Wireless Mobile Agent Systems

Damien Martin-Guillerez – MAASC – 12th of May, 2011

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Swarm Intelligence

Swarm?

- *A large number of insects, especially when in motion or (for bees) migrating to a new colony.*
- *A mass of people or animals in turmoil.*

Wiktionary.org, on the 9th of May, 2011

A mass of computer systems, e.g., robots

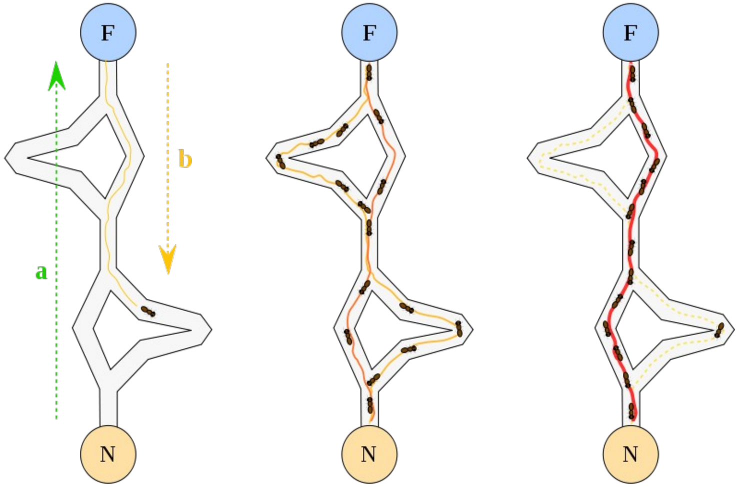
Intelligence?

- Leverage the **collaboration** of multiple simple systems
- To emerge a complex **intelligent behavior**

Techniques of swarm Intelligence

Mimicking the wild life

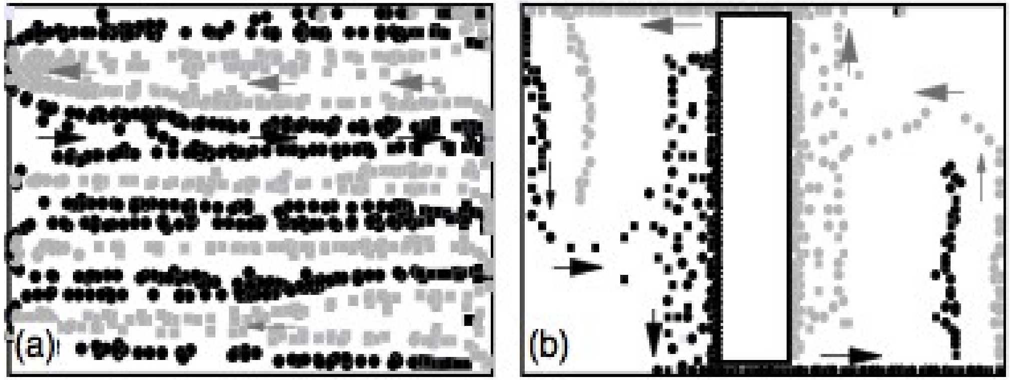
- Ants & pheromones
- Bird flocks



(Wikipedia.org, the 9th of May, 2011)

Mimicking physics

- Attraction and repulsion laws like electromagnetic
- Fluid mechanics



(Collet & Fanchon, ICSI 2011)

Multi-Agent Systems (MAS)

Agent

- Physical entity
- In a physical environment
  - Sensors
  - Actuators
- Limited computational capabilities

Multi-Agent Systems

- A model of Multi-Robot Systems (MRS)
  - Concentrate on swarm intelligence
- A model of physical particle systems

Wireless Mobile Agents

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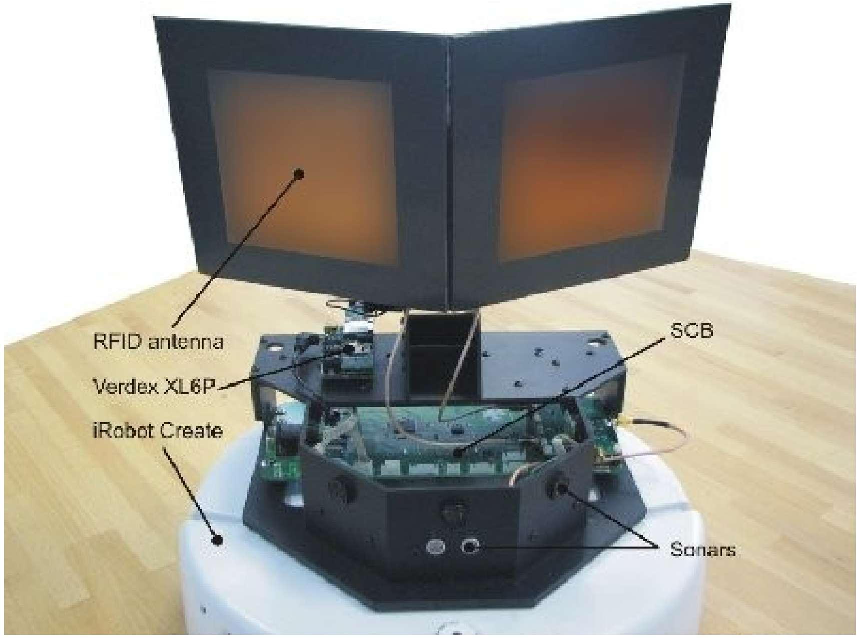
From a swarm robot

Roboswarm FP7 project robot

- Roomba iCreate
- Sensors
  - Laser range finder
  - Sonars
  - Bumper
  - RFID Reader
- Communication using WiFi
  - Bad in practice
  - Ad-hoc mode only
- Embedded linux
  - Low computational power
  - Low memory



(Roboswarm.eu, the 9th of May 2011)

A model of this swarm robot

A wireless mobile agent

- Interacts in a 2D physical world
- Has a simple behavior described by a state automaton
- Has **a short-range communication medium**
- Has **no global communication means**
- Consumes energy or other items

A model of most Multi-Robot System

- EPFL SwarmBot, MIT Swarmbot, I-SWARM, RoboSWARM, ...
- Nano-robots

The Holy Grail

Identifying compositional patterns to program WMAS

1. Simple programming patterns that give simple global behaviors
2. Rules to combine those patterns

Discrete model

Time and space discretization

Model 1 enables simulation

- Time and space discretization using small deltas
- Simplification of sensing and acting
  - No error
  - Simple energy / cost model

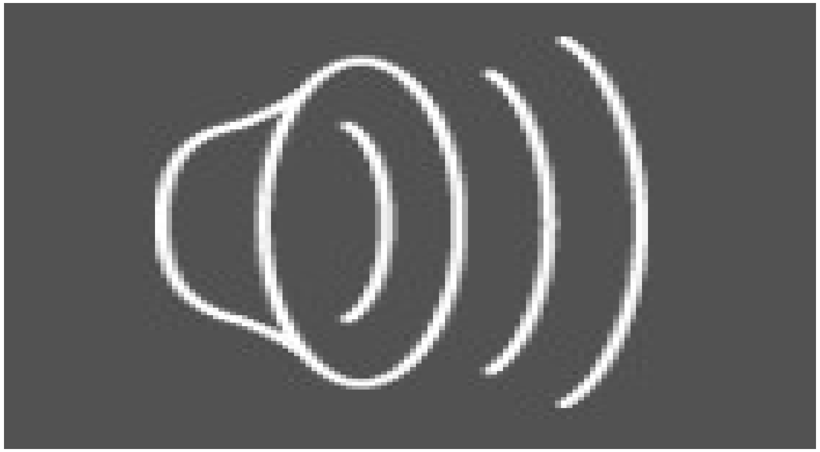
Enables tests

- On large population
- Large number of tests

Time and space discretization

Possiblities	Previous direction	Next agent state and direction	Decision
→	¬←		→
↑ ¬↓	←→↑↓		↑
↓ ¬↑	←→↑↓		↓
↑↓	← →		↑↓
↑↓	↑		↑
↑↓	↓		↓
←→	←		←
←	→↑↓	Same class ←	←
←	→↑↓	Opposite class → closer to its goal	←

(Martin-Guillerez & Fanchon, IntelNet 2010)



Time and space discretization

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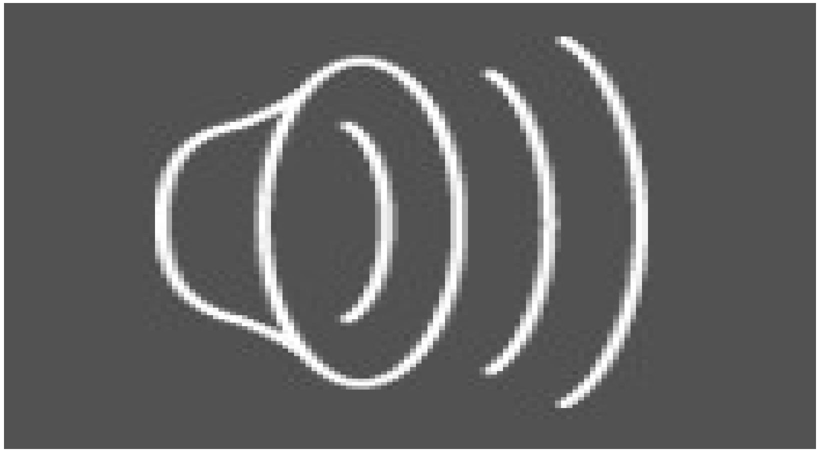
(Martin-Guillerez & Fanchon, IntelNet 2010)



Logic

Model 2 – Complete discretization

- Time atomicity = 1 action per unit of time
- Space atomicity = an agent takes exactly 1 unit of space

Linear Temporal Logic

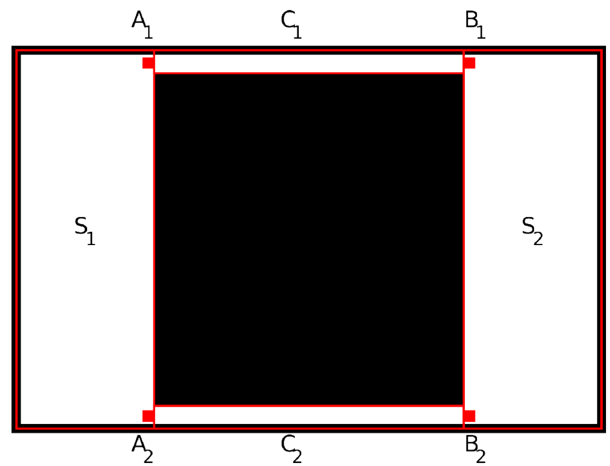
- $\neg, \wedge, \vee, \forall, \exists$
- O, ◊, □
- *succ, prec, left, right, top, bottom, state*
- Axioms: separation, celerity max 1, no collision

  Similar to *spatial logics* (Balbiani & Condotta, MFI 2001)

Proof of stabilization properties

- The carrier example

Proof of the carrier example stabilization



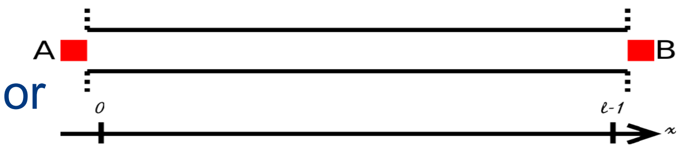
Decomposition of the space

- Two corridors C_1 and C_2
- Two storage places S_1 and S_2

Behavior is described by 5 relations

Properties proven

- A corridor has a direction and keeps that direction until all agents of this direction exit
- First agent to enter a corridor determines the direction of the corridor
- Density of S1 and S2 determines if the system is stable or not: $|S_1| + |S_2| > 2\frac{S}{l} + 2$



Logic

Enables

- Proof of properties of swarms
- Identification of hidden parameters
- Identification of compositional methods

Challenges

- Is model 2 equivalent to model 1?
  - Any system of model 1 can be represented in model 2
  - Transition between the two models can be hard
- Minimal logic to proof all properties in model 2?
  - Predicates, axioms, operators
  - Other logics: shared-memory systems, spatial logics
- Releasing the atomicity rules
  - Especially time

A programming framework

A programming framework

Several patterns identified

- Pheromonal foraging
- Physical laws movement

But...

- Not enough
- Not proven
- Properties are not identified
- **No compositional rules**
  - Work on tuning physical laws by (Collet & Fanchon, 2011)
  - Work on a programming framework by (Miller, 2009, PhD)

Conclusion

Multi-Agent Systems

A field with lot of existing works...

Multi-Agent Systems

A field with lot of existing works...

… and lot of challenges

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… and lot of challenges

Compositional framework

Reusing simple patterns

Proving patterns

Interesting related work

Collet: http://homepages.laas.fr/collet

Balbiani: http://www.irit.fr/~Philippe.Balbiani/ - *Spatial logic*

MAC Group at IRIT: http://www.irit.fr/Problematics,448

The Swarm Application Framework
http://maple.cs.umbc.edu/~don/projects/SAF/

Don Miller http://maple.cs.umbc.edu/~don/

And works of L.E. Parker on swarm robotics

Thank you!