AMYBIA: Aggregating MYriads of Bio-Inspired Agents

N. Fatès[1], B. Girau[2], H. Berry[3], G. Théraulaz[4]

[1]MAIA, CRI Nancy [2]CORTEX, CRI Nancy [3]ALCHEMY, CRI Saclay [4]Univ. Paul Sabatier, Toulouse

http://www.loria.fr/~fates/Amybia/project.html

Université Paul Sabatier Toulouse III

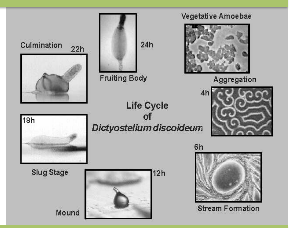
Introduction

General Issue

- Controlling massively parallel systems at low costs necessitates the development of new decentralized and locally expressed algorithms
- Need methodologies to control the emergent behavior of a myriad of locally interacting computing elements with defects or faults in their operations
- Present in several fields: job/tasks on a computer network, swarm robots on a surface.

Decentralized Gathering & Biological Inspiration

- Identical agents are initially randomly scattered and have to group to form a compact cluster
- They have no idea of their position but can send & relay messages, possibly with errors and perceive the state of only their neighboring cells
- To find minimal ingredients, we use inspiration from the social mold (amoeba) *Dictyostelium discoideum*

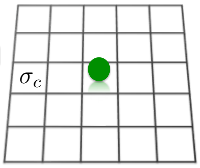


The Model

The Environment Layer

- A simple (*M*-state) Cellular Automata:

$$\sigma_c^{t+1} = \begin{cases} M & \text{with proba } p_T \text{ if } \sigma_c^t = 0 \\ & \text{and card } \{E_c^t\} > 0 \\ \sigma_c^t - 1 & \text{if } \sigma_c^t \in \{1, \dots, M\} \\ 0 & \text{otherwise} \end{cases}$$

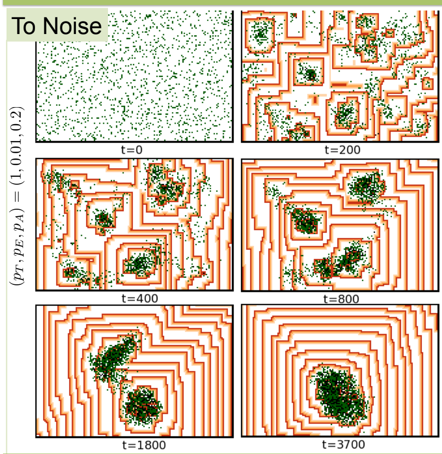


The Amoebae Layer

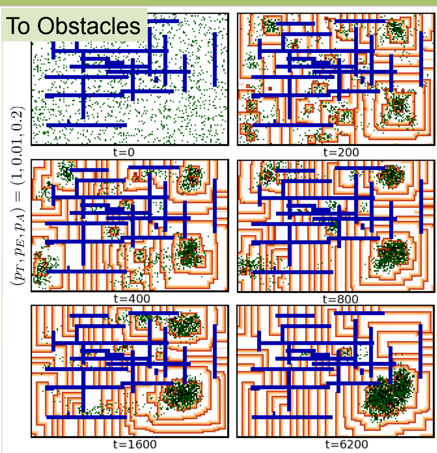
- For each amoebae: With proba p_A move to a neighbour free cell randomly. Else move randomly to a neighbouring free *excited* cell
- Coupling: $\sigma_c^{t+1} = M$ with proba p_E if $\sigma_c^t = 0$ and $P_c^t > 0$

Robustness

To Noise

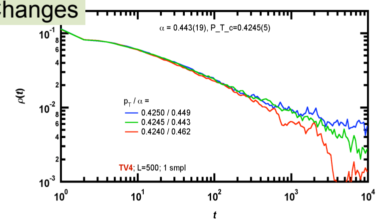


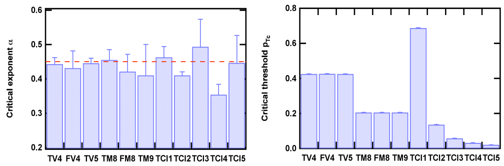
To Obstacles



To Topology Changes

- The active/ absorbing phase transition at low p_T





Various neighborhood topologies

Hardware Implementation on FPGA

Objectives

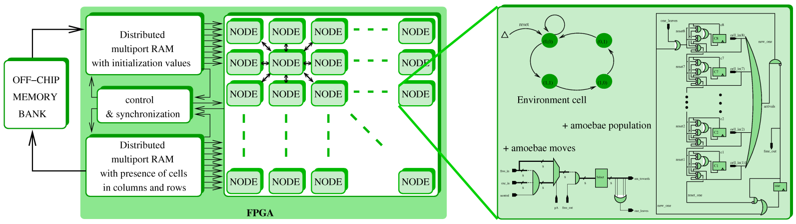
- Fast implementations to explore the model complex dynamics
- Test the model as efficient solution for large amounts of distributed computing units

Means

- Fully distributed implementation
- Optimized distributed random number generators with flexible precision
- FIFO implementation of each local population of amoebae

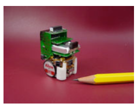
Results

- Implemented on a Xilinx Virtex 4 (135,168 logic cells)
- Speedup: x22000 (w.r.t. Pentium 4.2 GHz)
- But : only 30x40 environment size (LFSRs for random number generation: 50% of the FPGA resources)
- Next step: block-synchronous implementation (same speedup, larger environments)



Implementation on ALICE Robot Swarms

- Objectives: Sanity Check of our algorithm in "real conditions", i.e. to gather small mobile robots (with G.Theraulaz & S. Garnier, Univ. Toulouse).
- The device is made of three parts :
  1. An arena where the robots move (≈ 1 m x 2 m)
  2. A digital camera that acquires images of the scene and a video projector that enlightens the area
  3. A computer that receives the camera signal and that controls the image sent by the projector
- ALICE® robots react to light gradients (2 sensors) and hold a red diode to monitor their position.
- First experiments were run to calibrate the system (wave speed & gradient length, position of the robots, wave firing)
- Current work: how to program the robots for a correct response to the light signals.



Future Challenges

- Explore (simulations) the model complex dynamics and the coupling between the 2 layers
- Confirm the implementation on FPGA and robot swarms
- Quantify its main statistical properties:
  - average number or size of the aggregates as a function of time and parameters (including noise, failures, obstacles or topology)
  - average time to obtain a single (giant) aggregate,
  - expected final center of mass as a function of the initial positions…
- Compare performance (eg with ant algorithm
- More elaborate simulation tools (eg MGS, with O. Michel, Univ. Evry)
- Use evolutionary algorithms on the rules to obtain other decentralized behaviors

Publications of the ARC / Deliverables

- **PUBLICATIONS**:

- N. Fatès (2008) Gathering Agents on a Lattice by Coupling Reaction-Diffusion and Chemotaxis, submitted to *Physica D*, preprint HAL inria-00132266
- B. Girau and C. Torres-Huitzil (2008) Fast implementation of a bio-inspired model for decentralized gathering, submitted to the *2008 International Conference on ReConFigurable Computing and FPGAs, Reconfig'08*, Cancun, Mexico, December 3-5, 2008

- **SOFTWARE**:
  - The model and all its variations is implemented in N. Fatès' Software FiatLux (a cellular automata simulator in Java, http://webloria.loria.fr/~fates/fiatlux.html)