Indirect cooperation between mobile robots through an active environment

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Outline

1. Indirect cooperation
2. i-Tiles model
3. Experimentations
4. Conclusion

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To abstract the problem..

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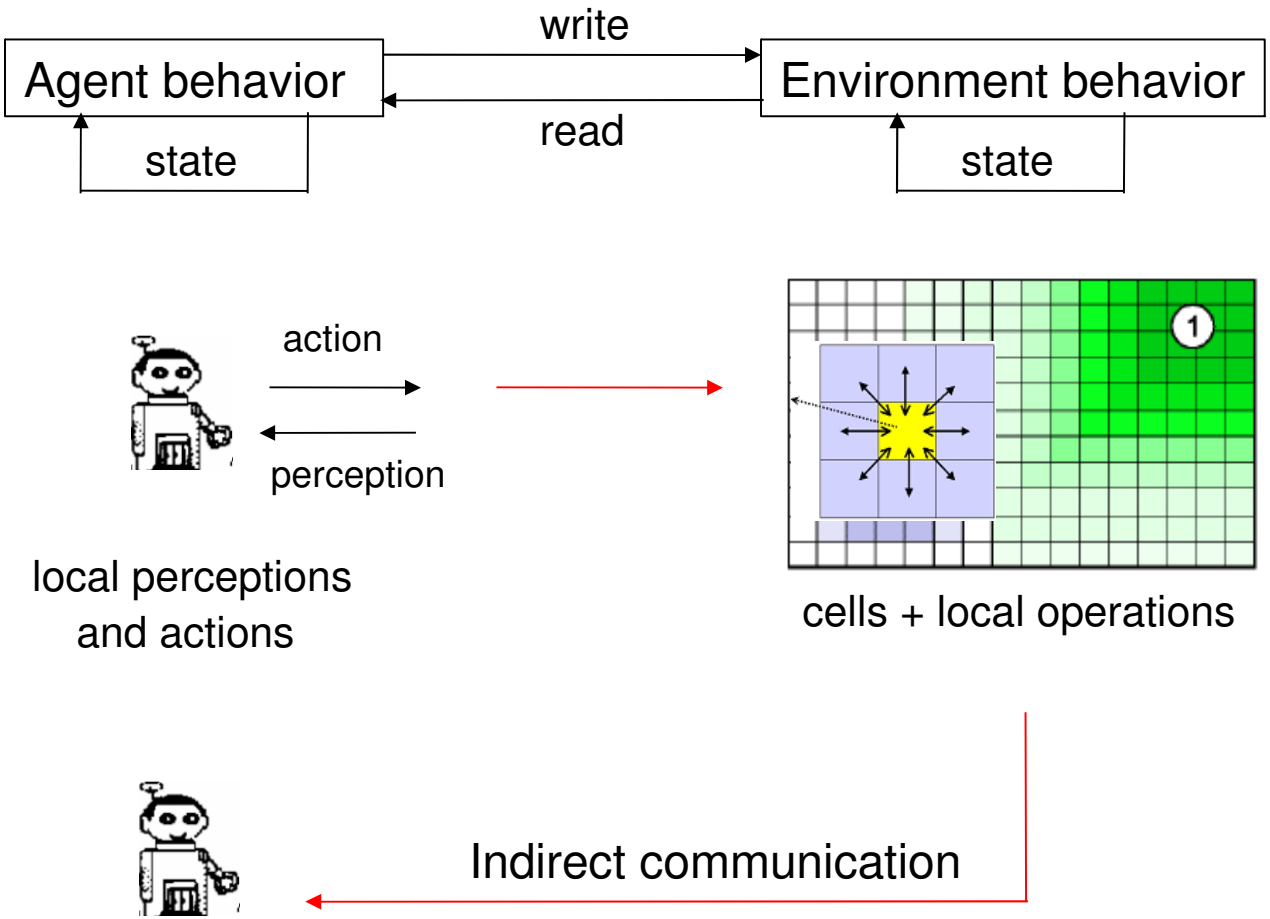
from simulations ..

.. to real robots

Indirect communication via the environment



How to define real active environments

which can **compute**

- pheromone marking/diffusion/evaporation
- message/signal diffusion

→ amorphous computing

and where **robots can**

- read/write information
- *interact with many others*

?

Existing approaches

Wireless networks/sensors

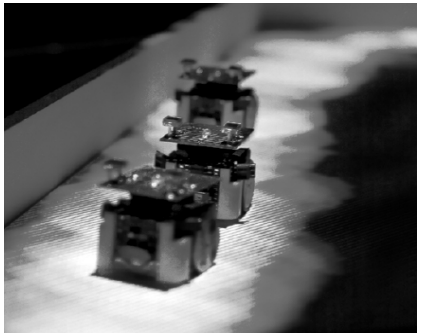
- [Mamei-Zambonelli 06] : augmented environment
- RFID tags : passive environment [Kodaka09, Park09]

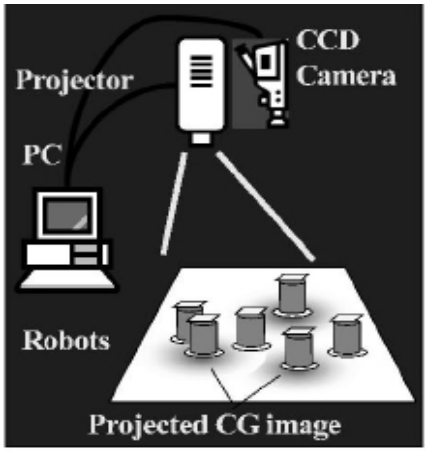
Displaying images on the ground and robots

- Video projector : passive environment

→ hard to tune, noisy

- [Wanabe06] [Theraulaz07]





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2. i-Tiles model
3. Application and Evaluation
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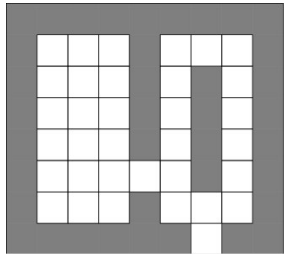
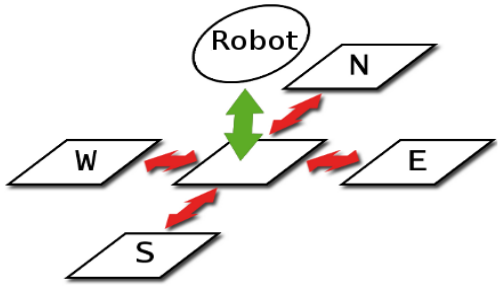
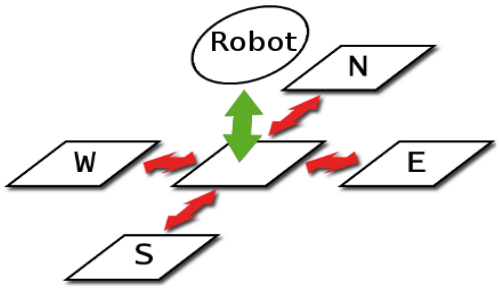
Paving the floor with communicating tiles

- Provide a regular communicating structure and a memory
  - → allow to **implement grid-based algorithms**,
  - → allow **indirect communication between robots**.
- Deployed in indoor environments





i-Tile : general features



Each tile

- executes an **autonomous process**
- uses a **limited memory**
- is **connected to its 4-neighbourings** tiles
- supports and **interacts** with **one robot** at once

Hypotheses on the mesh

- tiles are **independent** processes,
- tiles do **not** require to be **synchronized**.

Tile main process

A first thread handling

- **incoming messages** (FIFO queue)

→ execute non-blocking procedures

A second thread handling

- the **activity of the environment** (in the tile) → diffusion, evaporation, etc.

→ Details in [Pepin et al. ICAART'09]

```
While true
 If request R in queue Then
   Switch descriptor of R:
   Case descriptor_1:
      instructions
   Case descriptor_2:
      // example:
      for i in {N,S,E,W}
         send message to Tile(i)
   ...
   end Switch
  end If
end While
```

```
While true
 Every(delay1) do instructions
  ..
end While
```

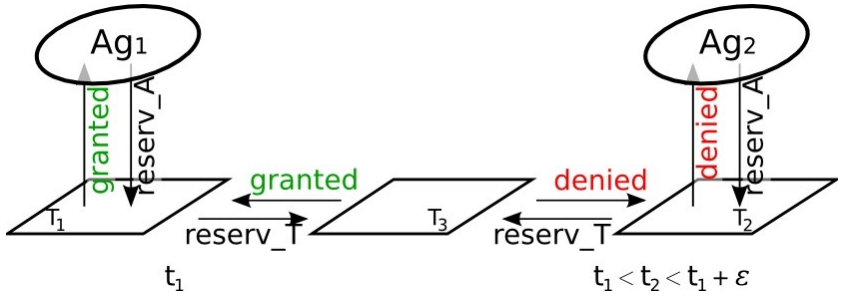
Displacement on a tile : concurrent access

A robot asks the **permission** to move on a target tile

→ it sends a **request** to its current **tile**

The target tile **grants** the access

to the **first received request**



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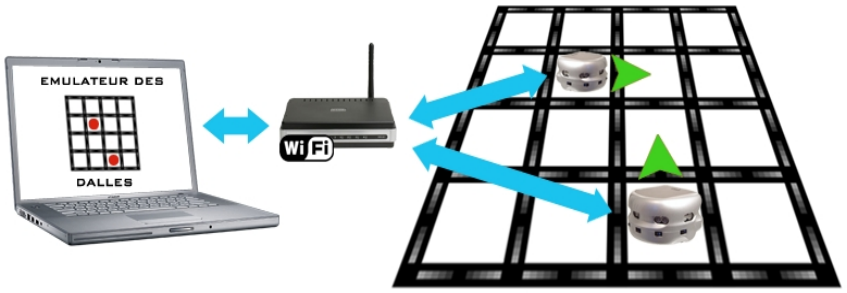
Experimental device

Khepera III robots

- can perceive tiles on floor
- no global positionning
  (nor coordinate information)
- no identification

Environment

- Tiles are represented on the floor
- Tiles' processes are emulated

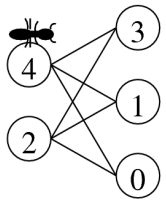


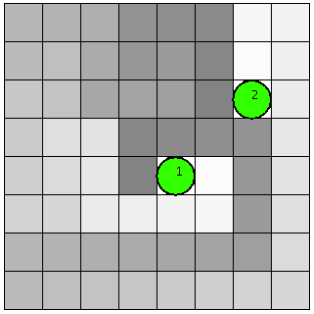
Moving on tiles : odometry correction

IR sensors used to detect

- Tiles border → angle error
- Gradient → lateral error

Experiment 1 : Digital Pheromone





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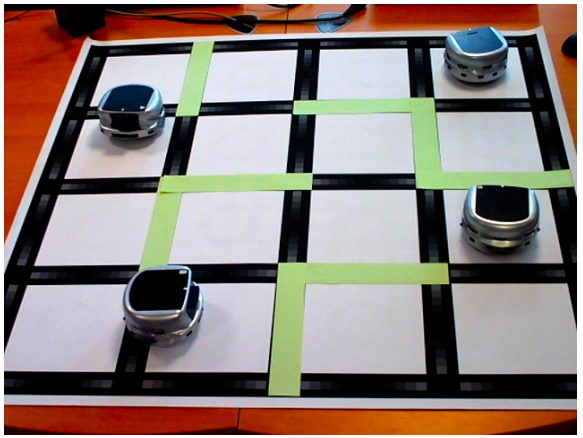
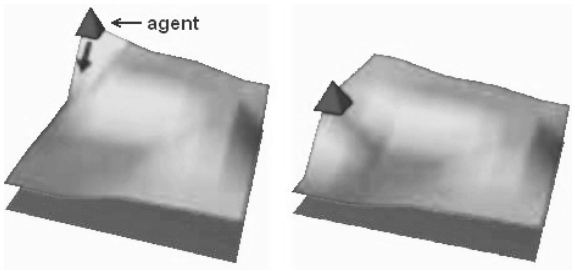


Ant-robot reading/writing pheromones, which evaporates, etc.

EVAP model in Tiles & Robots



[Glad et al. ECAI'08]

Algorithm 1: Behavior of an EVAP agent in a grid

while *true* **do**
- Find cell x of *Neighborhood* with the lowest value (in case of a tie, make some random choice)
- Move to cell x
- $Q_{pheromone}(x) \leftarrow Q_{Max}$

→ Robot

Algorithm 2: EVAP's Environment Algorithm

foreach *cell* $v \in$ *Environment* **do**
- $Q_{pheromone}(v) \leftarrow \rho.Q_{pheromone}(v)$

→ Tile

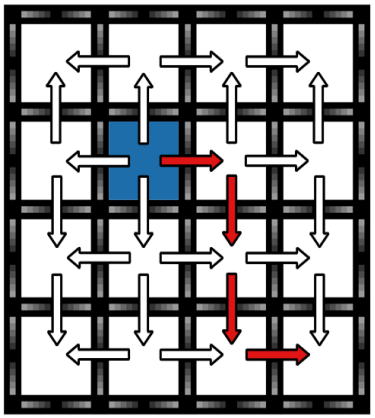
Experiment : video

Experiment 2 : diffusion of messages

Message *spread(text, nb_hop, [path])*

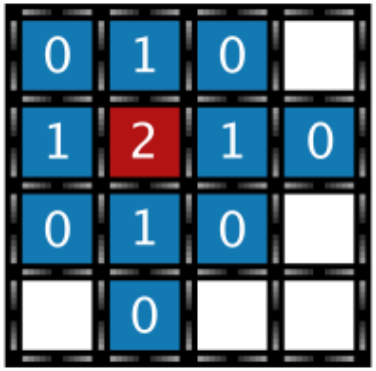
a spread message is **recursively diffused**:

- to its neighbours (except its sender)
- until counter nb_hop (radius) reaches 0



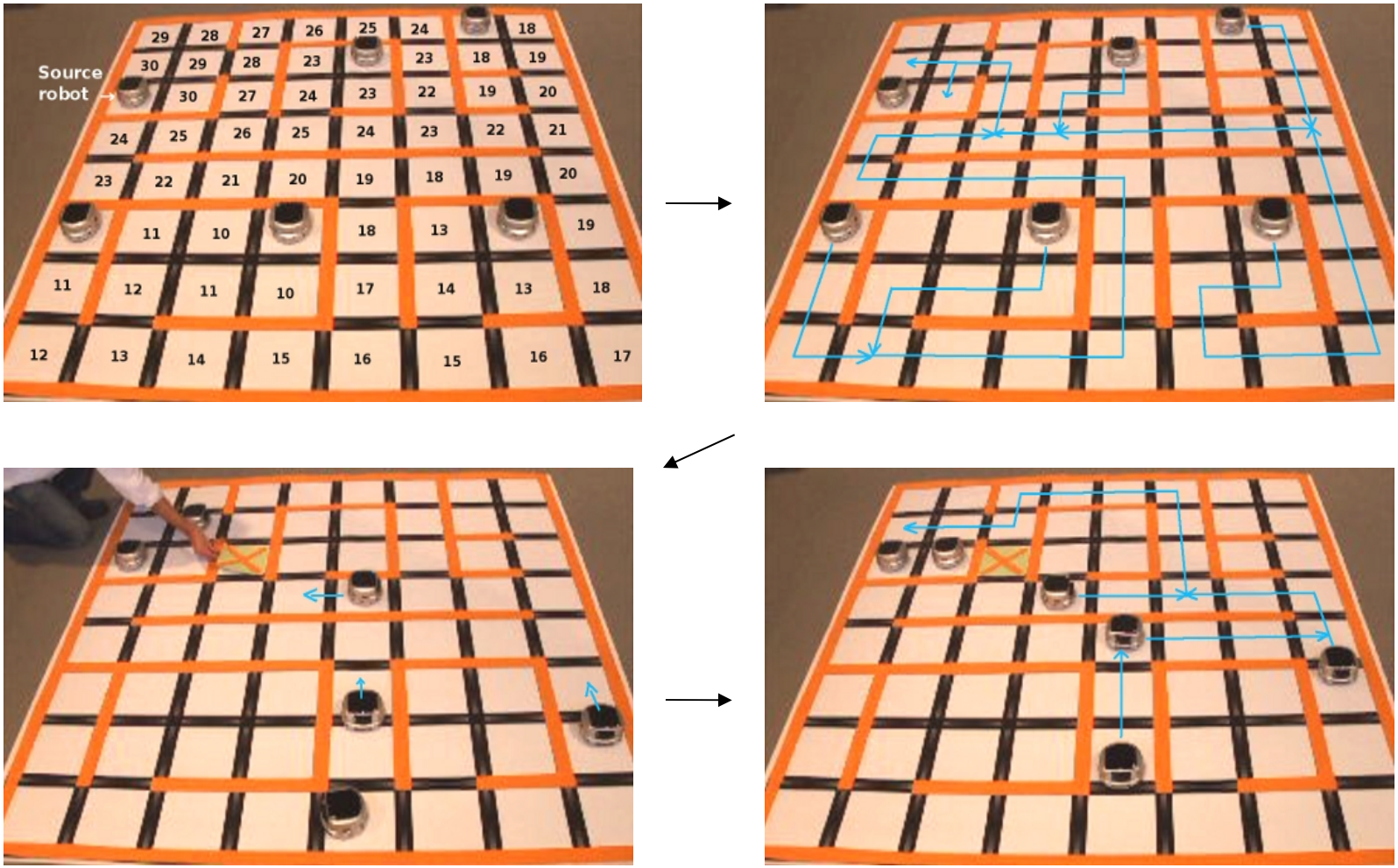
(E,S,S,E)

a tile propagates a message to its neighbours IF
- the message is new AND nb_hop > 0
- the message is known but
  nb_hop is greater
  OR the message is too old



nb_hop = 2 → 0

Dynamic path-planning (scenario)



Experiment : video

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Conclusion

First step towards indirect cooperation between robots

- i-Tiles model experimented with autonomous robots
- towards amorphous computing in real environments (CA models, digital pheromones,..)

A system based on

- local computation/connexion and using few memory

→ distributed and recursive algorithms

→ **scalability**

Perspectives

- (New) **distributed algorithms for robots' perception and comm.**
- Analysis of **performances**
- **Electronic design** of Tiles and tests with mobile **robots**

Applications

- Guidage de robots, coopération multi-robots

  Extension des perceptions, des communications..

- Actimétrie / suivi des personnes (non intrusif)

  Capteurs intégrés aux dalles → détection des chutes..

  Apprentissage des habitudes

→ CPER INRIA Lorraine « Informatique Située »

→ INRIA AEN PAL
(Personal Assisted Living)