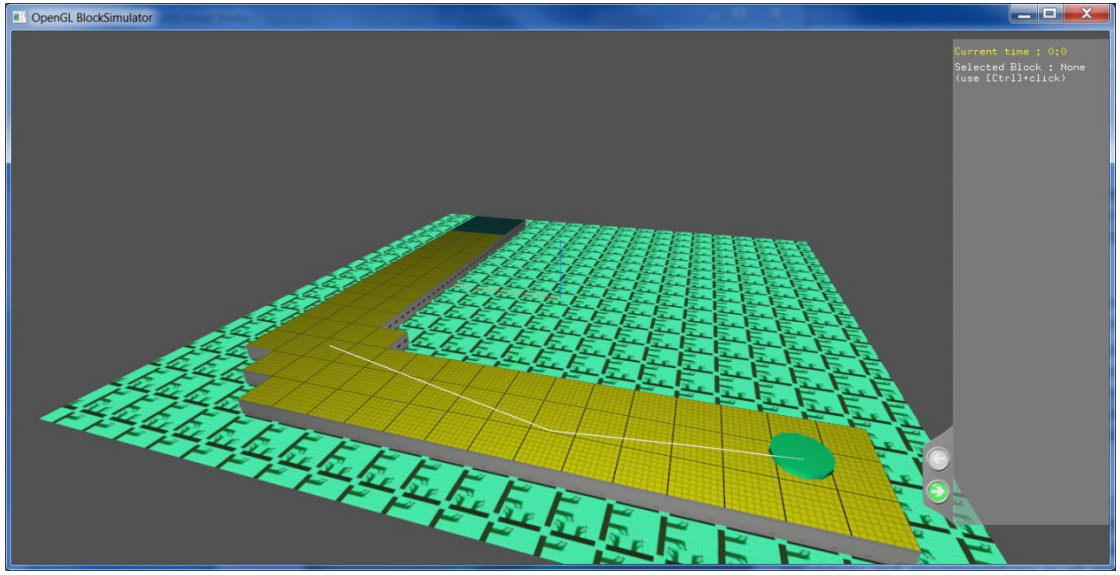
- Fault detection
  - Challenge: Propose a k-set agreement in an asynchronous message passing environment
- Scalable and efficient simulation
  - Challenge: Scale up in numbers while keeping sufficient precision

# Scientific objectives

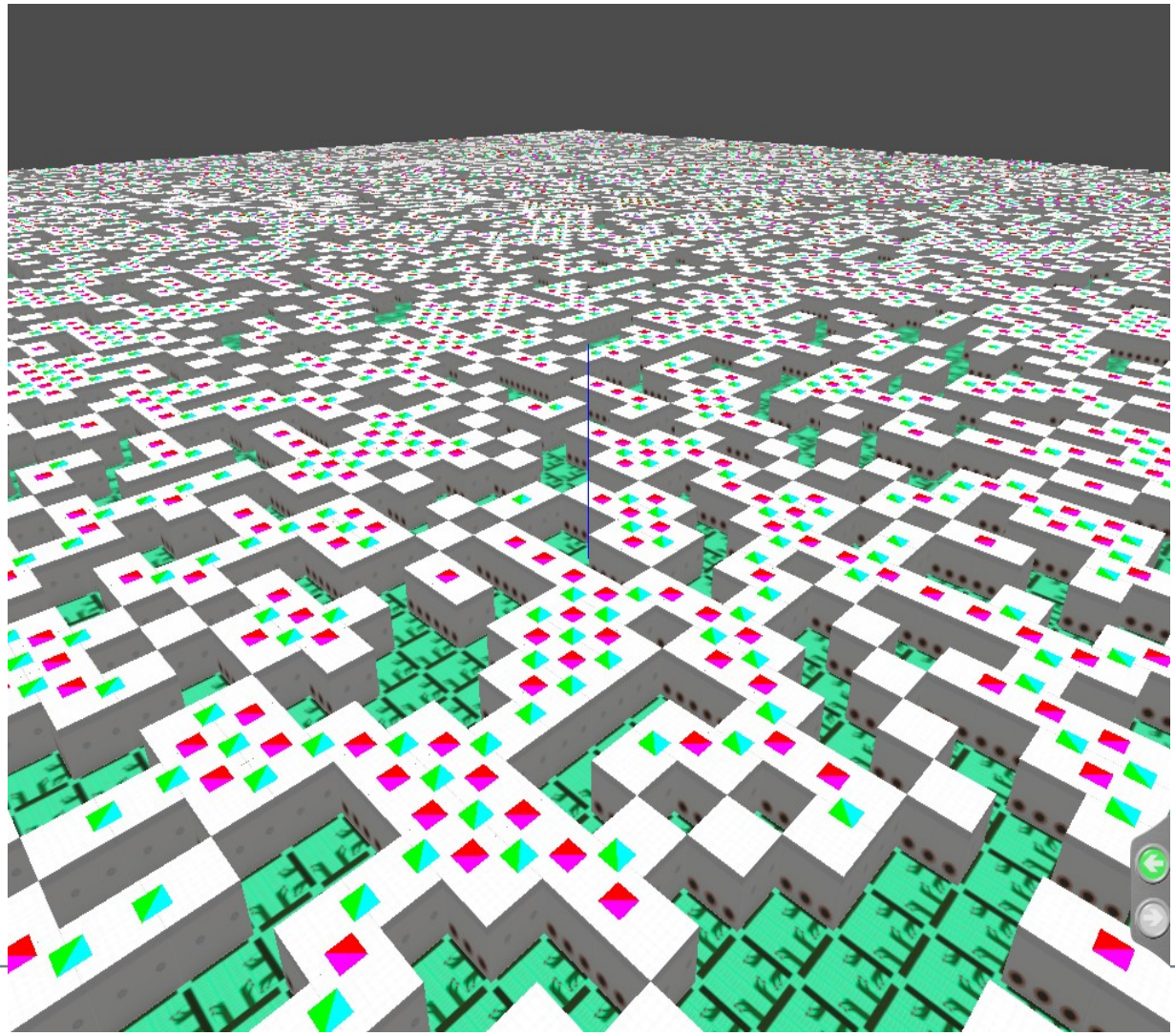
- Discrete events simulator with techniques originating from network simulation field
- Deterministic / ensure the reproducibility of the results
- Visualization to help understanding / debuging



# Scientific objectives

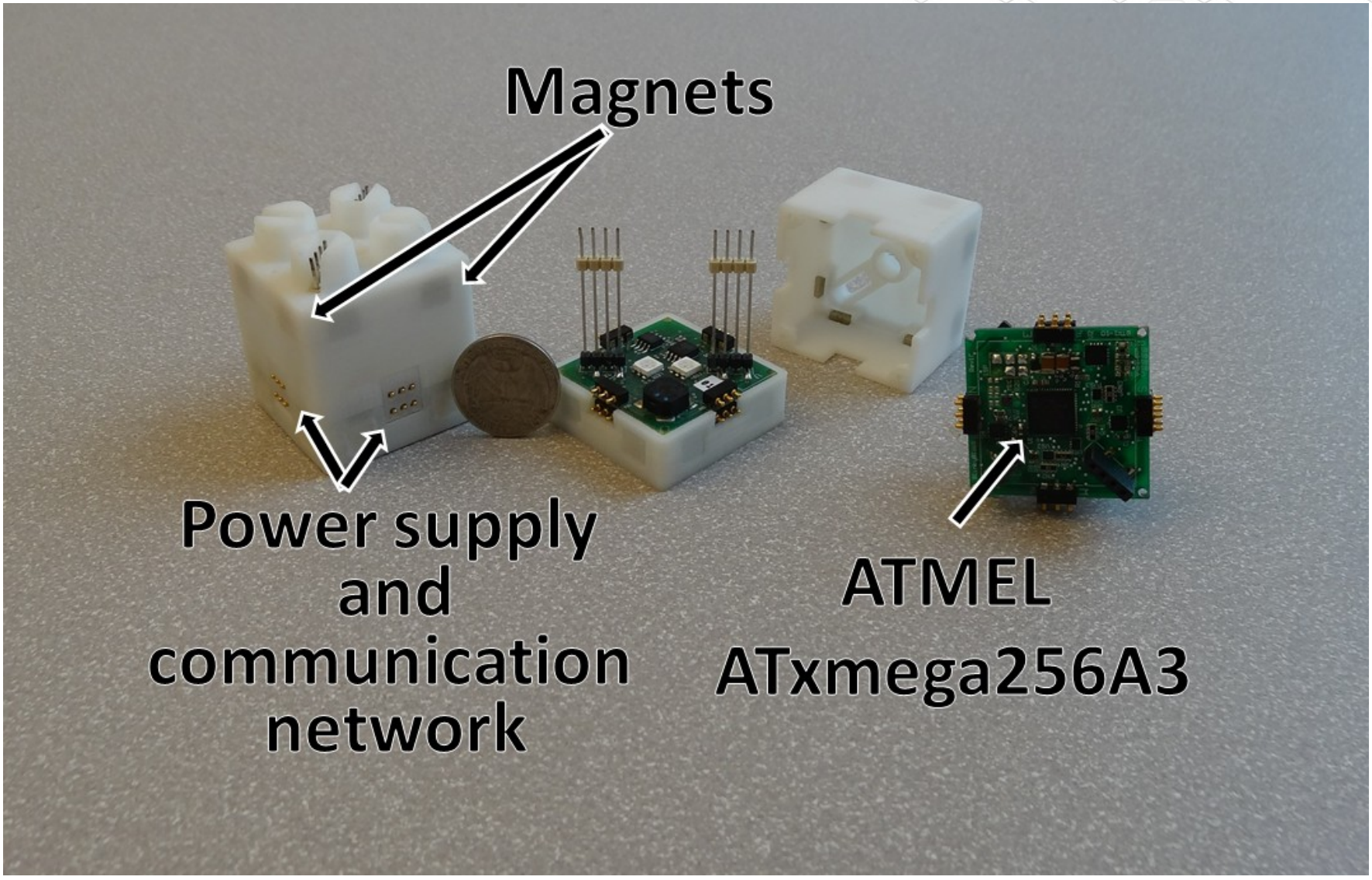
- Scale well



# Scientific objectives

- Four mains scientific challenges ...
- … Integrated into a unique project covering theoretical aspects up to real-world implementation

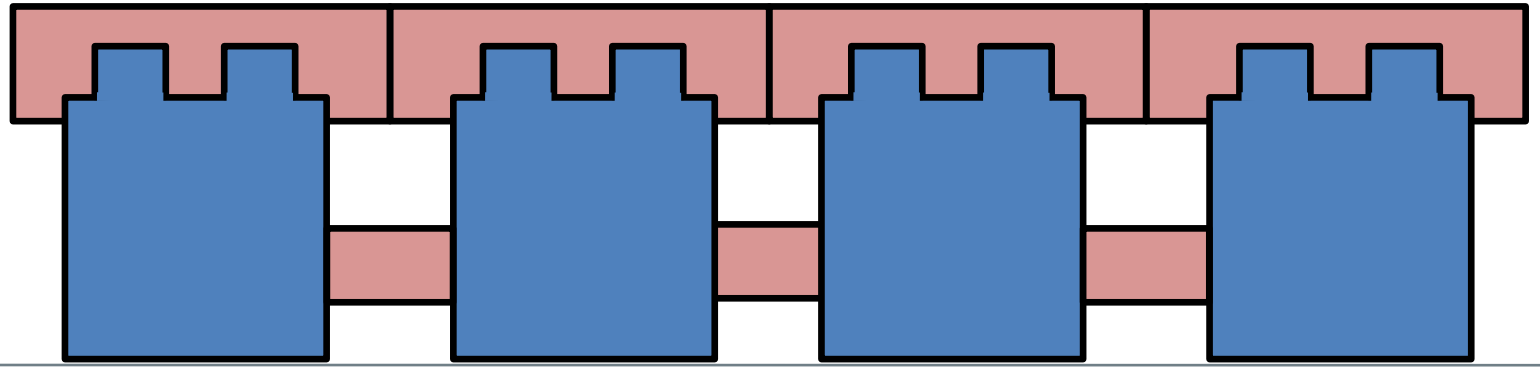
# Demonstrator: Blinky Blocks



# Demonstrator

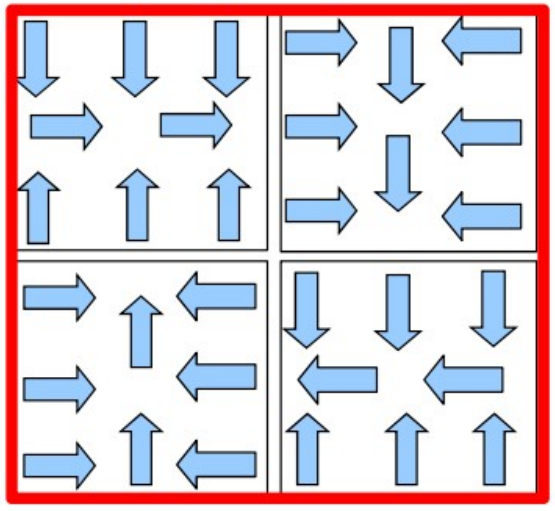
- Creating a conveying surface based on MEMS actuators
- Blinky Blocks will serve a a basis for computing/communication
- Two types of MEMS surface will be used

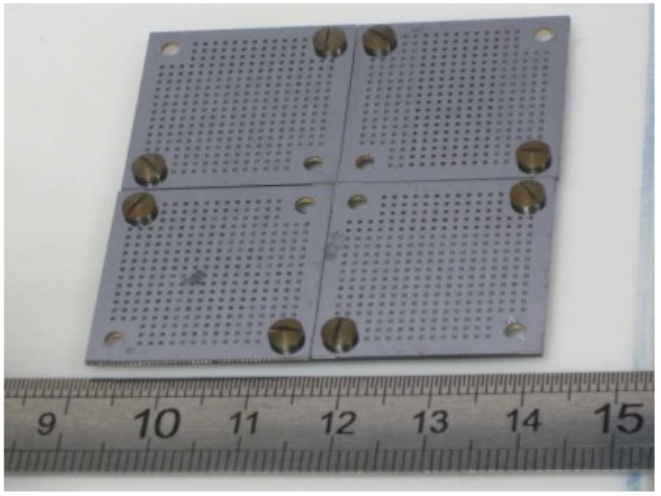
Conveying Surface

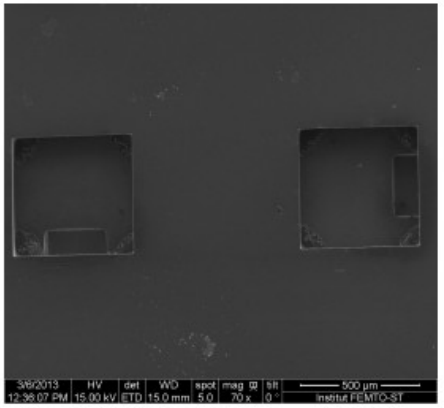


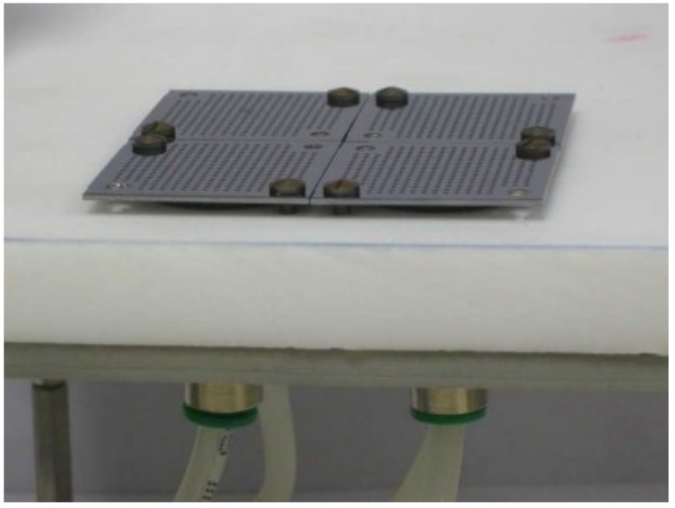
# Demonstrator: Pneumatic surface

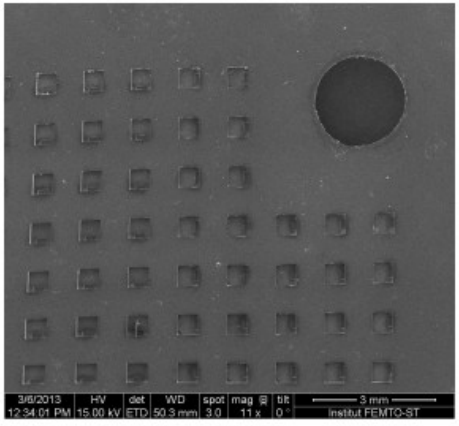
- **Quadblocks**









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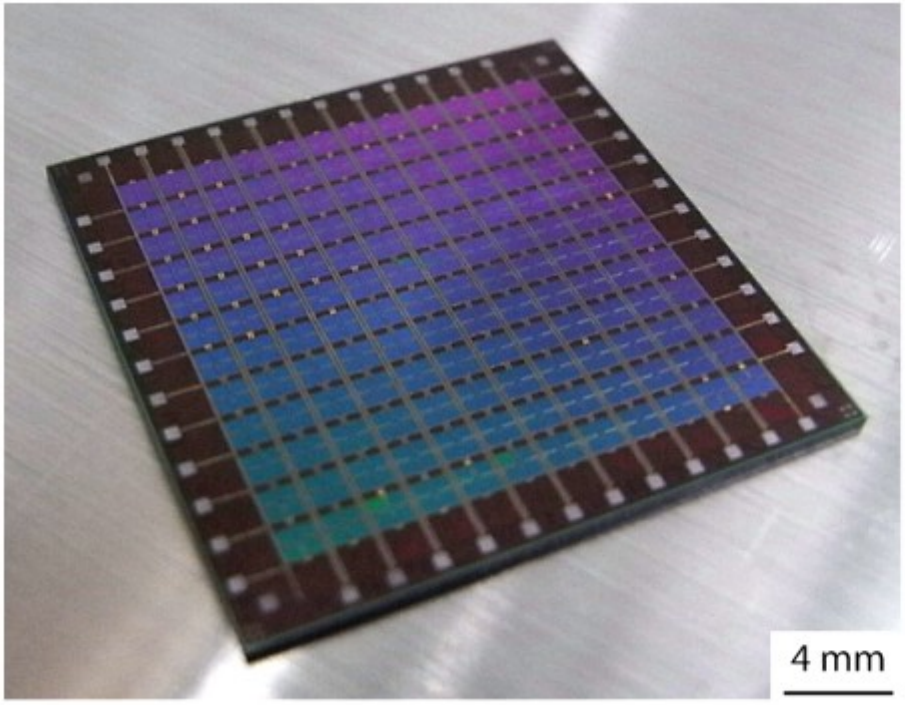
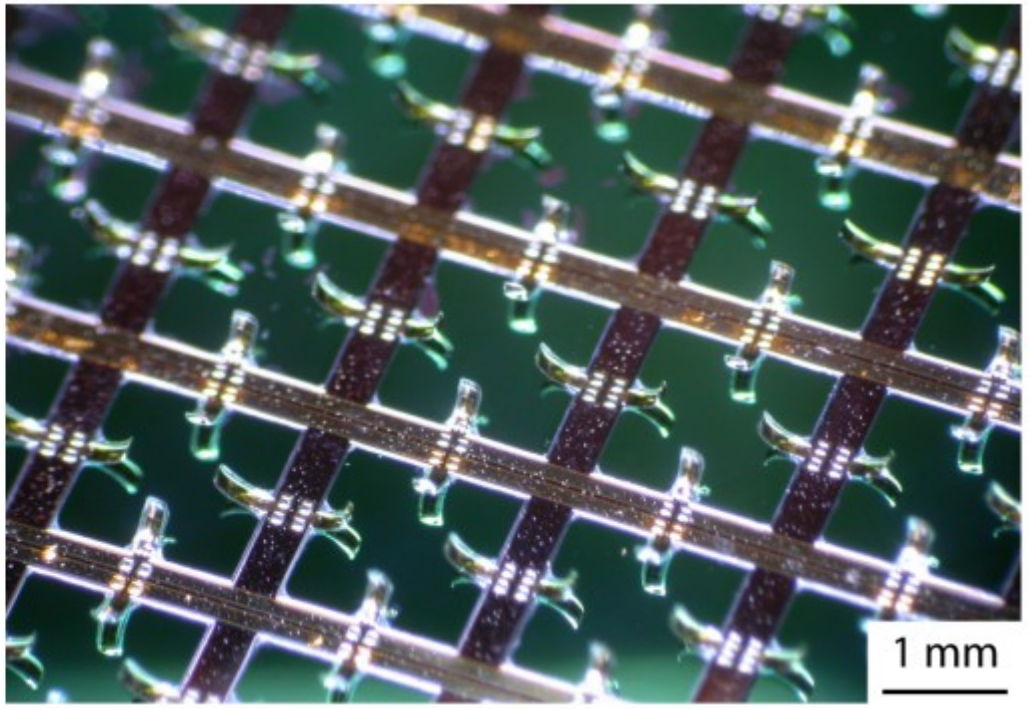
# Demonstrator: Ciliary surface

- Ciliary surface (actuators/sensors/processing)




Y. Mita,…

# Conclusion

- Our project addresses both **practical** and **theoretical** problems
- **Real experiments** and **simulations** will be used to assess its performance

- … also, this works is currently mainly funded by the french research agency (ANR), but we are looking for partners to join us in european projects.

# Questions?

# k-simultaneous consensus

- Context: asynchronous system
- Weaken the consensus problem in a k-set agreement problem
- k-set agreement can be solved despite asynchrony and unit failures when k > t but not when t >= k.

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