Oujda
16 October 2019

MAS Course 02

Yves Demazeau
Yves.Demazeau@imag.fr

CONTENTS

MATRICE ACTIVE

M@trice Active (& U. Paris 1 - Lavaud) [Gufflet 04]

VOWELS approach

- Extension of PACO environment E to a 3D world environment
- Elements as reactive agents A, evolving in E
- I and O wrt Kandinsky's rules of painting

Applications

- Variety of usages
  - Pedagogical : to explain and to explore Kandinsky
  - Artistic : to support Kandinsky's like painting
  - Creative : multi-user collaborative framework

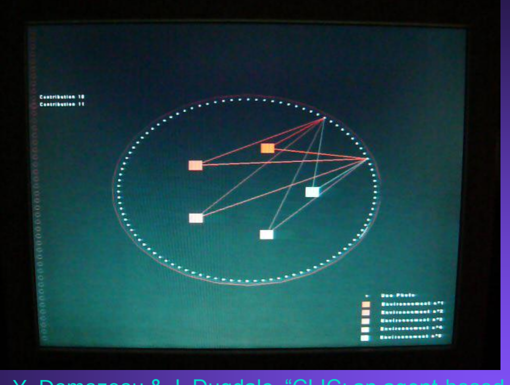
Y. Gufflet & Y. Demazeau, "Applying the PACO paradigm to a 3-dimensional artistic creation", 5th Int. Workshop on Agent-Based Simulation, ABS'04, pp. 121-126, Lisbon, 2004.

M@trice Active : the Kandinsky example

M@trice Active : the Kandinsky example

CLIC

CLIC (academic project) [Lacomme 2010]



L. Lacomme, Y. Demazeau & J. Dugdale, "CLIC: an agent-based interactive and autonomous piece of art". 8th Int. Conference on Practical Applications of Agents and Multi-Agent Systems, PAAMS'10, AISC 70, pp. 25-34, Salamanca, 2010.

ENVIRONMENTS

PHYSICAL ENVIRONMENTS

Natural Environment

Ant colony living environment
https://www.youtube.com/watch?v=IGJ2jMZ-gal

PHYSICAL ENVIRONMENTS

Natural Environment

Ant colony living environment
https://www.youtube.com/watch?v=IGJ2jMZ-gal

Artificial Environment

Human living environment
https://www.youtube.com/watch?v=Ya69WuHcq8M

PHYSICAL ENVIRONMENTS

Natural Environment

Ant colony living environment
https://www.youtube.com/watch?v=IGJ2jMZ-gal

Artificial Environment

Human living environment
https://www.youtube.com/watch?v=Ya69WuHcq8M

Properties

Partly accessible
- Only partial information of the environment is available to one given agent.

Continuous
- The number of possible actions and perceptions in the environment is infinite.

Deterministic
- A given action has only one single and certain effect in the objective environment.

Dynamic
- The environment may evolve independently of the actions of the agent.

Definitions

The *environment of an agent* refers to everything that is external to the agent

The environment is decomposed in two parts
- The *social environment*, meaning, the set of agents it is aware about at a given time, with which it may interact.
- The *physical environment*, meaning the resources being perceived by the agent and the ones he can act on.

World Modeler : Agents, their Envelop, the Updater

LEVEL 3 symbolic actions	**agent** **agent**	Symbolic Knowledge
LEVEL 2 geometric actions	**envelop** **envelop**	Physical Knowledge about the MAS
LEVEL 1 physical events	**envelop** **envelop**	Physical Knowledge about the agent
LEVEL 0	**updater** **updater**	Temporal Updating of the Real World

The envelop (levels 2 & 1) translates actions to be performed in the real world into the simulated world.

The updater (level 0) is the sequencer and processor of the events produced in the simulated world.

Definitions

The *environment of an agent* refers to everything that is external to the agent

The environment is decomposed in two parts

- The *social environment*, meaning, the set of agents it is aware about at a given time, with which it may interact.
- The *physical environment*, meaning the resources being perceived by the agent and the ones he can act on.

Without any mention, the *environment* refers to the objective physical one, shared by every agent.

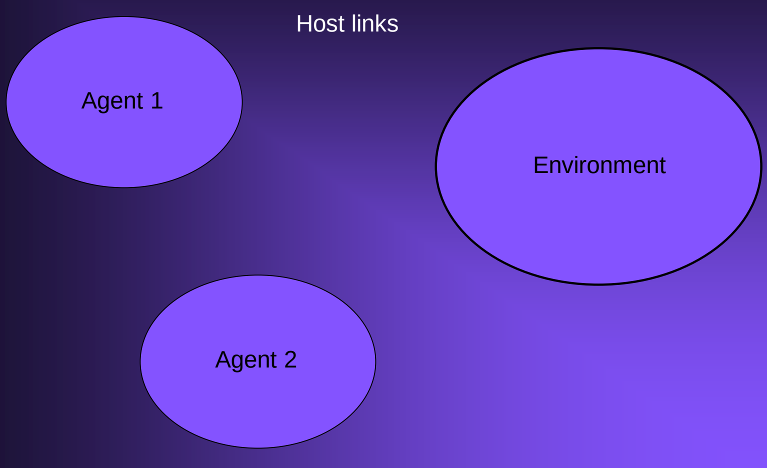
The *physical environment of an agent* is the subjective physical one, as it perceives it.

Objective & subjective representations of the world

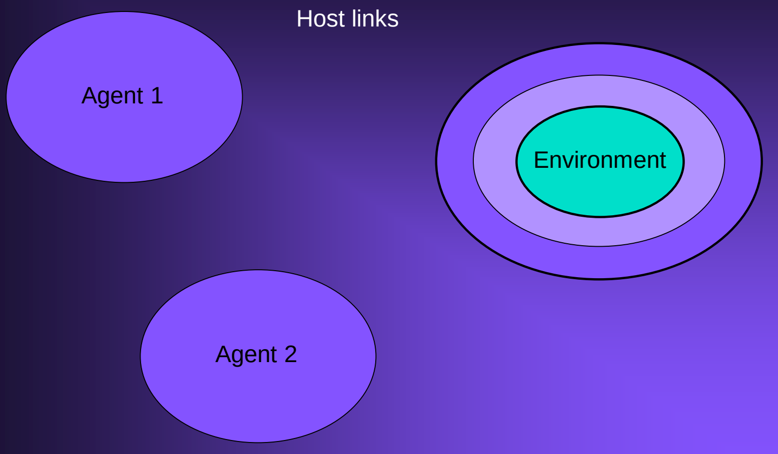
LEVEL 3 symbolic actions	**subjective** **subjective**	Symbolic Knowledge
LEVEL 2 geometric actions	**subjective** **subjective**	Physical Knowledge about the MAS
LEVEL 1 physical events	**objective** **objective**	Physical Knowledge about the agent
LEVEL 0	**objective** **objective**	Temporal Updating of the Real World

The subjective representation of the world by an agent is the one it perceives from the unique objective one that is encoded into the updater.

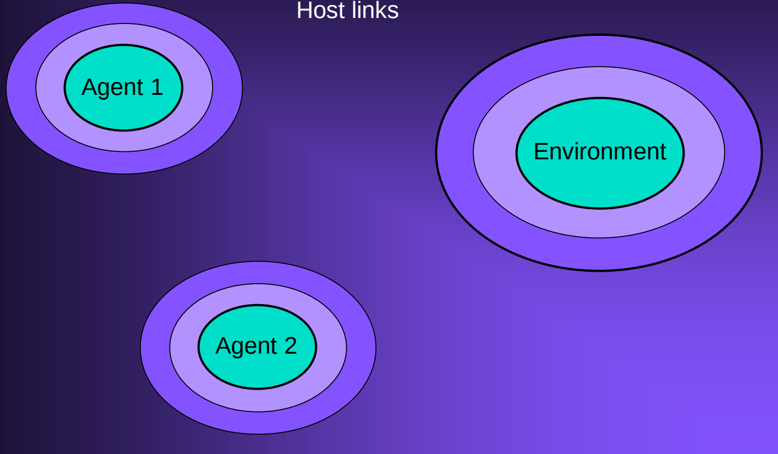
World Modeler : Basic components



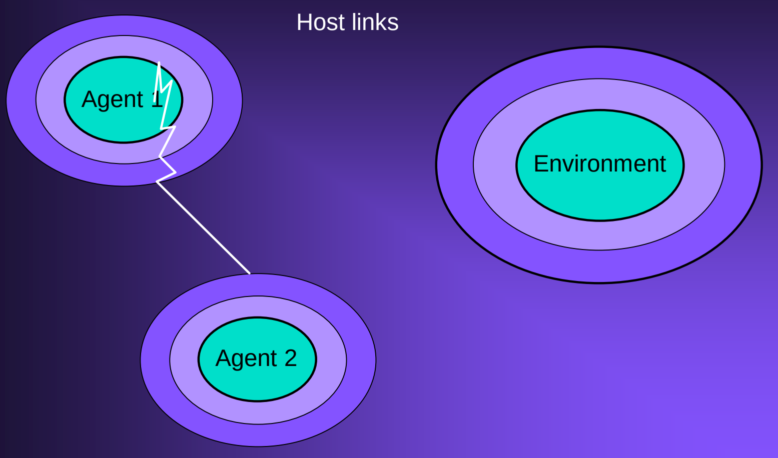
World Modeler : Multi-level environment description



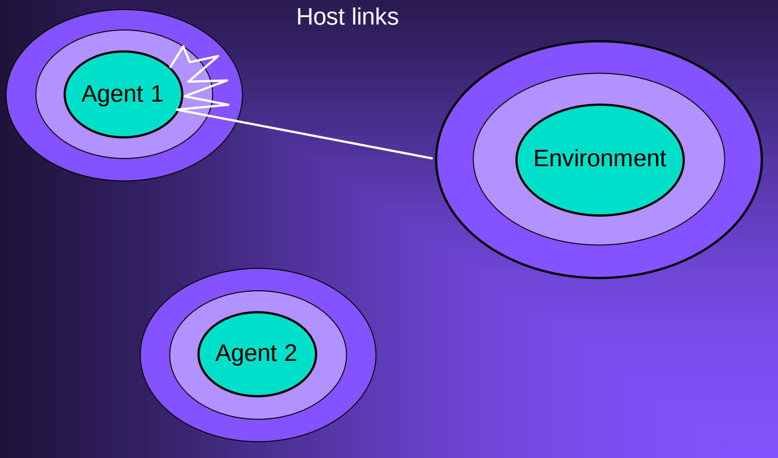
World Modeler : Multi-level agents description



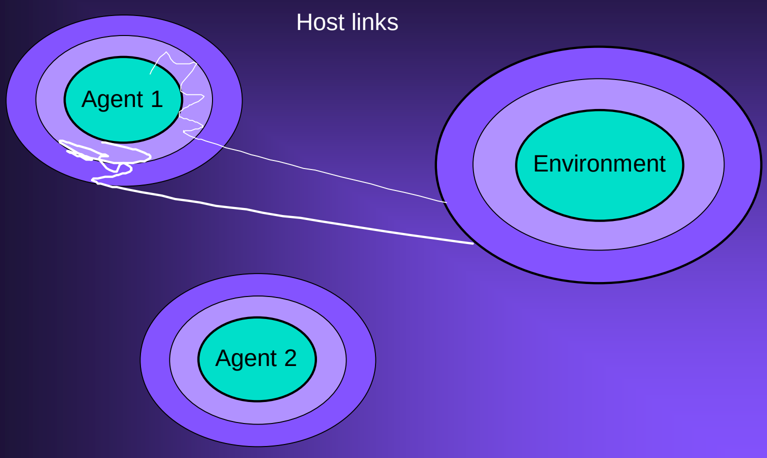
World Modeler : Implementing a Communication



World Modeler : Implementing an Action



World Modeler : Implementing a Perception

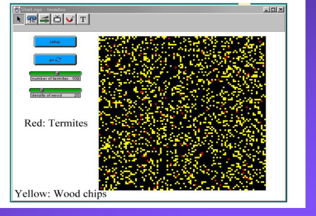


EMERGENCE

Example of emergent behavior

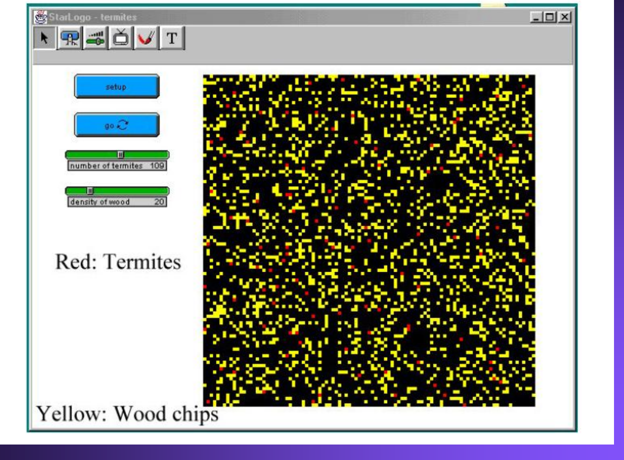
Computer simulation of Termite behavior

- Initial random covering of woodchips
- Wander randomly forever
  - **if bump into woodchip then**
    - **if carrying woodchip then**
      - **drop it**
    - **else**
      - **pick it up**
    - **endif**
  - **endif**

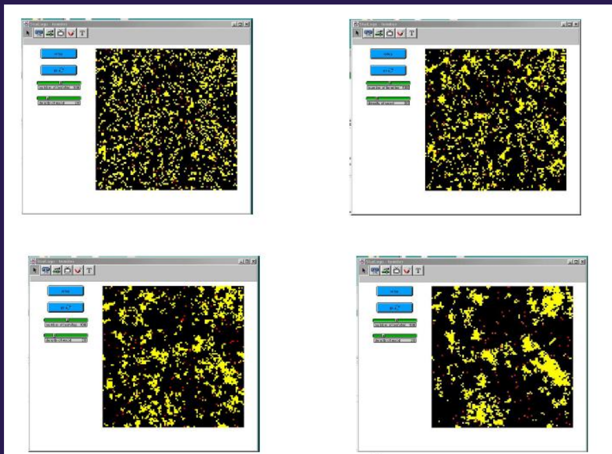


What will happen over time?

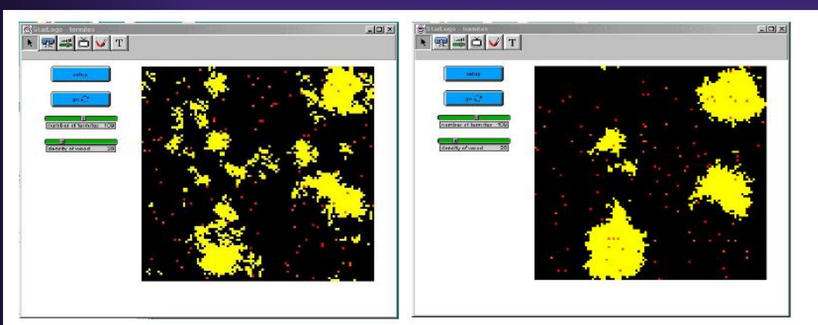
Initial state



Some steps later…



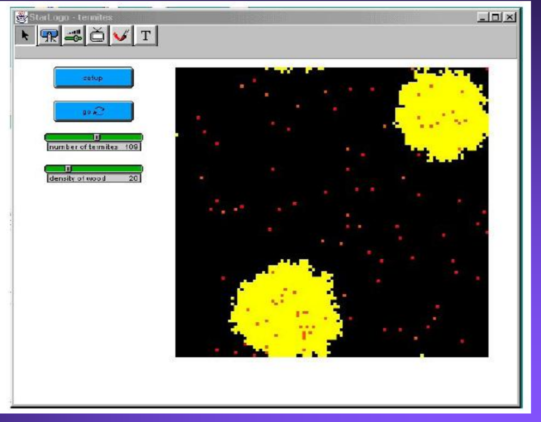
Some steps later…



Some steps later…

Termites have sorted the wood chips into clusters

Emergence of wood piles and the emergent sorting behaviour of The termites



Emergence

Intuition

- Emergent phenomena occur due to the non-linear and distributed interactions between agents.
- Emergent phenomena are observable at a macro-level, even if generated by micro-level elements.

First definitions

- Nominal : every macro property which does not apply to the micro level
- Weak : is nominal and optimal derivation is obtained though simulation
- Strong : is nominal and the macro property exhibits « irreducible « causal powers

Works in the French community

- M.R. Jean, Collective work 97
- J. Deguet 05

Analysis grid of emergences [Deguet 2005]

Five main definitions of emergence

- The whole system is more than the sum of its parts [Kubik]
- A complex behavior by simple entities [Holland]
- A surprising behavior given the agents [Ronald-Sipper]
- Impossibility to predict by simulation [Bedau]
- The presence of downward causation [Sawyer]

An analysis grid of the emergence notion

- The micro and the macro levels
- The design language and the observation language

No definition is better to us than others…

Analysis grid of emergences

The basic Agents	**vs.**	**The Multi-Agent System**
The Micro Level	**vs.**	**The Macro level**
Internal architecture	**vs.**	**External behavior**
The Observation	**vs.**	**The Description**

J. Deguet, Y. Demazeau & L. Magnin, "Elements about the Emergence Issue: A survey of emergence definitions", ComPlexUs, Int. Journal on Modelling in Systems Biology, Social, Cognitive and Information Sciences, Vol. 3, n° 1-3, pp 24-31, Basel, 2006

Complexity shift

[Bonabeau & Dessalles]

The observer is modeled by:

- a set of detectors D
- a set of tools T

During the observation of the system S, emergence happens when :

- a detector switches on
- this detection allows a shorter description of S using T

Emergence is the apparition of a synthetic entity

Complexity shift: Example

D = {Canada, France, Germany, Italy , Japan, Russia, UK, US}

T = Islands, EnglishSpeaking,G8,union,minus

At time t, detectors Canada, UK are on. Possible descriptions are:

- EnglishSpeaking minus {US}
- Islands union {Canada} minus {Japan}
- G8 minus {France, Germany, Italy , Japan, Russia, US}

At time t + 1 US has switched on, EnglishSpeaking has emerged as a synthetic entity

Complexity shift : Discussion

Emergence depends on the observer, i.e. D and T

No levels are assumed in the definition, but one single level is likely to forbid such complexity shifts

The system under observation is considered only through the detection apparatus

This define a low to high emergence going up the detection hierarchy

Surprise

[Ronald & Sipper]

Design: a system is described by local interactions between components in a first language

Observation : an observer describes a global behavior of the running system using a second language (excluding the first one)

Surprise : the causal link between the languages is not obvious to the observer, who is surprised

Then on a subjective level, if every one agrees it is surprising, it is emergent.

Similarly, if every one agrees it is intelligent, we say it is.

Surprise : Discussion

The second language models possible observations, defined as disjoint from design (observations used by agents are excluded)

The surprise is subjective as we have to assert how the causal link is easy to make

This is restricted to really well known systems (we know very well the way they work) as we must exclude what is used from observation

Simulation optimality

[Bedau]

A true emergent phenomenon is one for which the optimal means of prediction is simulation

This definition only applies when we can make a distinction between simulations and other means of prediction

Simulation optimality : Discussion

This is a micro to macro emergence

Based on system where we can talk about simulation/emulation

Many suggestions that such a criterion could be impossible to decide

Downward Causation

[Sawyer]

Bedau defined a weak emergence as he did not believe in downward causation.

Sawyer claims strong emergence is possible in multi-agent systems. He proposes:

- the emergent frame must be represented as a data structure external to the agents
- all emergent collective structures must be internalized by each agent, resulting in an agent-internal version of the emergent
- this internalization process is not deterministic and can result in each agent having a slightly different representation

Emergence Based Engineering [Deguet 2006]

Emergence based engineering

- Development of efficient methods to build systems that will produce emergent (and useful) phenomena
- The engineering objective allows to clarify existing emergence definitions
- The definitions do not permit to use classical software development strategies to build emergent systems

How to implement or generate the system without knowing how it works ?

- By limiting phenomena usually considered as emergent
- By using an incremental design process
- By developing self-adaptive systems

Unfortunately, there is no generalized way to do it

REACTIVE AGENTS

Classes of Reactive Agents [Erceau 91]

stimulus answer	finite state automata

Classes of Reactive Agents

coordinated actions	activation / inhibition mechanisms
stimulus answer	finite state automata

Classes of Reactive Agents

cooperative agents	recruiting and aggregating mechanisms
coordinated actions	activation / inhibition mechanisms
stimulus answer	finite state automata

Classes of Reactive Agents

reproducing agents	reproduction mechanisms
cooperative agents	recruiting and aggregating mechanisms
coordinated actions	activation / inhibition mechanisms
stimulus answer	finite state automata

Classes of Reactive Agents

organized agents	colonies
reproducing agents	reproduction mechanisms
cooperative agents	recruiting and aggregating mechanisms
coordinated actions	activation / inhibition mechanisms
stimulus answer	finite state automata

Colonies of reactive agents

Ant colony raids a rival nest
https://www.youtube.com/watch?v=X5YaihAtnC4

Daisy chain blue ants killing giant millipede
https://www.youtube.com/watch?v=Oc56_-wuPVc

Alternative Classification [Demazeau 91 -> 01]

Elementary situations

- Demazeau 90 — walking robots
- Agree, Chapman — games

Elementary behaviors

- Brooks, Steels — walking robots
- Steels, Maes — games

Elementary interactions

- Demazeau 93 — image analysis
- Ferber — games

Elementary capabilities

- Demazeau 96 — sociology
- Everybody — personal assistants

Freddy Walker (academic project)

A robot that learns to walk LIFIA-CNRS (F), VUB (B)

A legged robot which learns to coordinate the moves of its legs to achieve a go-forward gait

Tool

- ad-hoc metal structure, step-to-step motors
- global feedback sensor : forward, backward, no-move
- implementation of control and learning is not embedded

Freddy Walker (academic project)

A robot that learns to walk LIFIA-CNRS (F), VUB (B)

A legged robot which learns to coordinate the moves of its legs to achieve a go-forward gait

Tool

- ad-hoc metal structure, step-to-step motors
- global feedback sensor : forward, backward, no-move
- implementation of control and learning is not embedded

Model

- legs = agents as finite state automata
- node : position of the leg (4)
- weight : probability of transition between states

Freddy Walker (academic project)

A robot that learns to walk LIFIA-CNRS (F), VUB (B)

A legged robot which learns to coordinate the moves of its legs to achieve a go-forward gait

Tool

- ad-hoc metal structure, step-to-step motors
- global feedback sensor : forward, backward, no-move
- implementation of control and learning is not embedded

Model

- legs = agents as finite state automata
- node : position of the leg (4)
- weight : probability of transition between states

Freddy Walker (academic project)

A robot that learns to walk LIFIA-CNRS (F), VUB (B)

A legged robot which learns to coordinate the moves of its legs to achieve a go-forward gait

Reference to millipedes (Illacme plenipes: 750 legs)

Tool

- ad-hoc metal structure, step-to-step motors
- global feedback sensor : forward, backward, no-move
- implementation of control and learning is not embedded

Model

- legs = agents as finite state automata
- node : position of the leg (4)
- weight : probability of transition between states

Freddy Walker : experiments

Learning process

- choice of the next position : Bayes, Uniform Distr.
- updating of the weights : reinforcement learning
- satisfactory gait = 60 to 100 % forward
- experiments with(out) connection between graphs

Freddy Walker : experiments

Learning process
- choice of the next position : Bayes, Uniform Distr.
- updating of the weights : reinforcement learning
- satisfactory gait = 60 to 100 % forward
- experiments with(out) connection between graphs

A - E interactions alone
- autonomous legs : no interconnection between state graphs
- effective coordination in ± 300 steps

Freddy Walker : experiments

Learning process
- choice of the next position : Bayes, Uniform Distr.
- updating of the weights : reinforcement learning
- satisfactory gait = 60 to 100 % forward
- experiments with(out) connection between graphs

A - E interactions alone
- autonomous legs : no interconnection between state graphs
- effective coordination in ± 300 steps

A - E + A - A interactions
- semi-autonomous legs : fully interconnected state graphs
- extended learning process
- effective coordination in ± 100 steps

Freddy Walker : experiments

Learning process

- choice of the next position : Bayes, Uniform Distr.
- updating of the weights : reinforcement learning
- satisfactory gait = 60 to 100 % forward
- experiments with(out) connection between graphs

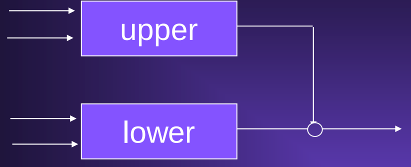
A - E interactions alone

- autonomous legs : no interconnection between state graphs
- effective coordination in ± 300 steps

A - E + A - A interactions

- semi-autonomous legs : fully interconnected state graphs
- extended learning process
- effective coordination in ± 100 steps

Agent Architecture [Brooks 86]

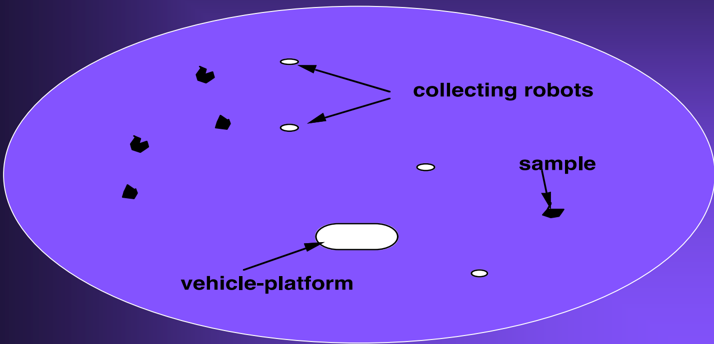


Each module is a finite state automaton
The message issued from the upper has priority in front of the message issued by the lower (subsumption architecture)

Realization of a number of real robots, including a soda can collector, a walking robot, ...

Steels agents : Problem to Solve

A set of robots have to collect samples and bring them to some vehicle-platform



Steels agents : Agent Design

obstacle avoidance	behavior handling
path attraction	
exploration movement	mode determination
return movement	
random movement	crumb handling

Steels agents : Control Behaviors

Behavior handling

- if I sense a sample and am not carrying one, I pick it up
- if I sense the vehicle-platform and am carrying a sample, I drop it

Steels agents : Control Behaviors

Behavior handling

- if I sense a sample and am not carrying one, I pick it up
- if I sense the vehicle-platform and am carrying a sample, I drop it

Mode determination

- if I am in exploration mode and I sense no lower concentration than the concentration in the cell on which I am located, I put myself in return mode
- if I am in return mode and I am at the vehicle-platform, I put myself in exploration mode
- if I am holding a sample, I am in the return mode

Steels agents : Control Behaviors

Behavior handling

- if I sense a sample and am not carrying one, I pick it up
- if I sense the vehicle-platform and am carrying a sample, I drop it

Mode determination

- if I am in exploration mode and I sense no lower concentration than the concentration in the cell on which I am located, I put myself in return mode
- if I am in return mode and I am at the vehicle-platform, I put myself in exploration mode
- if I am holding a sample, I am in the return mode

Crumb handling

- if I carry a sample, I drop 2 crumbs
- if I carry no sample and crumbs are detected, I pick up one crumb [Montanus, Das Erdkulhlein, 1559] [Perrault, Le Petit Poucet, 1697] [Grimm, Hansel & Gretel, 1812]

Steels agents : Control Behaviors

Behavior handling

- if I sense a sample and am not carrying one, I pick it up
- if I sense the vehicle-platform and am carrying a sample, I drop it

Mode determination

- if I am in exploration mode and I sense no lower concentration than the concentration in the cell on which I am located, I put myself in return mode
- if I am in return mode and I am at the vehicle-platform, I put myself in exploration mode
- if I am holding a sample, I am in the return mode

Crumb handling

- if I carry a sample, I drop 2 crumbs
- if I carry no sample and crumbs are detected, I pick up one crumb

Steels agents : Movement Behaviors

Obstacle avoidance

- if I sense an obstacle in front, I make a random turn

Steels agents : Movement Behaviors

Obstacle avoidance

- if I sense an obstacle in front, I make a random turn

Path attraction

- if I am not carrying a sample and I sense crumbs, I move towards the highest concentration of crumbs

Steels agents : Movement Behaviors

Obstacle avoidance
- if I sense an obstacle in front, I make a random turn

Path attraction
- if I am not carrying a sample and I sense crumbs, I move towards the highest concentration of crumbs

Exploration movement
- in exploration mode I chose the direction with the lowest gradient

Steels agents : Movement Behaviors

Obstacle avoidance
- if I sense an obstacle in front, I make a random turn

Path attraction
- if I am not carrying a sample and I sense crumbs, I move towards the highest concentration of crumbs

Exploration movement
- in exploration mode I chose the direction with the lowest gradient

Return movement
- in return mode I chose the direction of highest gradient

Steels agents : Movement Behaviors

Obstacle avoidance
- if I sense an obstacle in front, I make a random turn

Path attraction
- if I am not carrying a sample and I sense crumbs, I move towards the highest concentration of crumbs

Exploration movement
- in exploration mode I chose the direction with the lowest gradient

Return movement
- in return mode I chose the direction of highest gradient

Random movement
- choose randomly a direction to move and move in that direction

Steels agents : Movement Behaviors

Obstacle avoidance
- if I sense an obstacle in front, I make a random turn

Path attraction
- if I am not carrying a sample and I sense crumbs, I move towards the highest concentration of crumbs

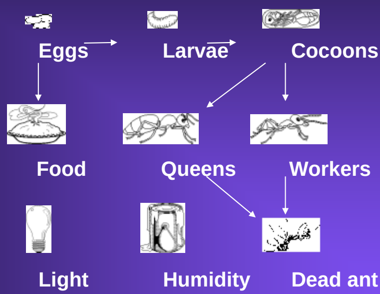
Exploration movement
- in exploration mode I chose the direction with the lowest gradient

Return movement
- in return mode I chose the direction of highest gradient

Random movement
- choose randomly a direction to move and move in that direction

The Manta project (academic project)

Behavioral modeling of a society of ants Ectatomma ruidum and emergence of social structures



Developed by Drogoul / Ferber at U. Paris 6, in cooperation with Fresneau / Corbara, U. Paris 13

Manta : experiments

300 artificial societies of ants (from foundation to adulthood)

Manta : experiments

300 artificial societies of ants (from foundation to adulthood)

Social organization

Organization evolution

Demographical dynamics

Evolution with food restriction

Polygenic evolution (with multiple queens)

Manta : experiments

300 artificial societies of ants (from foundation to adulthood)

Social organization

Organization evolution

Demographical dynamics

Evolution with food restriction

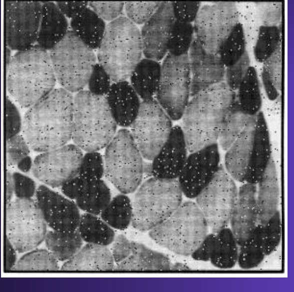
Polygenic evolution (with multiple queens)

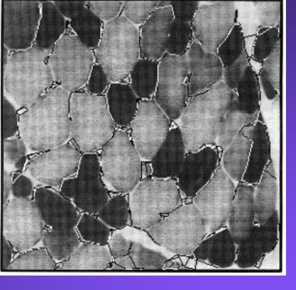
PACO [Demazeau 90]

A solution of a problem is an equilibrium global state of a set of independent programmable agents

A problem is reputed as being solved by as soon as the set of agents reach a <u>perceived</u> equilibrium

EPs : Segmentation into Regions





PACO

A solution of a problem is an equilibrium global state of a set of independent programmable agents

Each agent is characterized by a perception scope, a communication scope, and an action scope

A problem is reputed as being solved by as soon as the set of agents reach a <u>perceived</u> equilibrium

PACO Agents and Environment

Environment

- subset of an N-space, shared by the agents. Static or dynamic values.

Agents Xi

- the agent state denotes a part of the global solution.
- mass, position, speed, acceleration, scopes

Agent's Scopes Si

- perception scope PSi : determines the subset of the environment that the agent can perceive at a given time.
- communication scope CSi : determines the subset of agents the agent can communicate with at a given time
- action scope DSi : determines the subset of actions that the agent can perform at a given time
- static or dynamic scopes, but controlled by the agent according to its state and to the global goal to be satisfied.
- analogy with the Fire-Fighting

PACO

A solution of a problem is an equilibrium global state of a set of independent programmable agents

Each agent is characterized by a perception scope, a communication scope, and an action scope

Each agent locally interact one with the other as well as with the environment data by means of forces

A problem is reputed as being solved by as soon as the set of agents reach a perceived equilibrium

PACO Interactions and Organisation

Interactions with the environment

- Each agent interacts with each element of the environment which it can perceive at a given time
- Interactions are modelled by as many types of forces that the agent is able to distinguish types of entities in the environment (not necessarily physical) (EF)

Interactions with the other agents

- Each agent interacts with the other agents with which it can communicate at a given time
- Interactions are modelled by forces (usually spring forces) that translate the granularity and the rigidity of the solution (IF)

PACO Dynamics

Local Perception and Communication
- tune the sensitivity with the environment (PSi)
- perceive
- tune the sensitivity with other agents (CSi)
- communicate

Local Processing
- compute the interactions with the environment (EF)
- compute the interactions with other agents (IF)
- combine of the forces exerted on the agent

Local Action
- tune the sensitivity to act using action scope (ASi)
- act

PACO

A solution of a problem is an equilibrium global state of a set of independent programmable agents

Each agent is characterized by a perception scope, a communication scope, and an action scope

Each agent locally interact one with the other as well as with the environment data by means of forces

The model is defined by the predefined combination of the forces that remains constant over time.

A problem is reputed as being solved by as soon as the set of agents reach a perceived equilibrium

PACO Interactions and Organisation

Interactions with the environment

- Each agent interacts with each element of the environment which it can perceive at a given time
- Interactions are modelled by as many types of forces that the agent is able to distinguish types of entities in the environment (not necessarily physical) (EF)

Interactions with the other agents

- Each agent interacts with the other agents with which it can communicate at a given time
- Interactions are modelled by forces (usually spring forces) that translate the granularity and the rigidity of the solution (IF)

Organisations

- possible constraints to the agents by initial links between them a well as other kinds of constraints

PACO Interactions and Organisation

Interactions with the environment

- Each agent interacts with each element of the environment which it can perceive at a given time
- Interactions are modelled by as many types of forces that the agent is able to distinguish types of entities in the environment (not necessarily physical) (EF)

Interactions with the other agents

- Each agent interacts with the other agents with which it can communicate at a given time
- Interactions are modelled by forces (usually spring forces) that translate the granularity and the rigidity of the solution (IF)

Organisations

- possible constraints to the agents by initial links between them a well as other kinds of constraints

PACO

A solution of a problem is an equilibrium global state of a set of independent programmable agents

Each agent is characterized by a perception scope, a communication scope, and an action scope

Each agent locally interact one with the other as well as with the environment data by means of forces

The model is defined by the predefined combination of the forces that remains constant over time.

A problem is reputed as being solved by as soon as the set of agents reach a perceived equilibrium

Elastic Patterns (academic project)

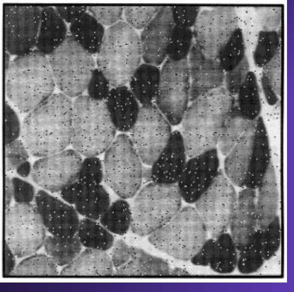
The PACO resolution LIFIA-CNRS (F), VUB (B)

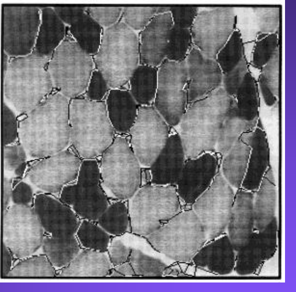
Feature extraction and tracking in 2D environments

Approach

- following the PACO approach
- simple agents with perception, communication, and action scopes
- implicit linking to extract complex image features
- full implementation on C/Parallel Fortran - Sun WS / DAP (SIMD architecture)
- application to image feature extraction
- application to robot path planning

EPs : Segmentation into Regions





EPs : Segmentation into Regions

Environment

- {Yj} set of contrast points

Agents Xi

- PSi : infinite or fixed
- CSi : 1 ≤ Card(Xj/Xi perceives Xj according CSi) ≤ 3
- DSi : in coherence with the contrast

Interactions with the environment

- ∑j (PSi |Xi - Yj| + 1)**(-k), k=1, 2
- ∑j exp -(PSi ln |Xi-Yj| -f(PS))**2

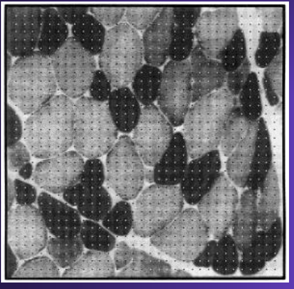
Interactions between agents

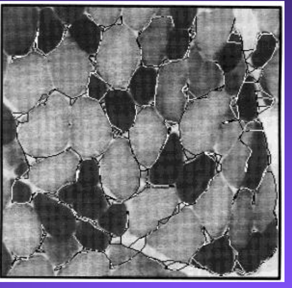
- ∑j //CSi(j)// sign (|Xi-Xj| - µ) [ß(|Xi-Xj| - µ]**k, k=1, 3

Getting the solution (by an external operator)

- Visualizing the links between mutually perceived agents

EPs : Segmentation into Regions (cells)





EPs : Intelligent Contour Detection

Environment
- {Yj} set of contrast points

Agents Xi
- PSi : infinite or fixed
- CSi : 1 ≤ Card(Xj/Xi perceives Xj according CSi) ≤ 2
- DSi : in coherence with the contrast

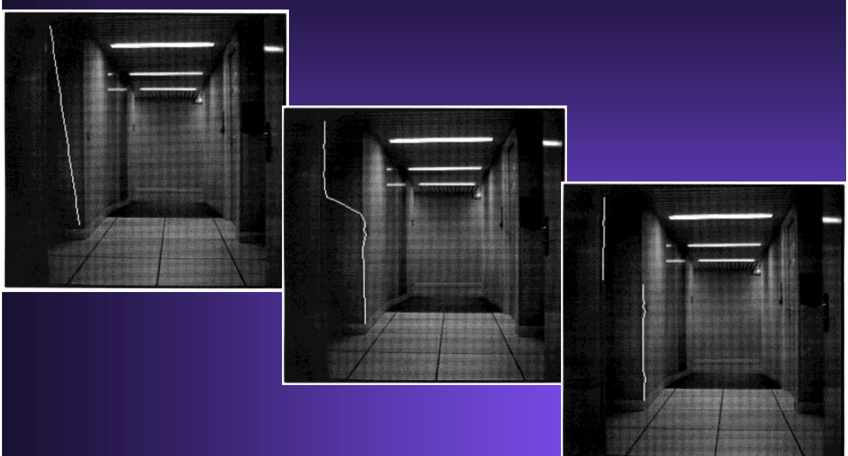
Interactions with the environment
- ∑j (PSi |Xi - Yj| + 1)**(-k), k=1, 2
- ∑j exp -(PSi ln |Xi-Yj| -f(PS))**2

Interactions between agents
- ∑j //CSi(j)// sign (|Xi-Xj| - µ) [ß(|Xi-Xj| - µ]**k, k=1, 3

Getting the solution (by an external operator)
- Visualizing the links between mutually perceived agents

EPs : Intelligent Contour Detection (Niçoise)

EPs : Intelligent Contour Detection (corridor)



EPs : Intelligent Contour Tracking (mask)

EPs : Intelligent Contour Tracking (mask)

EPs : Planning trajectories

Environment
- {Yj} set of heights

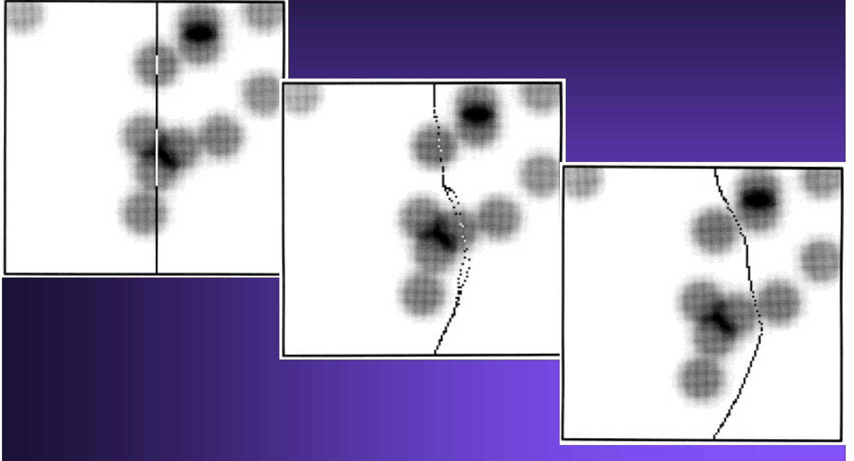
Agents Xi
- PSi : infinite or fixed
- CSi : 1 ≤ Card(Xj/Xi perceives Xj according CSi) ≤ 2
- DSi : in coherence with the height

Interaction with the environment
- gravity forces

Interactions between agents
- ∑j //CSi(j)// sign (|Xi-Xj| - µ) [ß(|Xi-Xj| - µ]**k, k=1, 3

Getting the solution (by an external operator)
- Visualizing the links between mutually perceived agents

EPs : Planning trajectories (desert)



EPs : Execution control of trajectories

Environment
- {Yj} set of heights, static & dynamic obstacles

Agents Xi
- PSi : infinite or fixe, extended to temporal dimension
- CSi : 1 ≤ Card(Xj/Xi perceives Xj according CSi) ≤ 2, + constraints about the identity of the neighbors
- DSi : ...

Interaction with the environment
- several kinds of forces, cf. obstacles, gravity, driving rules

Interactions between agents
- + driving rules, mechanical constraints.

Getting the solution (by an external operator)
- Visualizing the links between mutually perceived agents

PacoVision (industrial project)

A Reactive Multi Agent Approach to Image Feature Abstraction LIFIA-INPG (F), ELF Aquitaine Production (F)

Extraction of complex image features in 2D dense images

Approach
- simplified Demazeau's PACO agent model
- agents : one per column of the image
- determination of the best neighbors for each agent
- implicit linking to extract complex image features
- validation by human expert
- full implementation on C++/C - Sun WS

SMAALA (academic project)

A reactive multi-agent approach to over-constrained optimization; application to linear planning LEIBNIZ-UJF (F), CERREP (F)

Interacting reactive agents and global dynamics for distributed spatialized problem solving

Approach

- extends the PACO approach (+ formal model)
- supports expert analysis of a spatial project
- explores tool for spatial alternatives, with environmental, structural and social constraints
- allows hypothesis tests and dynamic add of constraints
- implementation on C++ on Sun WS - LAN
- parallelism is simulated : synchronous or asynchronous

DECIDE+ (academic project) [Hallenborg 07]

K. Hallenborg, A. Just, & Y. Demazeau, "Reactive agent mechanisms for manufacturing process control", 7th Int. Conferences on Web Intelligence and Intelligent Agent Technology Workshops, 2007 IEEE/WIC/ACM, pp. 399-403, Silicon Valley, 2007.

REACTIVE COORDINATION

Reactive Coordination through Marks Control

Behavior handling

Mode determination

Crumb handling

- if I carry a sample, I drop 2 crumbs
- if I carry no sample and crumbs are detected, I pick up one crumb

---

Obstacle avoidance

Path attraction

- if I am not carrying a sample and I sense crumbs, I move towards the highest concentration of crumbs

...

Reactive Coordination using Force Fields

Force fields

- Forces are defined as the gradient of a potential field
  $F(p) = -grad(U(p))$
- Goals are represented as attractive fields
- Obstacles are represented as repulsive fields

Motion is obtained as a combination of attractive and repulsive forces

The resulting field U is defined as the sum of an attractive and repulsive field

$$U(p) = U_{attr(p)} + U_{repul(p)}$$

Importance of the environment

Reactive Coordination through Cohesion Fields

Force fields

- Forces are defined as the gradient of a potential field
  $F(p) = -grad(U(p))$
- Goals are represented as attractive fields (external field)
- Obstacles are represented as repulsive fields (external field)
- Coordination is represented by cohesion fields (internal fields)

Motion is obtained as a combination of internal and external forces

$$U(p) = U_{inter(p)} + U_{exter(p)}$$
$$U(p) = U_{inter(p)} + (U_{attr(p)} + U_{repul(p)})$$

BOIDS

BOIDS

A computer model of coordinated animal motion such as bird flocks.

Boids reacts only to members within a certain small neighbourhood.

The flocking behaviour emerges as a natural result of the interactions of the agents.

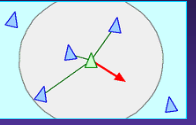
http://www.red3d.com/cwr/boids/

Key feature of Reynolds' `boids' simulation: it is based on just three simple rules for controlling the behaviour of individual agents.

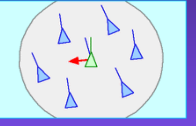
https://www.youtube.com/watch?v=bqtqltqcQhw

BOIDS 3 rules

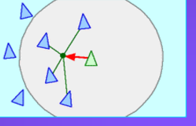
Separation: steer to avoid crowding local flock mates.



Alignment: steer towards the average heading of local flock mates.



Cohesion: steer to move towards the average position of local flock mates.



The Use of BOIDS in the Animation Industry

1987: Stanley and Stella in Breaking the Ice
- Director: Larry Malone, Producer: Symbolics & Whitney/Demos

1992: Batman Returns
- Director: Tim Burton, Producer: Warner Brothers

1994: The Lion King
- Director: Allers / Minkoff, Producer: Disney

The Use of Reactive Agents in the Movies Industry

1987: Stanley and Stella in Breaking the Ice
- Director: Larry Malone, Producer: Symbolics & Whitney/Demos

1992: Batman Returns
- Director: Tim Burton, Producer: Warner Brothers

1994: The Lion King
- Director: Allers / Minkoff, Producer: Disney

1998: Antz
- Director: Darnell et al, Producer: DreamWorks/PDI

1998: A Bug's Life
- Director: Lasseter/Stanton, Producer: Disney/Pixar

1998: The Prince of Egypt
- Director: Chapman et al, Producer: DreamWorks

1999: Star Wars: Episode I - The Phantom Menace
- Director: Lucas, Producer: Lucasfilm

2000: Lord of the Rings (Bonus Return of the King)
- Director: Jackson, Producer: New Line Cinema

…/…

COMPLEMENTARY REFERENCES

Complementary references

An reference survey about AB modelling and simulation
R. Allan, “Survey of Agent Based Modelling and Simulation Tools”, Technical Report. STFC. 2009.

A tutorial on AB modelling by the fathers of RePast
Ch. Macal & M. North, “Tutorial on Agent-Based Modelling and Simulation”. 2005 Winter Simulation Conference, Kuhl, et al, eds. 2005.

The use of reactive agents to simulate financial markets
Ph. Mathieu, O. Brandouy, “Introducing ATOM”, PAAMS 2012, pp. 269-272, 2012.

Alternative decomposition into elementary activities
M. Sierhuis, “It’s Not Just Goals All the Way Down, It’s Activities All the Way Down”, Engineering Societies in the Agents World VII, ESAW 2006, pp. 1-24, 2007.