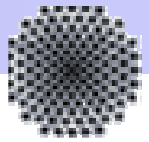


IPVS

University of Stuttgart

New principles of coordination in large-scale micro- and molecular-robotic groups

Sergey Kornienko

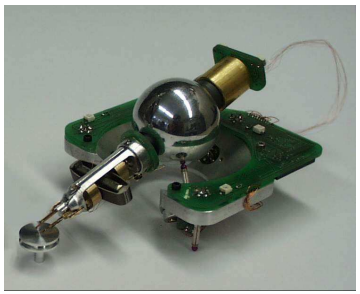
Olga Kornienko

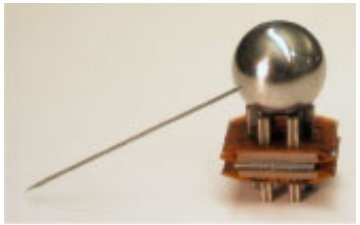
Chen Xuan, Patrick Schmider, Mauricio Fernandez, Omer Warraich,
Juan Fuentes, Frank Mletzko, Manuel Jimenez, Roland Geider, Afshin Attarzadeh, Victor Prieto,
Glenn Zetterström, Dagmar Häbe, Kristof Jebens, Tanya Kancheva

1. Large-scale micro-robotics
2. Principles of Bio-Chemical coordination
3. Examples and Experiments

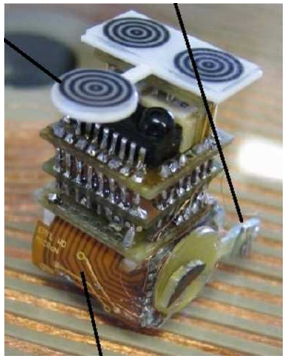
Introduction: miniaturization vs “intelligence”

MiniMan, ~100 mm cube





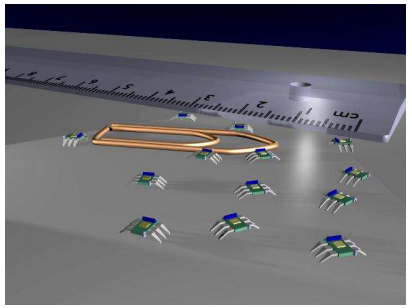
MiCRON, ~10 mm cube



Solid body
0.1-0.01 mm.
N>1

?

I-SWARM, ~3 mm cube



~1000 robots

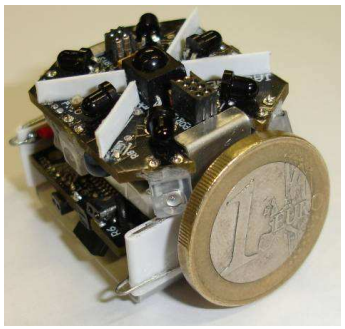
„mobile micro-/nano- manipulators“

„mobile and autonomous micro- (swarm) robotics“

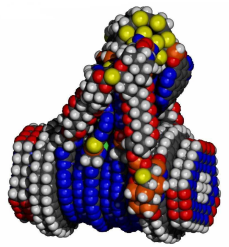
IRobot ~100 mm cube

~100 robots

Jasmine, ~25 mm cube

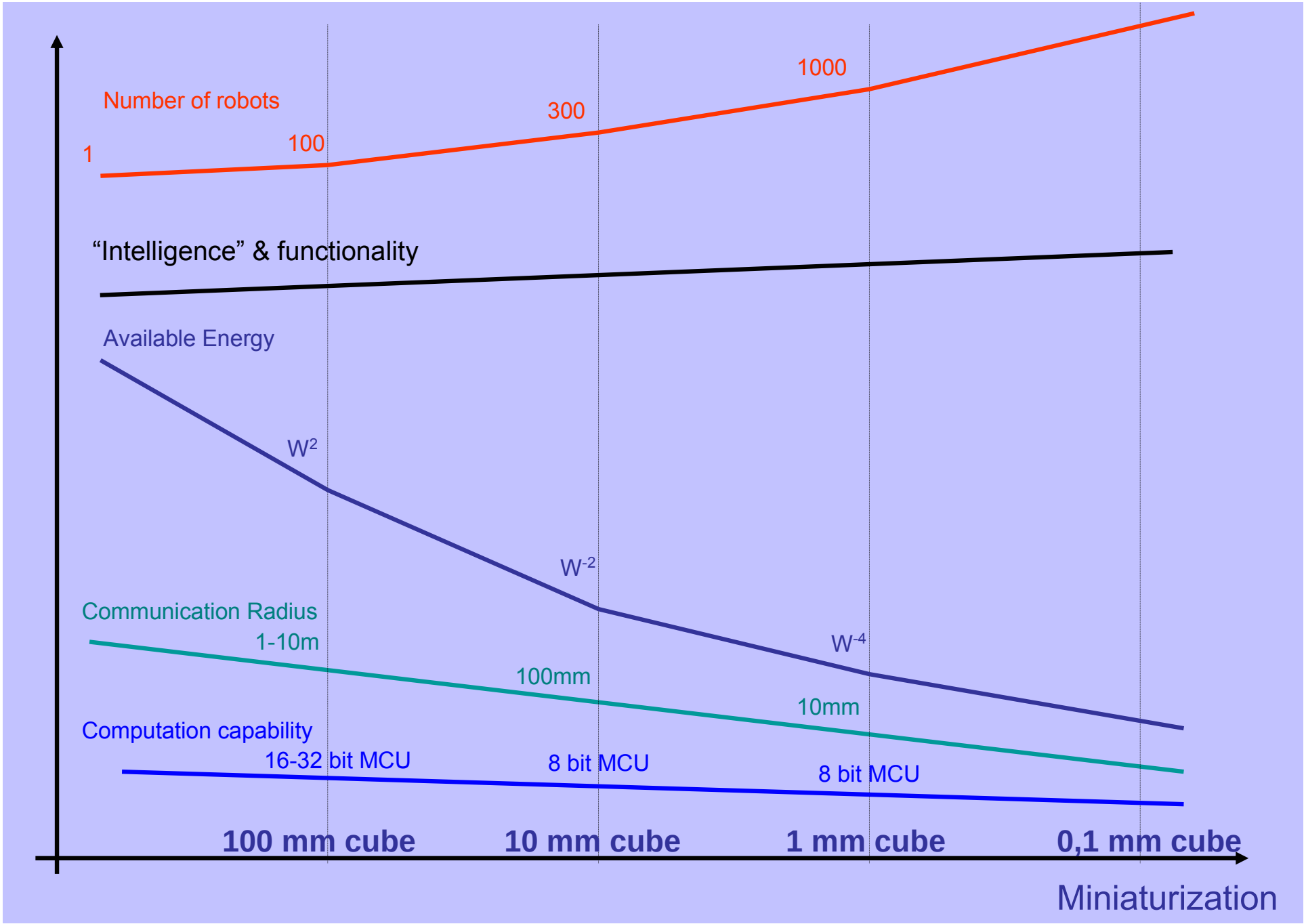


~300 robots



Molecular
0.1-0.01 mm.
N>1000

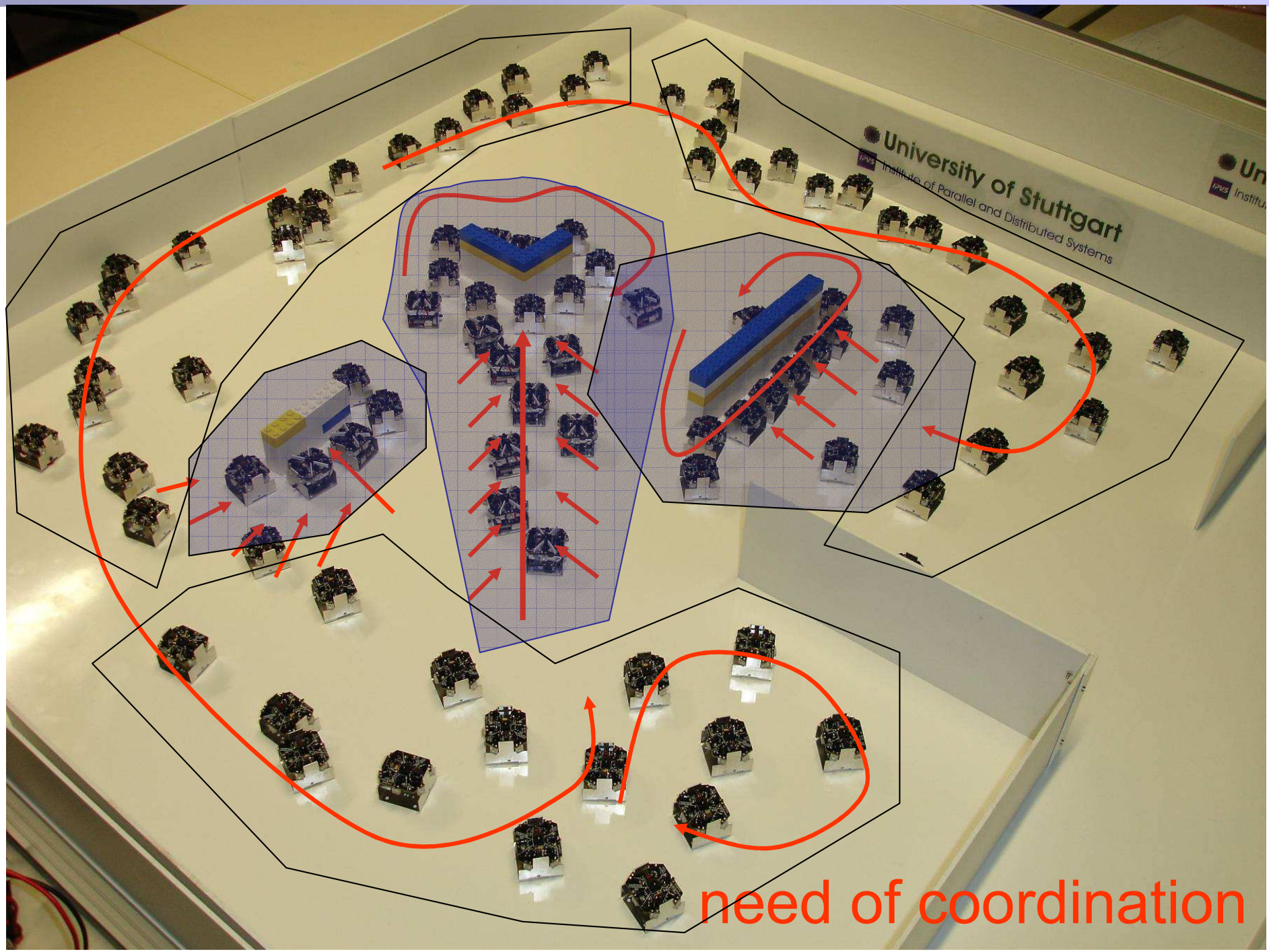
Introduction: miniaturization vs “intelligence”



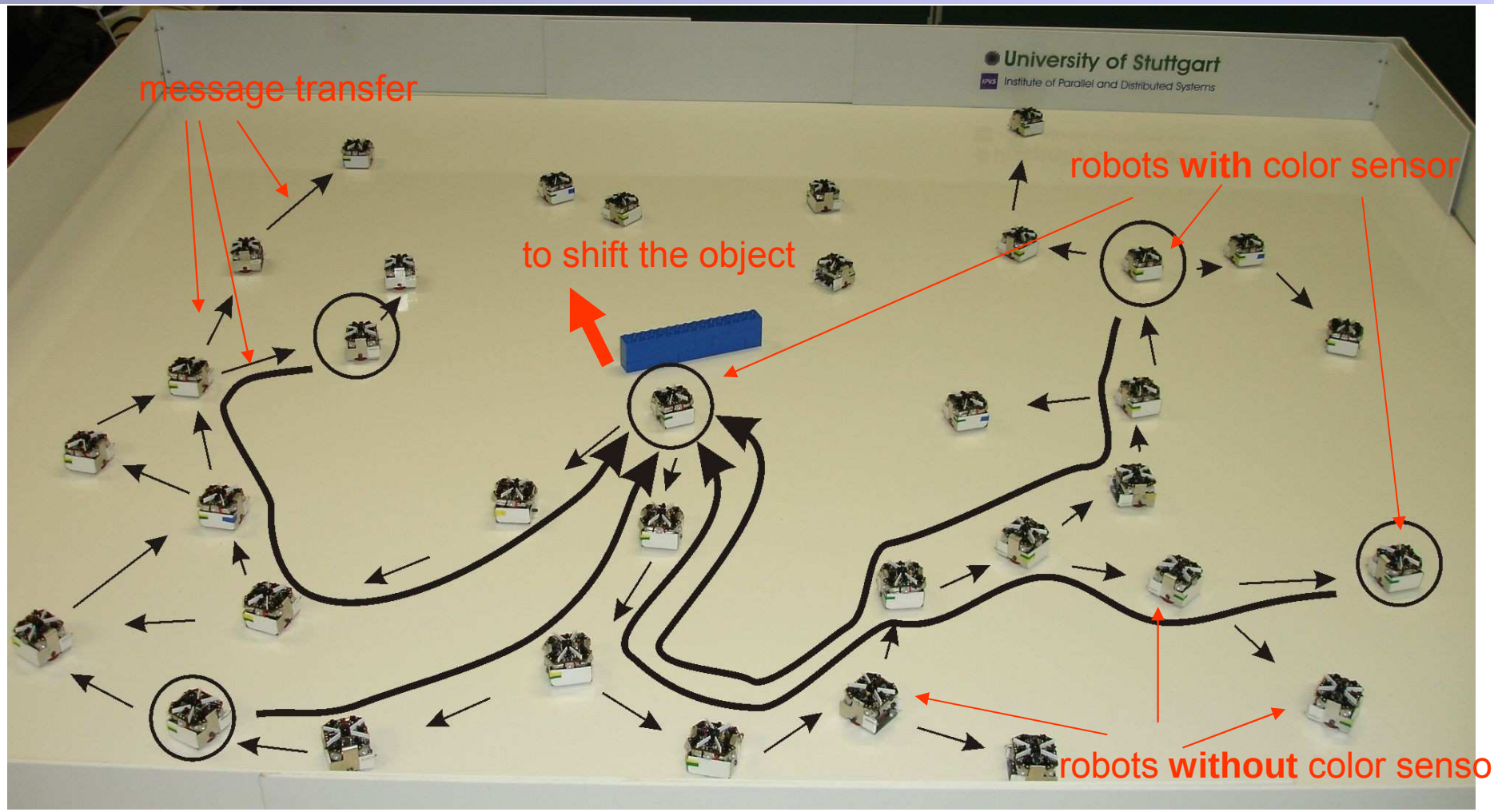
Increasing the number of robots:

What does it means ?

1. Large-scale micro-robotics: coordination



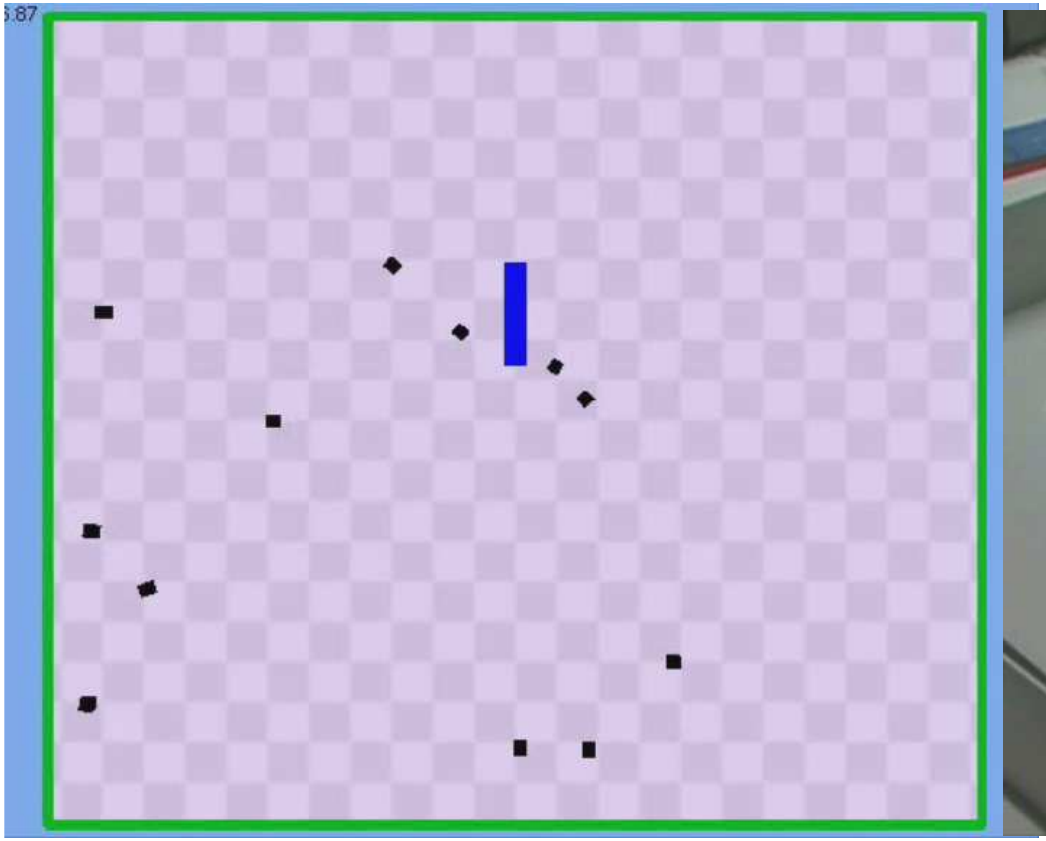
1. Large-scale micro-robotics: cooperative actuation

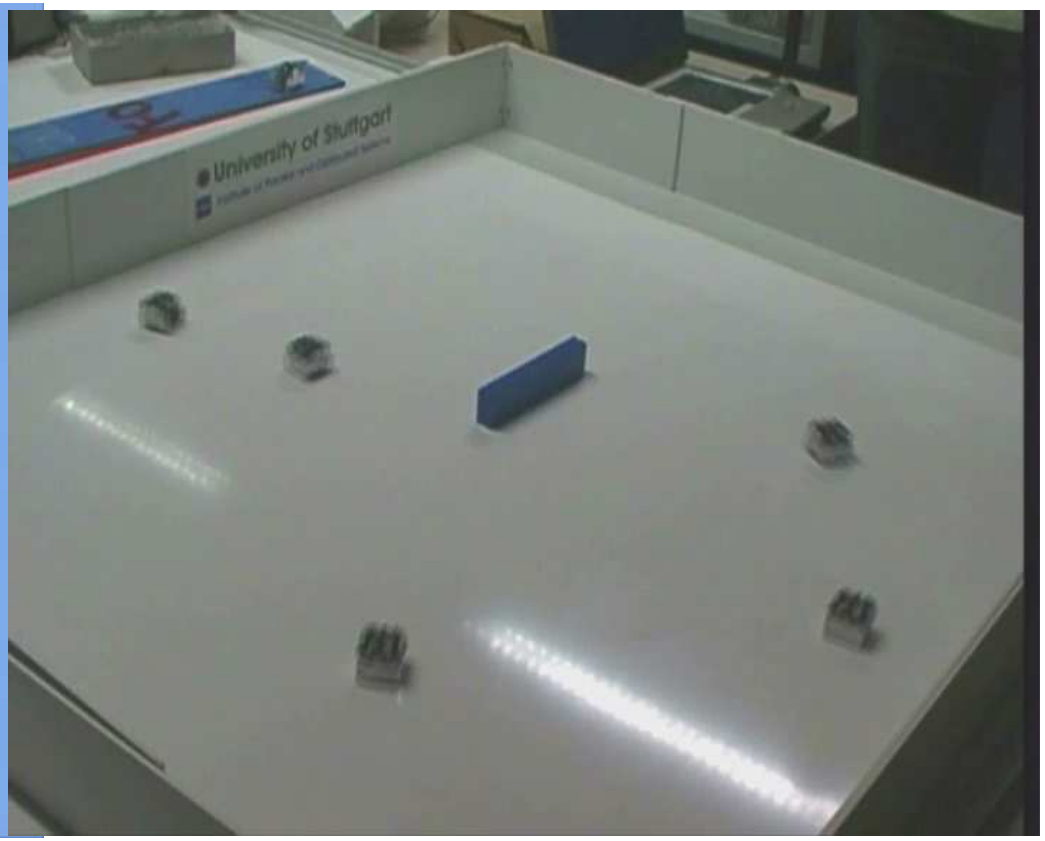


coordination means primarily communication (global message transfer) among robots:

- right transfer
- right timing

1. Large-scale micro-robotics: fail of coordination



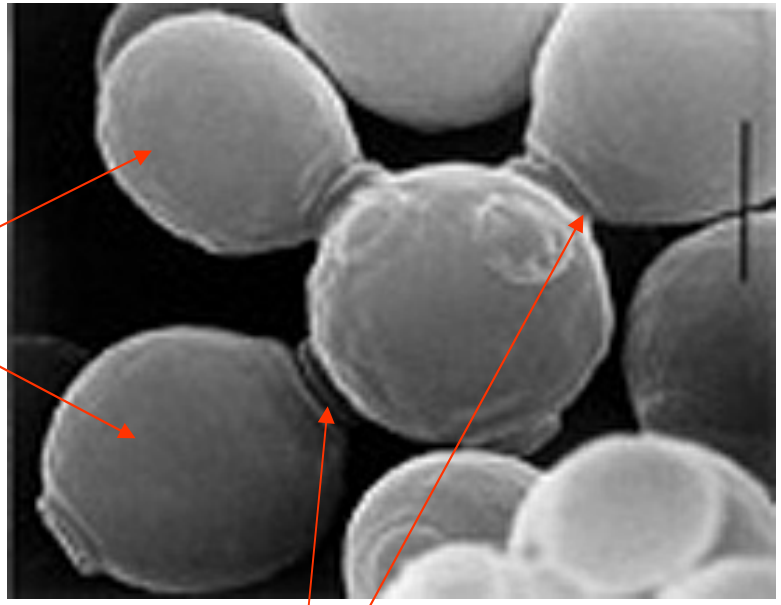


1. Coordination mean communication effort
2. Increasing the number of robots increases load on the global communication
3. In micro-systems the global communication is hard limited
4. This coordination is almost not scalable

2. Bio-chemical coordination

Distributed molecular systems process and transfer information in another way

Chemical/biological oscillators or nonlinearities



Local chemical/potential exchange

Distributed molecular systems make large-scale coordination only on this basis

biological macromolecular evolution (M. Eigen, 1971)

$$\dot{\zeta}_i = \zeta_i \left(\alpha \zeta^{p-1} - \frac{1}{\tau} \sum_{k=1}^{N} \alpha_k \zeta_k^p \right), \dim \forall i \in N,$$

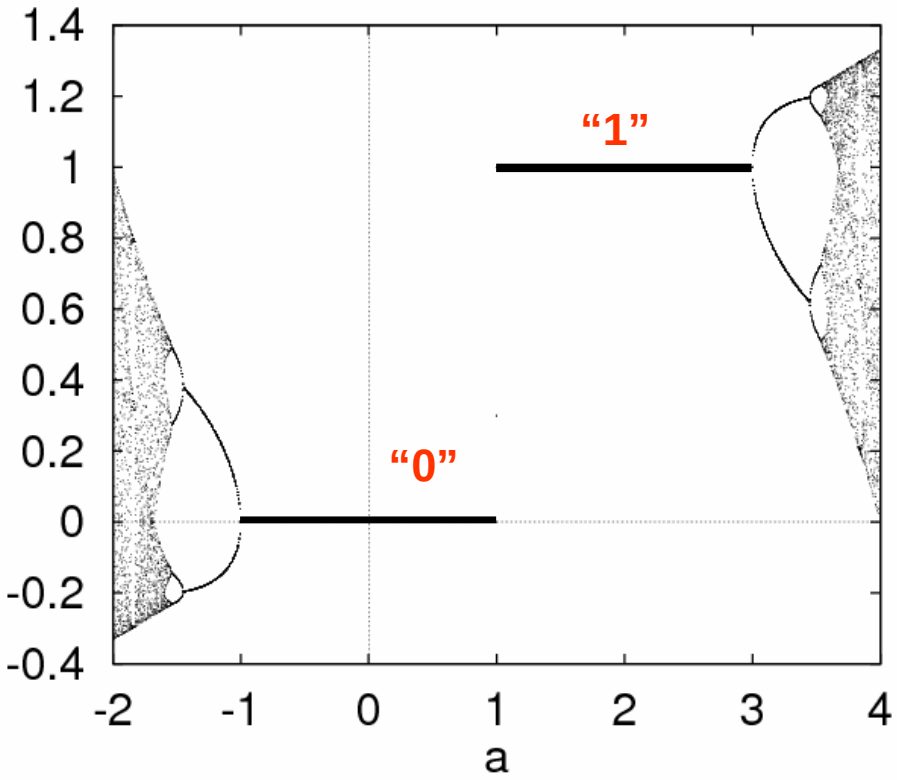
N is the number of molecules (N is large)

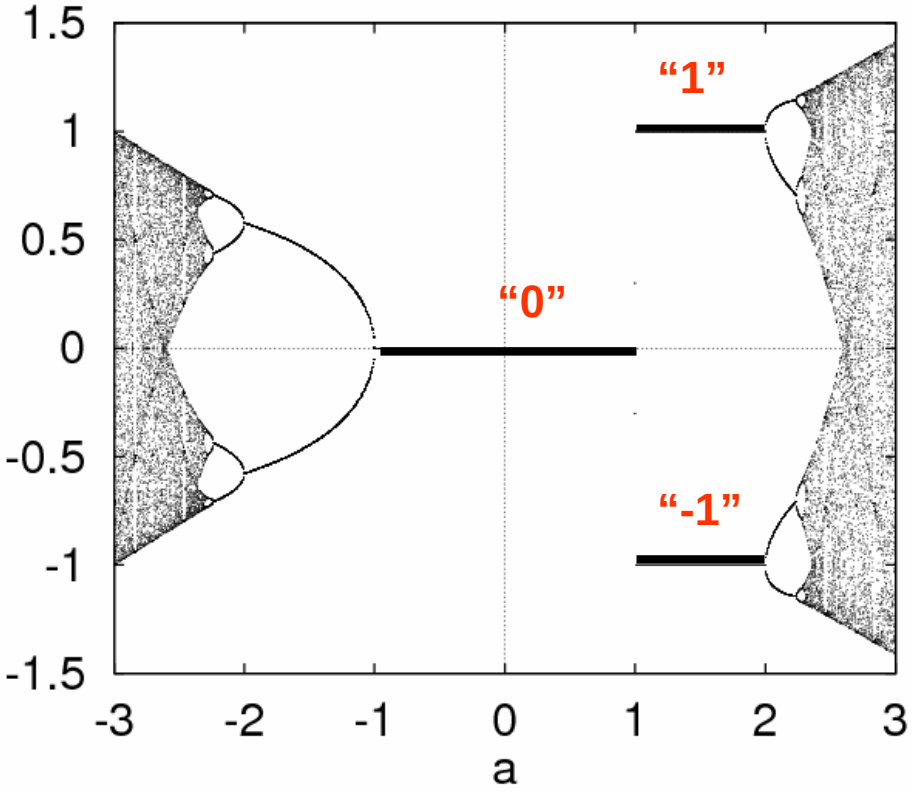
This system can be implemented:

- in chemical way;
- by analog electronic circuit
- in opto-electronic way
- by digital MCU

2. Bio-chemical coordination

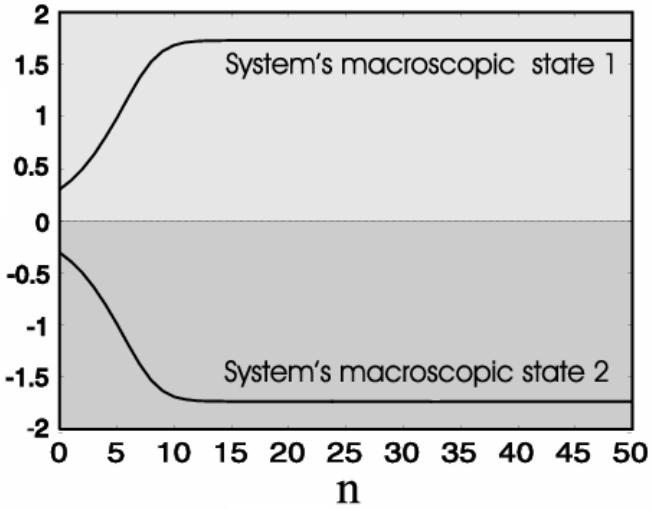
$$\zeta_{n+1} = \alpha\left(\zeta_n - (\zeta_n)^r\right) + (\zeta_n)^r, \quad \zeta_n \in \mathbb{R},$$

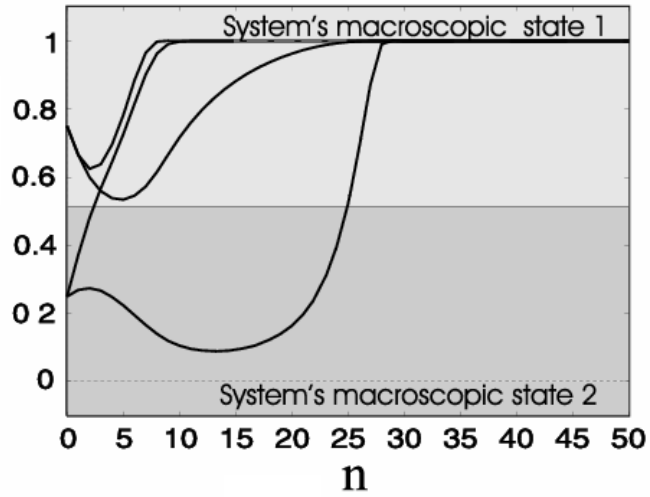




this system possesses "digital" and "analog" interfaces

Large-scale collective decision making





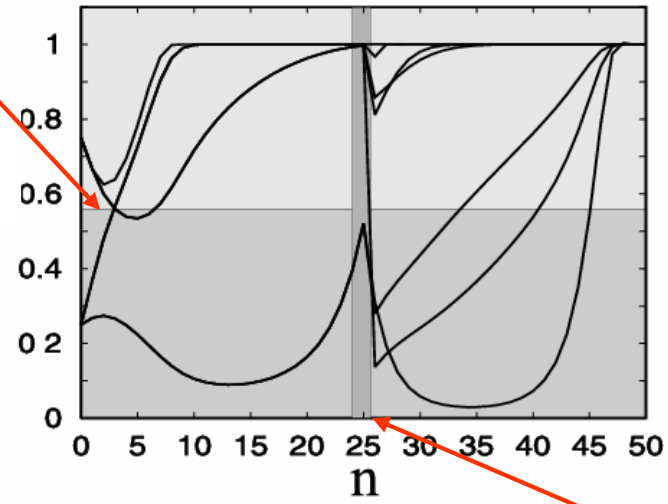
all to "1"

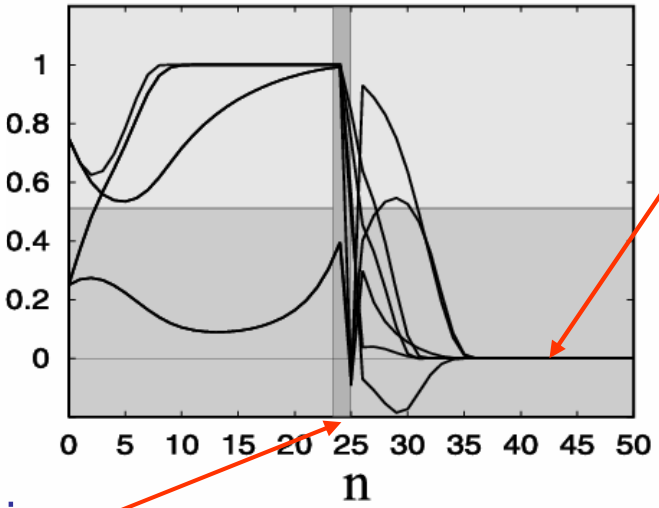
or

all to "0"

Initial robots proposals

Final collective decision

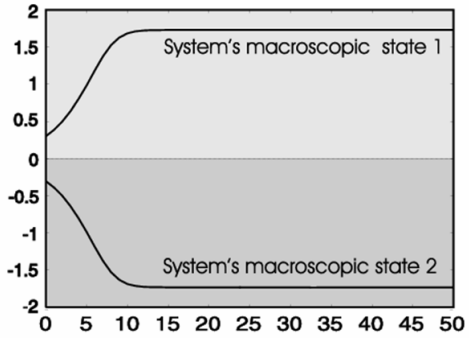




perturbation

3. Examples and experiments (1)

Each robot:
number of local
neighbors



all robot moves:
(low robots density)

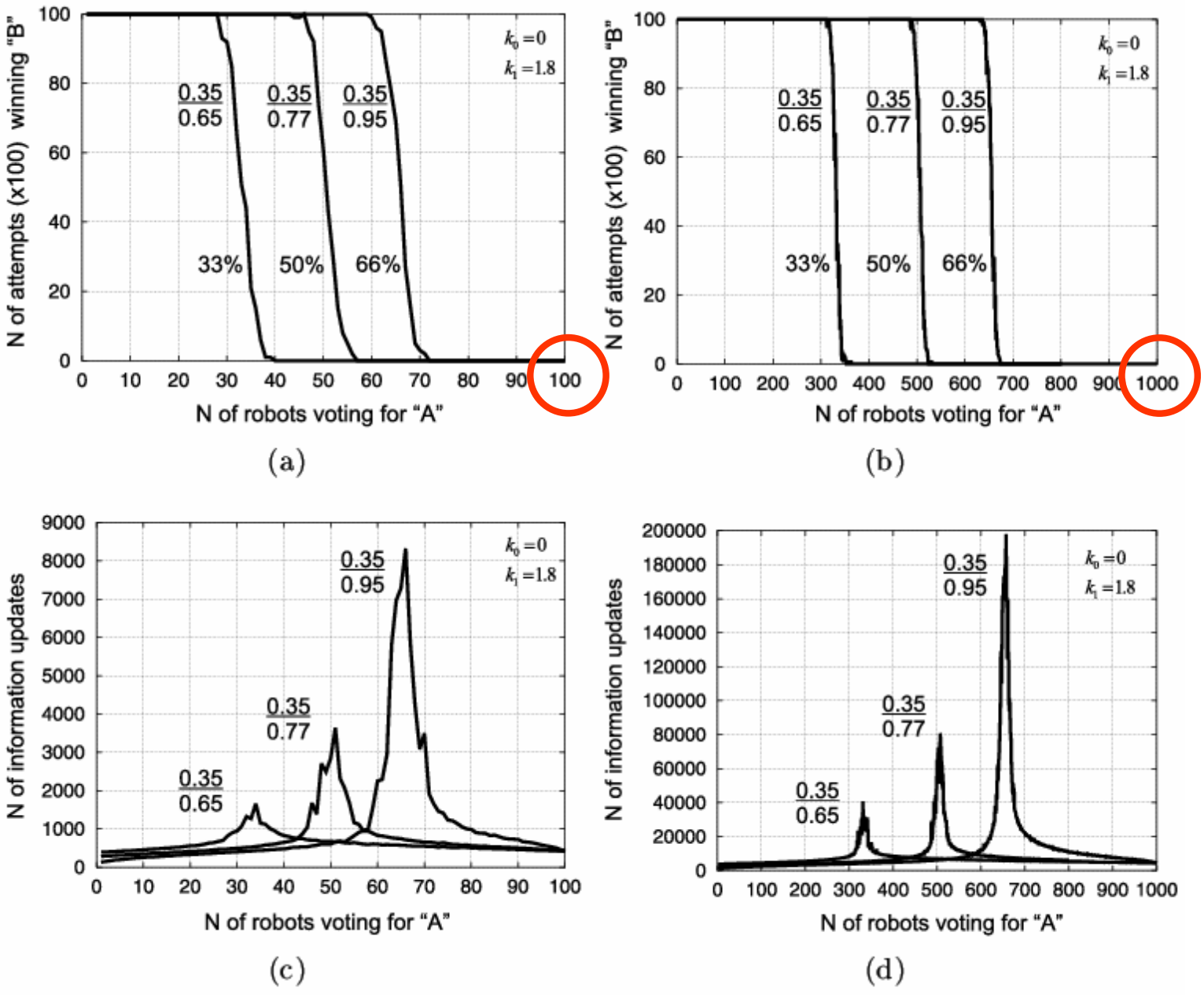
all robot stops
(high robots density)

only local interaction ⇒ know the global state

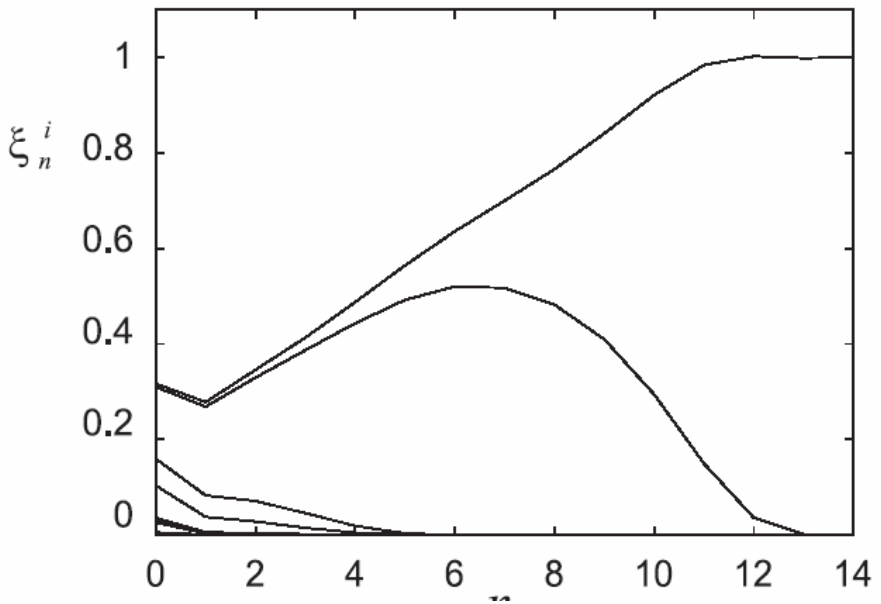
More then 17 robots

Less then 17 robots

3. Examples and experiments (1)



Large-scale collective selection process

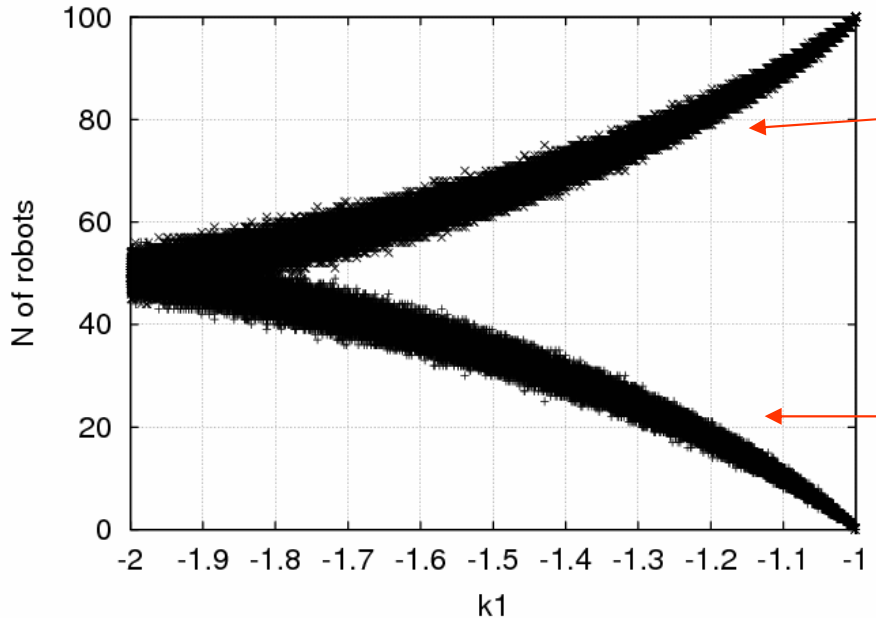


only a few equal "1"

and

rest equal "0"

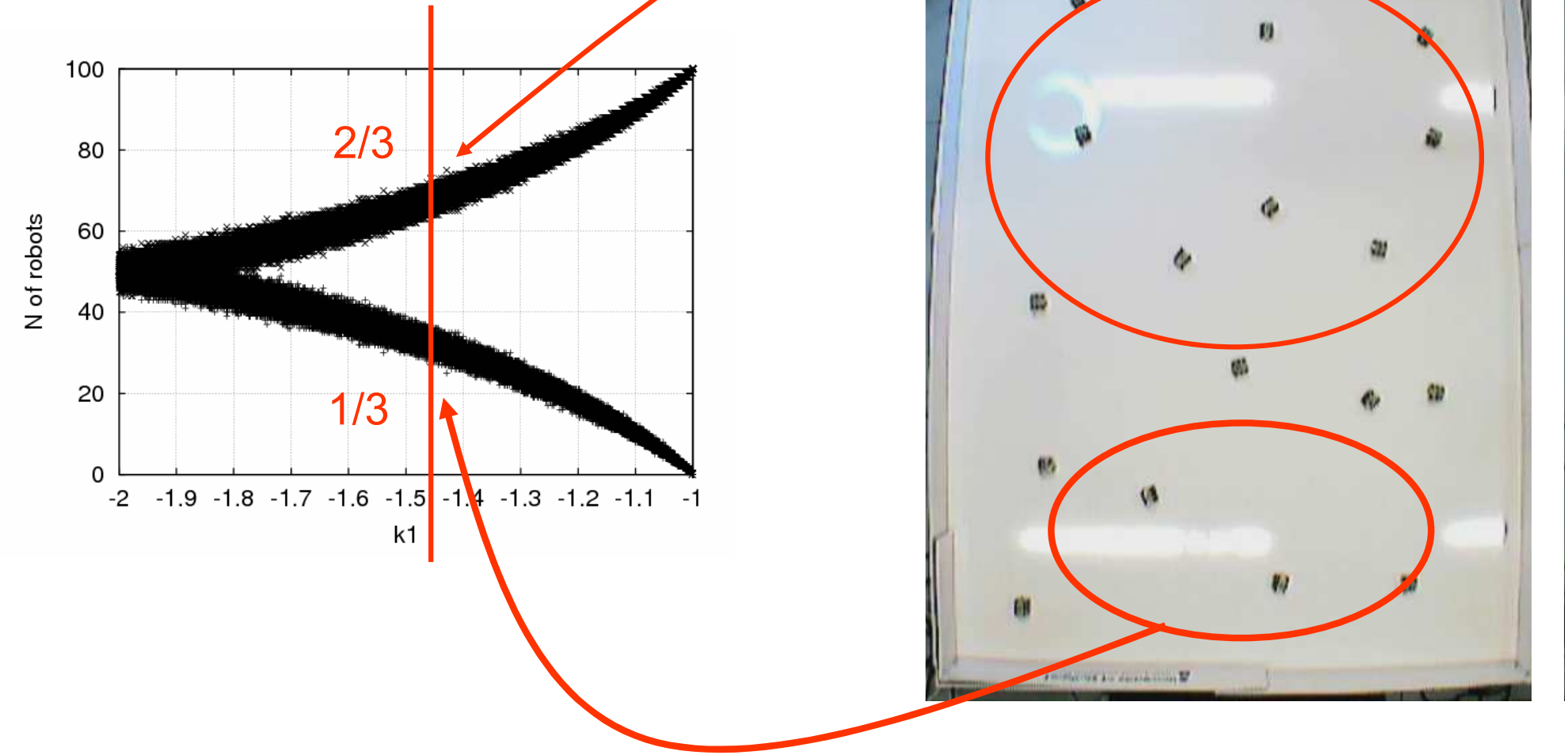
totally
100 robots



N of robots getting "1"

N of robots getting "0"

3. Examples and experiments (2)



What is possible till now:

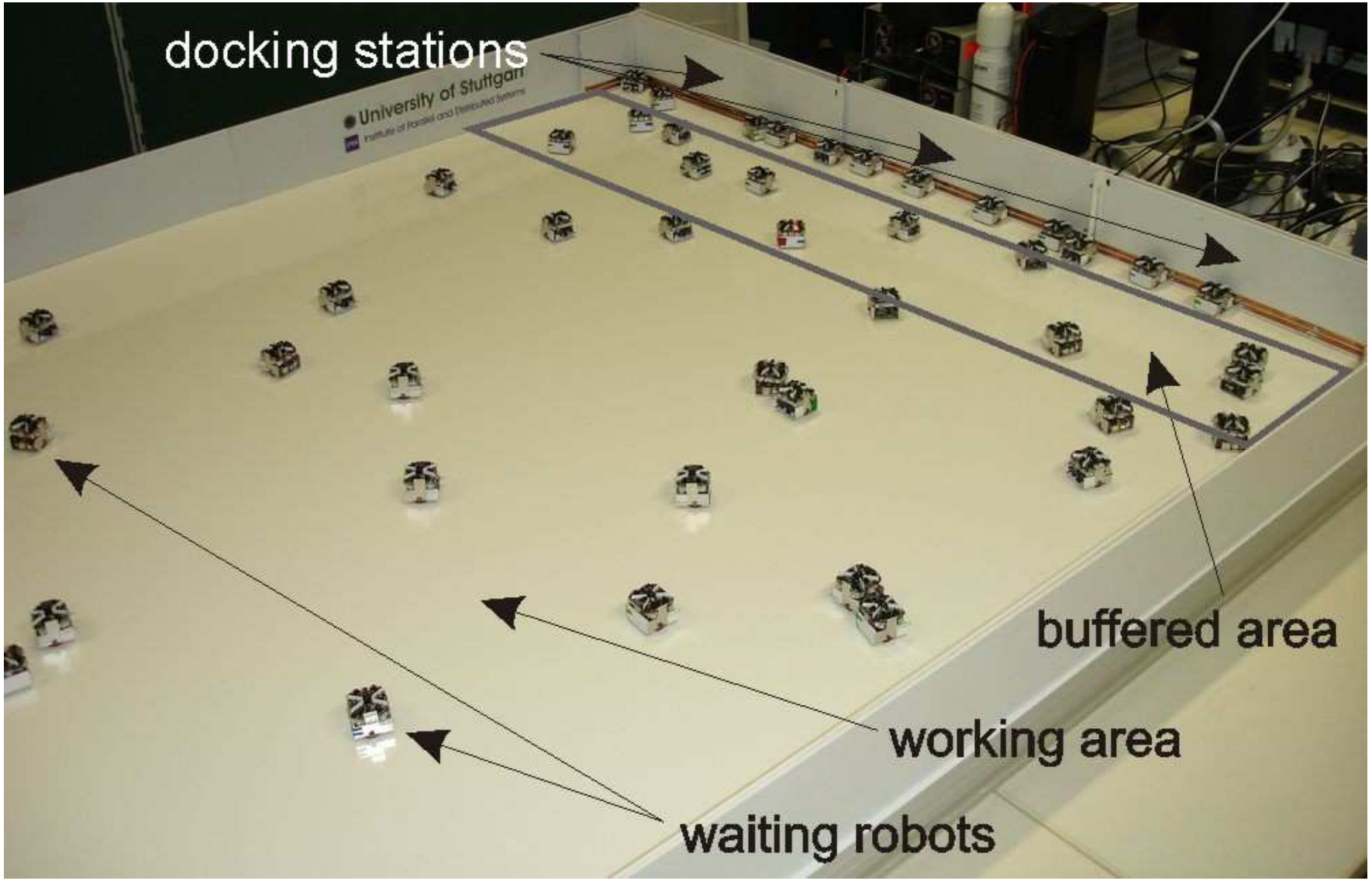
- simple distributed arithmetical and logical operations (averaging, AND, etc);

- collective decision making;

- synchronization in cooperative actuation;

- simple forms of adaptive coordination;

3. Examples and experiments



Conclusion

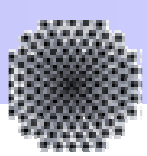
- coordination mechanisms, implementable in different physical platforms (chemical, bio, opto, analog/digital)

- no need of microcontroller/complex electronics

- no global signal transmission at all

- scalable at least up to 3 orders

- extremely robust



IPVS

University of Stuttgart

The END

New principles of coordination in large-scale micro- and molecular-robotic groups

Sergey Kornienko

www.swarmrobot.org