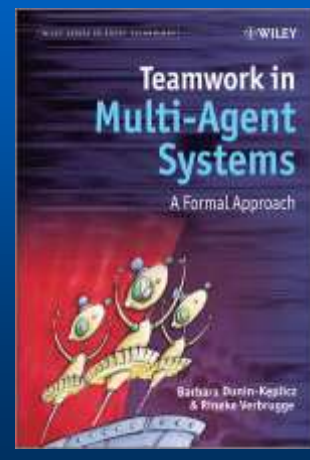
Introduction to Multi-Agents Simulation

Credit : Michal Pěchouček, Wikipedia

MAS – Part I – Basics



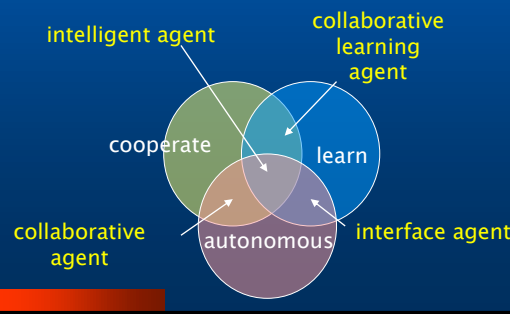
Distributed Artificial Intelligence

- **Torsun:**
  "Distributed Artificial Intelligence is a branch of Artificial Intelligence solving problems with a group of collaborating agents. Agents are logically independent and autonomous, they reason, plan, learn and communicate"
- **A collective architecture : decomposes the problem among collection of autonomous, cooperating, knowledge sharing agents,**

Case specific : distributed system with an integrating number of heterogeneous agents of a different nature, complexity reduction

Agent

- **Jennings: "An agent is a computational system, situated in some environment, that is capable of intelligent, autonomous action in order to meet its design objectives."**



Agents are not "Objects"

- Objects unlike Agents
  - are passive, do not operate unless activated
  - are not organized (vs. Agent/Community/System)
  - exchange too primitive imperative message, (agents communicate declarative knowledge)
  - do not support flexible organisational relationship, the systems object model is fixed
  - present designed behavior, while agent can form they own behavioral patterns emergently (from interaction)

Links between objects, actors & agent

- Object : attributes + methods
- Actor : an autonomous object able to run in concurrency with others…
  - See Actor's language MIT & Japan in the 80s
- Agent : an actor with specific goals able to interact with other agents
  - Social behavior
  - Often comes with a common collective goal

6

Agent's Intelligence (1)

- Reactivity – ability to provide intelligent responses to percepts and agent senses from the environment (user interface)
- Proactivity – ability to maintain agents long term intention, organize its behavior in order to meet targeted goals
- Social Intelligence – ability to perform reasoning about other agents abilities, intentions, current status and possible future course of actions

Agent's Intelligence (2)

- Reactive Agent – agent presenting a reactive intelligence only
- Cognitive Agent – manipulate symbolic model about their own status, and capabilities (proactivity) and about its collaborative environment

Reactive Agents (1)

- **Reactive agents** do not have individual intelligence
- They possess simple mechanisms enabling reactions to some events
- They sometimes have a goal, but they do not have a plan stating how they will reach their goals
- The functioning of reactive agents is based on a function of this kind
  - *f*(stimulus)→ response, where
  - stimulus f(environement, other agents)
- Reactive MAS manage a great number of agents

9

Reactive Agents (2)

- Reactive agents are agents that do not contain any symbolic knowledge representation (ie: no state, no representation of the environment, no representation of the other agents, ...). T
- Their behaviour is only defined by a set of perception-action rules.
- "Subsumption" architecture – System of ordered layers of perception-action rules, where the lower layers take precedence.

Reactive Agents (3)

Example of "rock sample collecting robots" (Steels),

Inspired by ants:

```
if detect an obstacle then change direction
if carrying samples and at the base then drop samples
if carrying samples and not at the base then travel up
if detect a sample then pick sample up
if true then move randomly
```

Cognitive Agents (1)

- **Mainly used in Distributed Artificial Intelligence**
- **Each agent is considered as an expert system**
- **Knowledge is guiding actions**
- **A small number of agents manage their knowledge necessary to handle specific tasks and they interact with each other and with the environment**

12

Cognitive Agents (2)

- Cognitive Agents are agents with an explicit knowledge representation of own capability, other agents, the environment, etc.
- There are various models of agents' cognitive states (differ in purpose, generality, …) –
  - BDI (Belief Desire Intention) : *A Framework for reasoning about formal abstract models of mental states*
  - Joint Intentions Theory
  - 3bA (Tri-Base Acquaintance Model)
  - …

Belief Desire Intention – (1)

- Contains representations (as objects, data structures, or whatever) of:
  - beliefs, which constitute its knowledge of the state of its environment (and perhaps also some internal state),
  - desires, which determine its motivation what it is trying to bring about, maintain, find out, etc.,
  - intentions, which capture its decisions about how to act in order to fulfil its desires
- Intentional Attitudes
  - informational attitude – knowledge, belief
  - pro-atitude – desire intention, choice, commitment

Belief Desire Intention – (2)

- A control mechanism which ensures that:
  - beliefs change over time in response to external events,
  - intentions determine and cause sequences of actions to be taken,
  - intentions change over time as a result of beliefs changing, desires becoming fulfilled or failing to be fulfilled, actions being taken, new events being received.
- Representation of intentional attitudes
  - limitation of propositional logic,
  - modal logic, meta-logics, dynamic logic of action, temporal logic
  - Possible Worlds Semantics, Interpreted Symbolic Structures

Modal logic (basics)

- Modal logic is a type of logic that allows to formalize modal elements, ie to specify the qualities of “assertions”.

Example of modal elements "can", "it is necessary", etc.

For example, proposal arouns “It rains" could be like this:

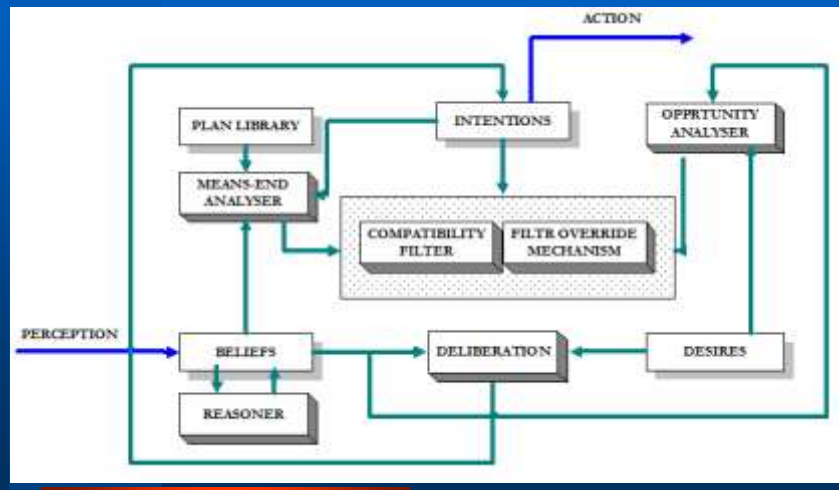
- It is possible that it rains;
- It is shown that it is wrong it rains;
- It is not allowed to rain. (modal but totally weird ?!)

- Modal logic is behind the alethic logic – which that takes into account the beliefs of the speaker as in the sentence: “Christopher Columbus is believed to be in Asia”.

16

Example of BDI Architecture – IRMA

(original fig. with typos)



Interaction among Agents (1)

- **Organization**
  - an arrangement of relationships between individuals or components, division of tasks, distribution of roles, and contribution-awards
- **Cooperation**
  - sharing responsibilities in satisfying shared goal and generating mutually dependent roles in joint activities
- **Coordination**
  - management of agents activities so that they coordinate their deeds with each other in order to share resources, meet their own interests

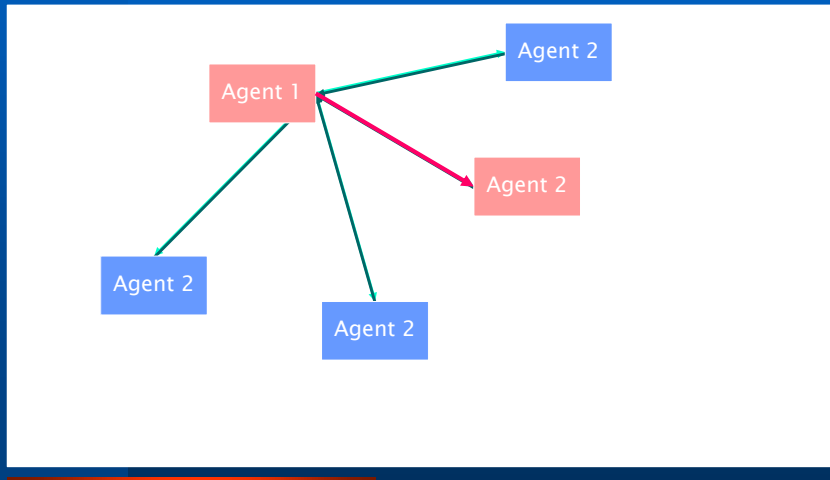
Interaction among Agents (2)

- Negotiation
  - information exchange aimed at resolving conflict of access to resources,
  - different solutions to the same problem or goal conflicts
- Communication
  - information, knowledge and request exchange via mutually agreed communication language
- Benevolence
  - agent are benevolent if they will agree to cooperate in asked/required

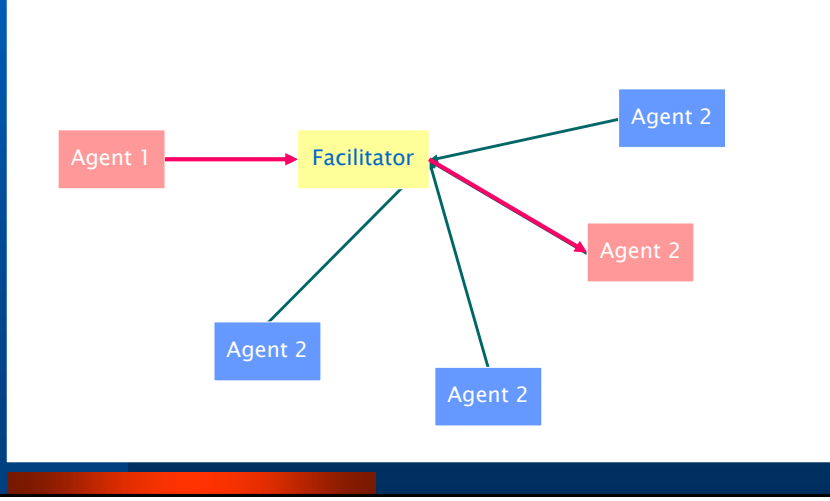
Basic Models of Communication

- Broadcasting of a task announcement
  - autonomous communication
  - communication intensive
- Central Communication Agent
  - well organized, saves communication
  - central, fragile, communication bottleneck
- Acquaintance Models
  - model of the environment in an abstract sense

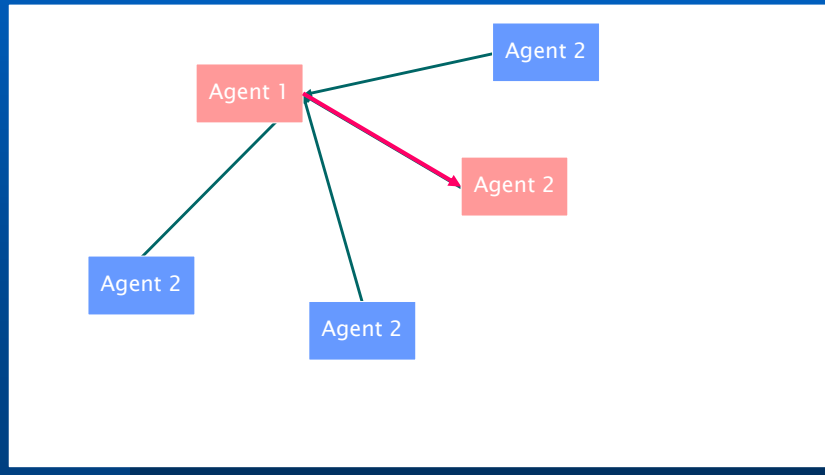
Broadcasting a Task Announcement



Central Communication Agent



Utilisation of an Acquaintance Model



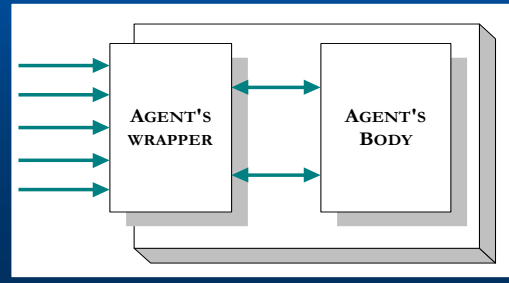
Agent Communication Language

In order to ensure agent interoperability, mutually agreed communication protocol (ACL) must be provided

- **Mutual knowledge understanding**
  - **translating from one knowledge representation language into another**
  - **sharing of semantics (and often pragmatics)**
- **Inter Agent Communication**
  - **transport protocol (e.g. TCP/IP, SMTP, HTTP, …)**
  - **communication language**
  - **interaction protocol**

Ex: of an Agent's Abstract Architecture

- Agent's Communication Wrapper
  - translation to and from ACL (Agent Communication Language)
  - physical connection and responsibility delegation
  - perception × action
  - social model

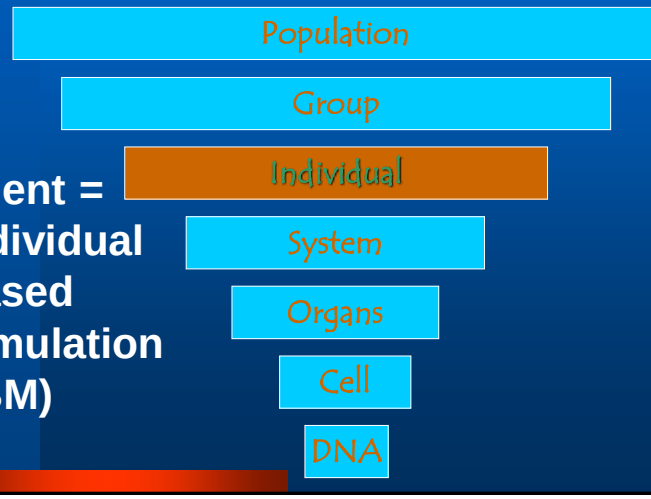


Knowledge Sharing Efforts

Deals with agent interoperability and knowledge sharing

- Ontolingua - a software tool and methodology for - means for sharing semantics (and often pragmatics) of represented knowledge;
- Knowledge Interchange Format (KIF) - an inter-lingua for translations between different knowledge representations;
- Knowledge Query and Manipulation Language (KQML) - a language for communicating attitudes about the shared knowledge.
- Ontologies-KIF-KQML is sometimes denoted as an ACL. An ACL message is a KQML expression where arguments are KIF sentences formed from terms from appropriate ontologies.
- Foundation for Intelligent Physical Agents Organization (FIPA).

The notion of Scale…



- **Agent = Individual Based Simulation (IBM)**

27

Meta-Agent

- **An independent agent observing the community**
- **Unlike information brokers or facilitator agents it is not a central agent**
- **Can provide efficiency consideration, maintenance of parameters,…**
  - **passive role – visualization (community structure, workflow, distributed plans, etc.)**
  - **active role – affects community operation (updates contents of agent bases)**

Ex: Active Role of a Meta-Agent

- agent's termination
  - record retraction from the cooperator base
- agent's loss/acquiring of its capability
  - plan section redesign, re-planing
  - record retraction from the cooperator base
- agents creation
  - registering agent, autonomous re-planing
- agents properties change
  - plan section redesign, re-planing

Computer Science Domains concerned

- **Discrete Event Simulation**
  - Enables taking into account the spatial distribution of individuals in the considered environment
- **Multi-Agents Systems and Distributed AI**
  - Direct representation of individuals and their interactions
  - Modelling of individual behaviors
  - Interactions between individuals can lead to emerging phenomena
- **Computer Graphics & Visual Interactive Simulation**
  - Facilitates the Verification & Validation process
  - Allows the observation of global and correlated simultaneous events
  - Helps in presenting results to decision makers

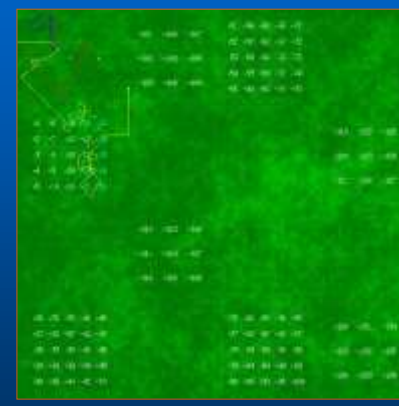
30

MAS – Part II – Local Application examples

31

Ewe memory simulation (1)

- Simulation of a group of ewes at pasture.
- They look for specific preferred food introduced in green bowls and placed in patches on a delimited experimental field
  - Multi-agent Simulation
  - Spatial distribution
  - Modelling and understanding of the spatial memory of ewes



In collaboration with Dr. Dumont INRA

32

Web-based predator - prey (2)

- Designed from a generalization of the simulation of pasturing ewes
- Preys and predators are in a limited environment
- The behaviour of agents is simulated with fuzzy logic

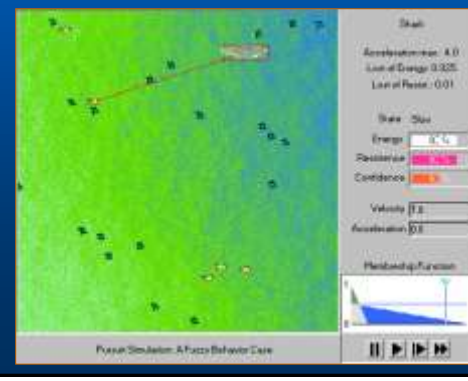
$$fuite \Leftarrow près(x) \wedge \neg loin(x)$$

$$près(x) = \begin{cases} 1 & \text{si } x \le p \\ \dfrac{x - p^U}{p - p^U} & \text{si } p < x \le p^U \\ 0 & \text{autrement} \end{cases}$$

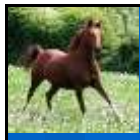
$$loin(x) = \begin{cases} 0 & \text{si } x \le q^L \\ \dfrac{x - q^L}{q - q^L} & \text{si } q^L < x \le q \\ 1 & \text{autrement} \end{cases}$$

x = distance du prédateur

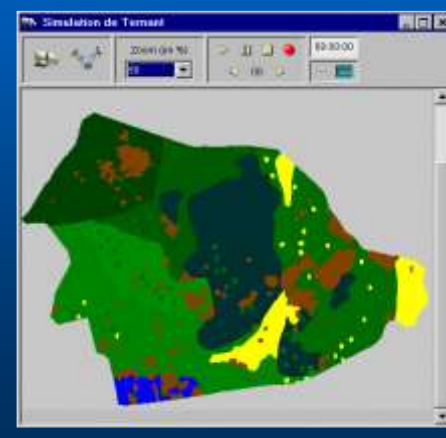
n, n^U, p et $p^L = f$ (fatigue, direction, …)



Pasture & herbivores (3)



- A landscape above Clermont-Ferrand (Ternant)
- Pastured by cows and horses
- Multi-agent simulation

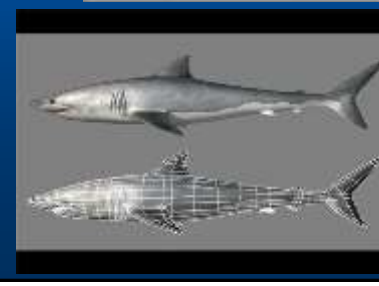


- Herbivores are moving depending on :
  - food, water, salt stone,
  - Herd rules (group behavior)

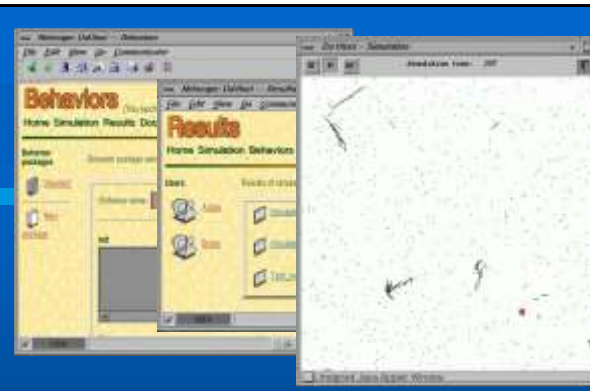
Animals are followed thanks to GPS

(4) Web-based Predator-Prey 3D

- Validation of the visual aspects of a framework
- Proposition of a 3D interface for the Web
- Java – VRML link - Cosmo player pluggin (in 1998 !)

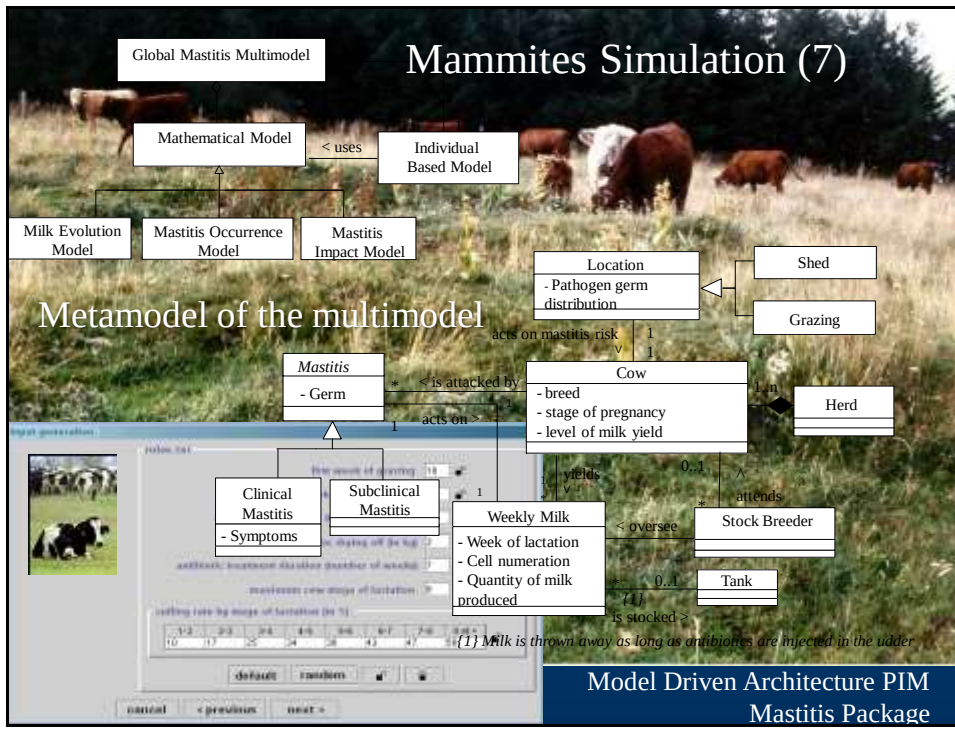


Examples developed for the Web (5)

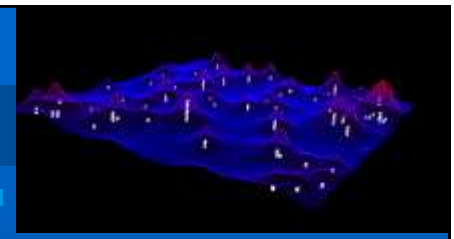


Multi-model « Grassland / Herd » (6)

Mammites Simulation (7)



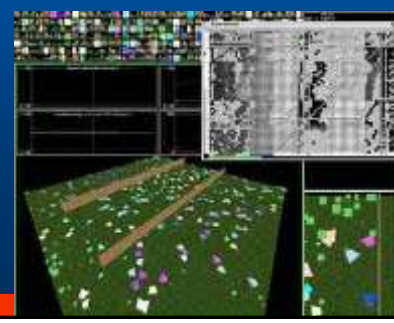
Example of Artificial Societies (8)



- Robert Axtell scientist in Social Sciences at Mason's Center for Social Complexity (CSC) proposes model to study human interactions with MAS.
- « Interactions could be social, financial or political. It's very hard to render those models mathematically," he says. "It's not easy to summarize the functionality or the performance of the simulation groups in numbers or graphs. Often what we'll try and do is depict the entire market as it emerges."

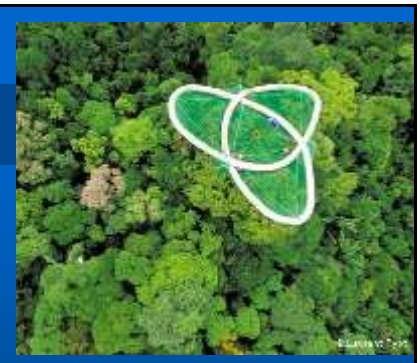
Robert Axtell
Brookings Institute

Polyworld, heatbugs, SugarScape…



Da Vinci (9) with Bruno Corbara

- Da Vinci : ***Designing Ant/Agents: a Visual Interactive Nest Construction involving Internet***
- Artificial life Environment
- Tropical arboricol Ant
  - ***Pachycondyla goeldii***



From models to reality (9)

Blaise Pascal University

41

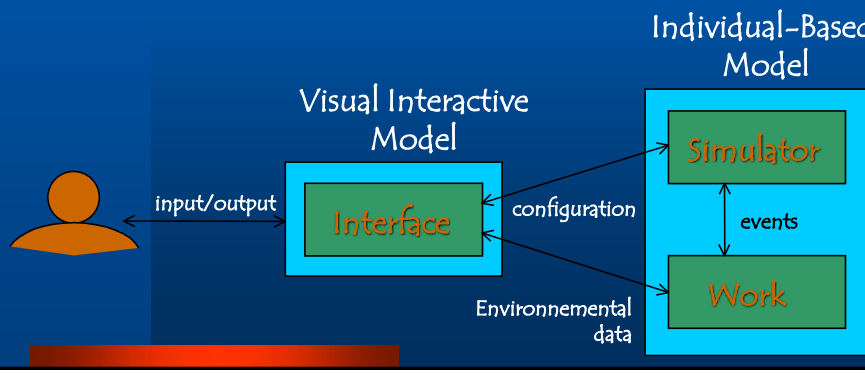
Ants creating a lifeboat in the Amazone jungle (10)

- http://www.youtube.com/watch?v=A042J0IDQK4

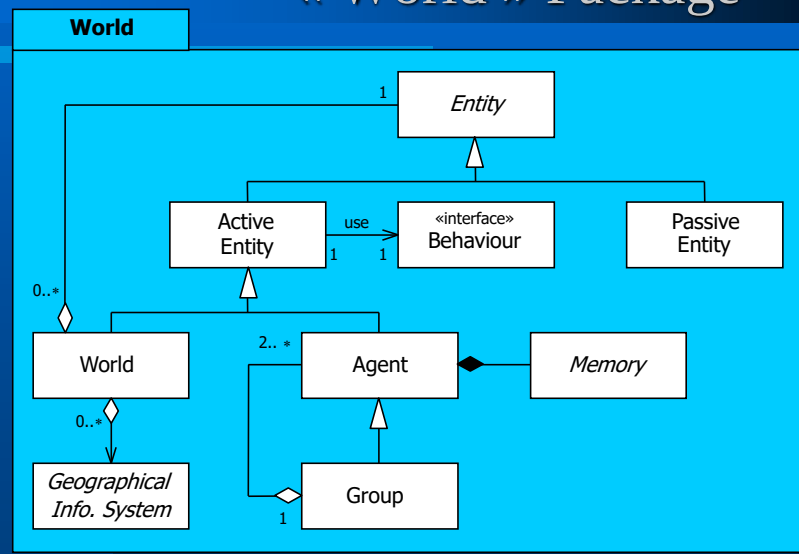
42

MAS – Part III – Design examples
MAVIS : A. Campos & D. Hill

- **General Architecture**
  - **Framework and package**



« World » Package



MAVIS Agent model

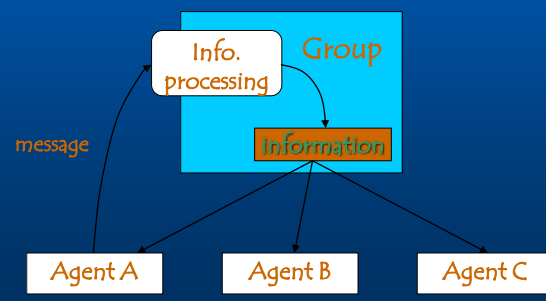
- « Active Entity » Class → reactive agents
  - *f* (current state, local perception) ⇒ action
  - Actions considered as « atomic »
  - The environment (« World ») is an active entity of the system
  - Communication

- « Agent » Class
  - *f* (current state, local perception, memory) ⇒ action
    - Possibility of action scheduling → cognitive agents
  - Communication (+)
    - Direct
    - Indirect (through the group) → Black board

45

Communication (group)

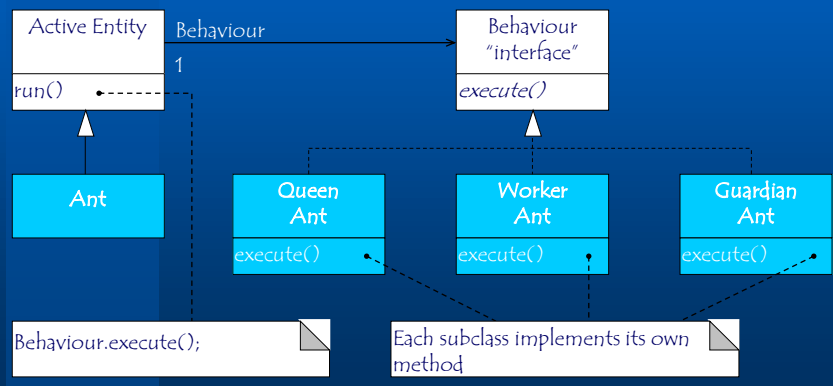
- Information shared by the group members
- Possibility of group nesting
  - Hierarchical distribution of messages



46

Behavior

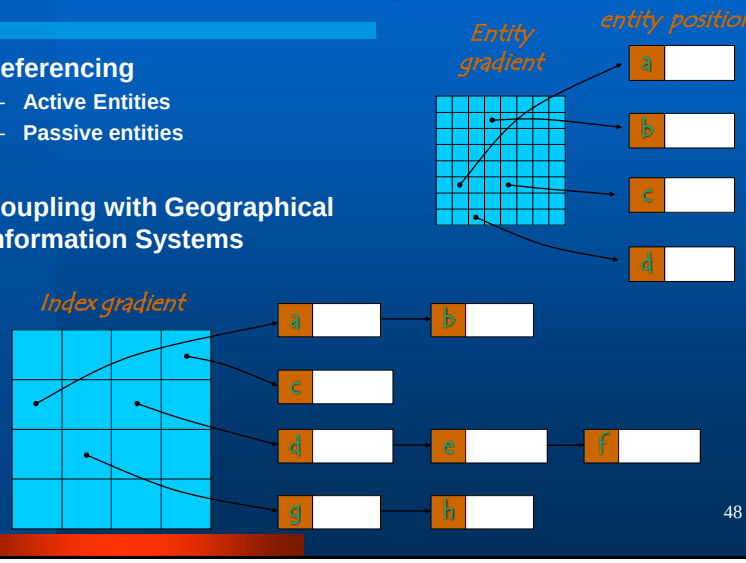
- A Behaviour interface is separated from the agent class
  - Flexibility / Updates / Prototyping
- Dynamic Changes at run time



47

Environment and space

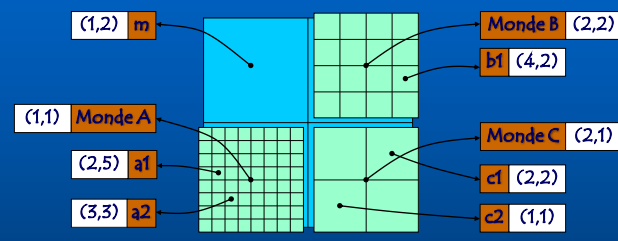
- Referencing
  - Active Entities
  - Passive entities
- Coupling with Geographical Information Systems

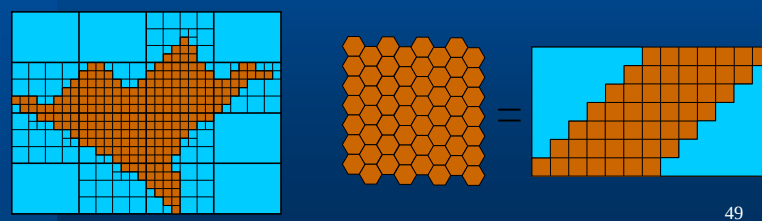


48

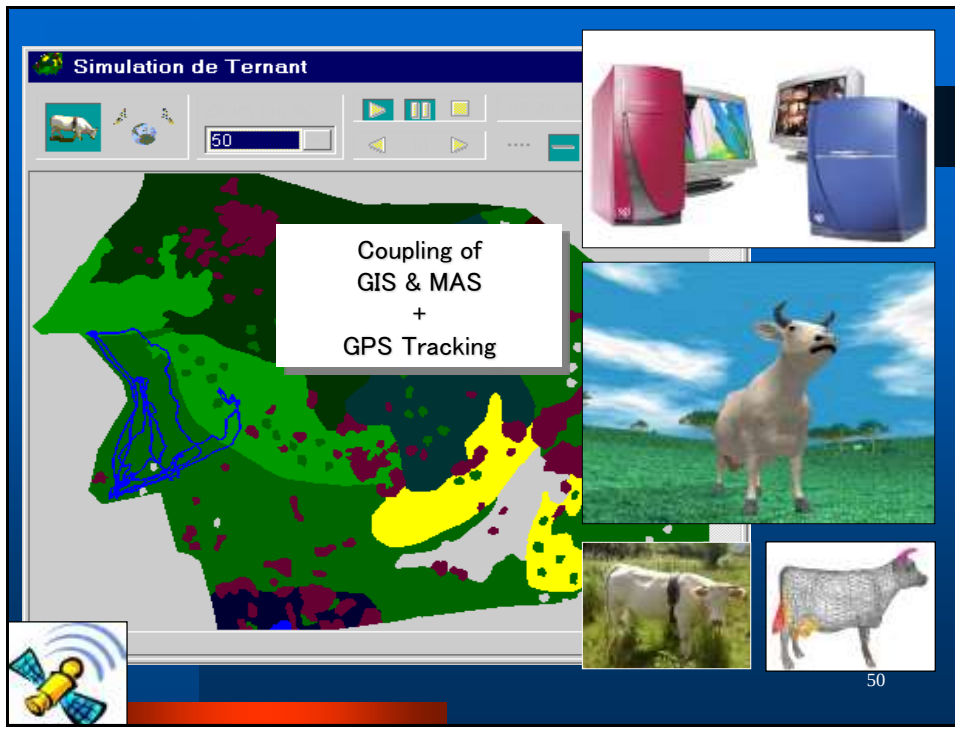
Imbrication of Worlds – Multi-scales

- The world modelled with different levels of details





49

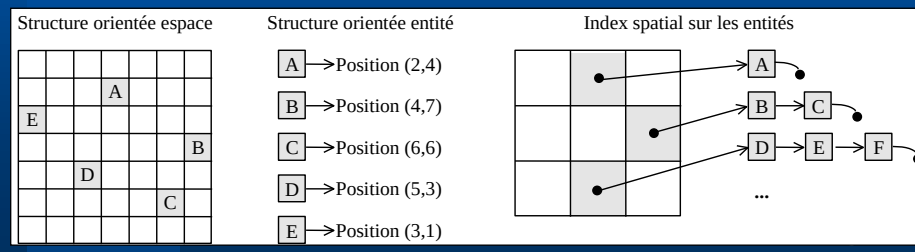


50

Limits of GIS/Simulation coupling

- Heterogeneity of GIS software
- The writing of dedicated software to import/export GIS data
- The performances are limited if the simulation and GIS software are running simultaneously with data request from the simulator

A better approach – embedding GIS data inside the simulation software
Various data structures can be employed

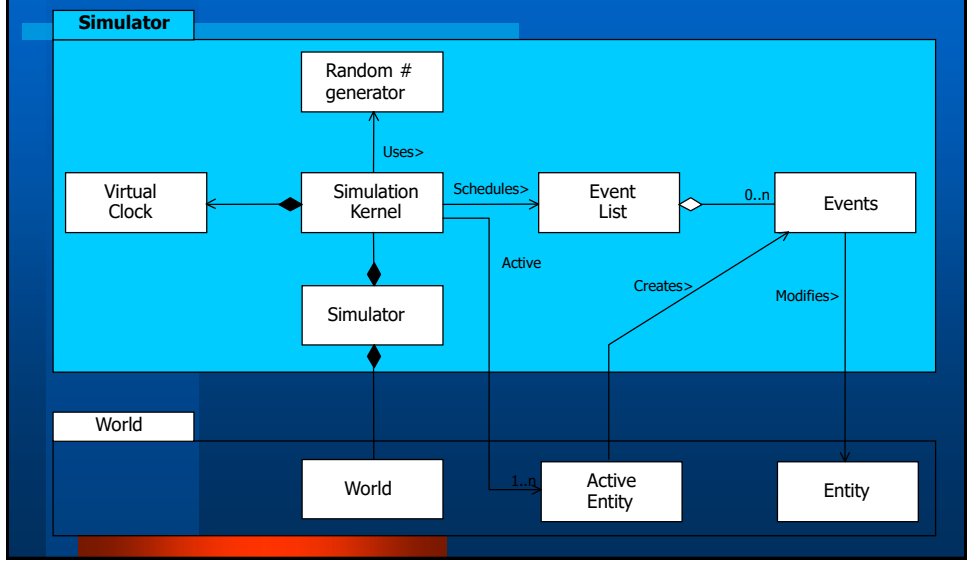


Parallelism and MAS

- **! External management of parallelism is OS dependent !**
  - **Threads or Light Weight Processes**
  - **Asynchronous message management**
  - **! Not adapted to stochastic models !**
- **Internal Management**
  - **A better approach to handle conflicts (particularly spatial conflicts)**
  - **Agent actions are considered as parallel processes**
    - ⇒**Actions have the same level of « granularity »**

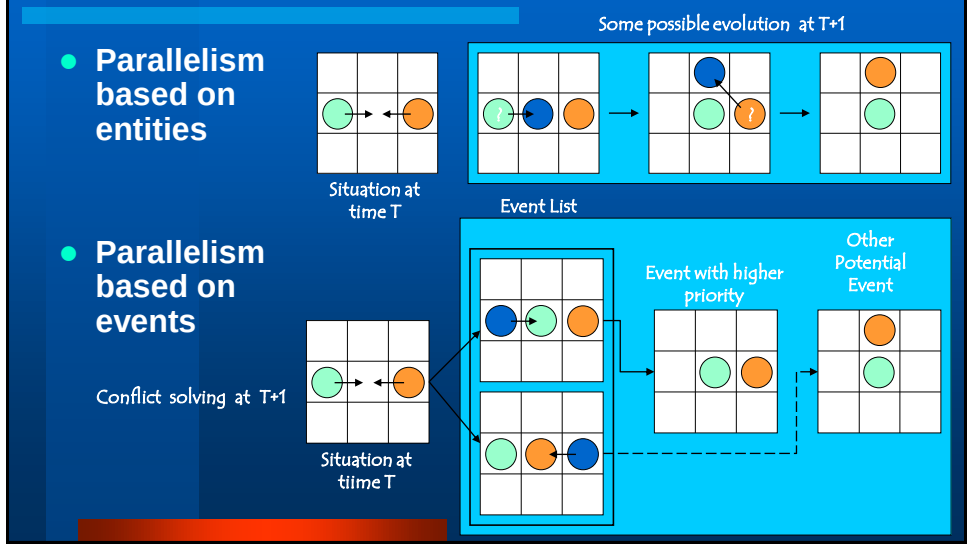
52

The « Simulator » Package



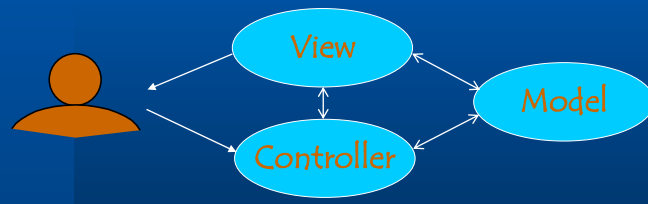
Spatial resource conflicts

- **Parallelism based on entities**
- **Parallelism based on events**



Visual Abstraction

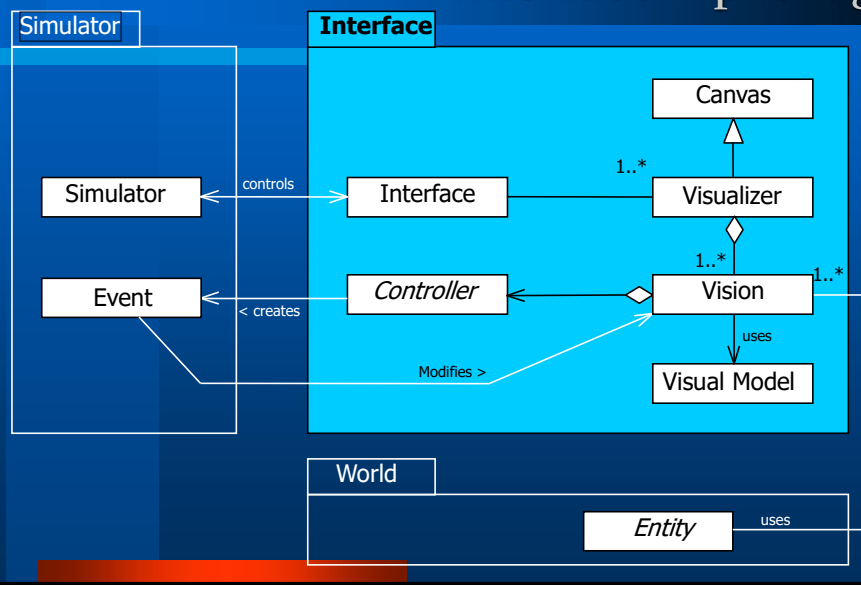
- Separation of the model information & the visualization
  - Independence from the graphical platform
  - Flexibility in changing visualization methods
  - Adapted from the MVC pattern



  - Nested visualization forbidden
  - Possibility to change the reference data (with events f.i.)

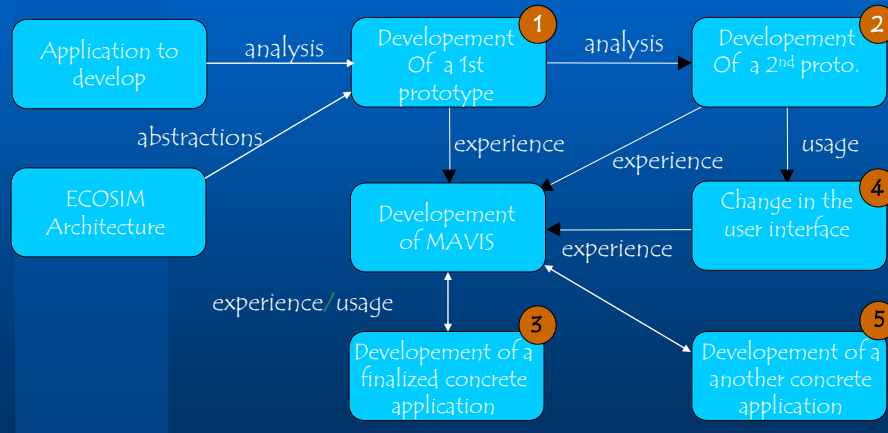
55

« Interface » package



56

Possible agile development cycle…



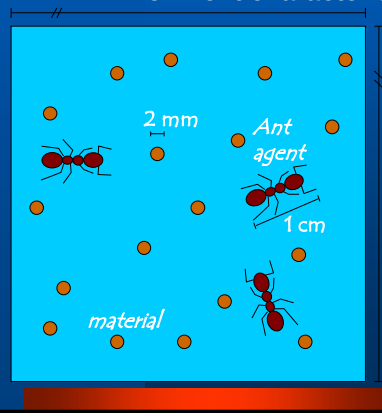
57

Ant colony simulation with MAVIS Goals of Da Vinci platform

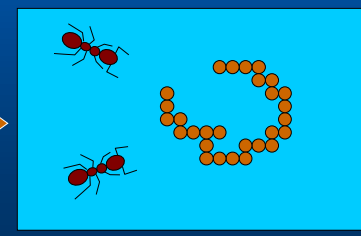
- **Design of an Artificial Life Laboratory**
  - **Ant – agents**
- **Exploitation of the environnemental resources with reactive agents**
  - **Simple behaviour rules (production rules)**
  - **Limited local perception**
  - **Possibility of behaviour change**
  - **validation of emergence thanks to local interactions**
- **Study of a nest morphogenesis**

Separation of Aspects

- **Structural Aspects**
  - **Environment characteristcs**



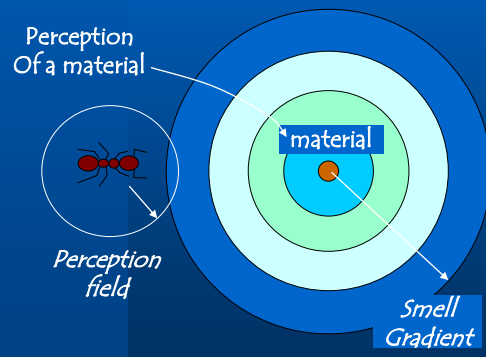
- **Functional aspects**
  - **Behaviour settings**
  - **User configurable**



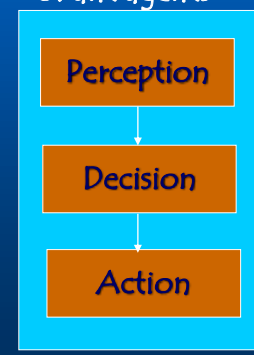
59

Action dynamics

- **Activated by the perception of Ant**
- **Material with a precise odor *f(distance)***



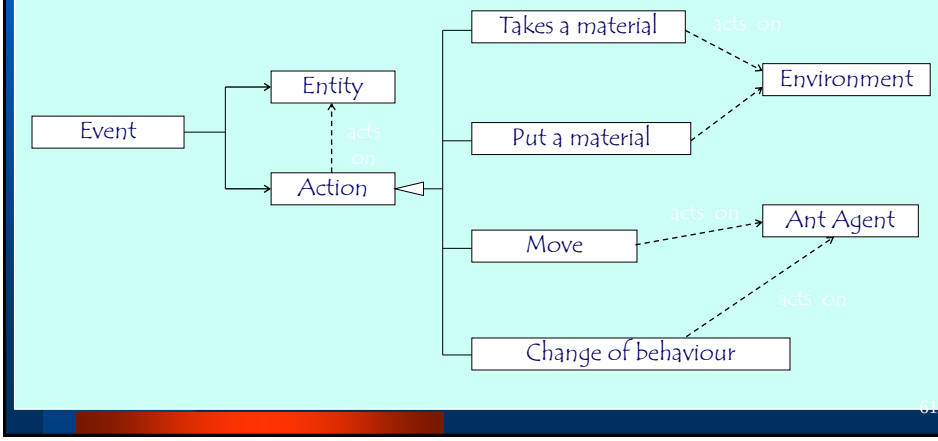
Modular Architecture of ant agents



60

Actions

- Indirect Actions
  - Resulting from events dealing with ant agents
- Action modelled



61

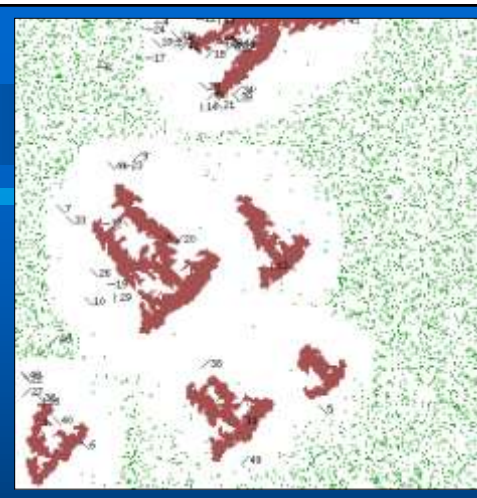
Behavior

- Four types of behaviours
  - Place a material
  - Move in groups
  - Look for materials
  - Compose an aggregate

Example : compose an aggregate

```
Look for a transformed material in my perception field
If there is a material
  If the material is close to me then
    Look for the position with the strongest smelling
    Create the event « put an item » at this place
    Create the event « change the behaviour » to look for raw item
  Else
    Create the event « move to » the closest item
Else
   Create the event « random move »
```

Sample results



- Emergence of forms
- Volumes produced by the spatial constraints
- This tendency is produced the perception of ant agents
- A small change in ants behavior or in sensitive parameters conduces to significant modifications in the produced structures

MAS – Part 4
Summary, perspectives and Lab

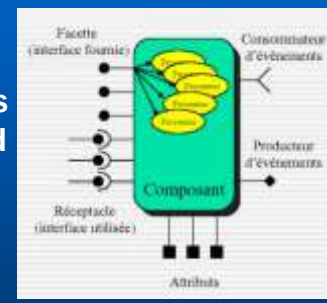
Summary of difficulties in MAS

- Problem with the quality & quantity of data
- Problems with the memory size needed
- Problems with the management of spatial interactions
- Problems with the implementation of concurrent processes (in space & time)
- Problems to analyze spatial stochastic simulation results
- Problems to setup inter-disciplinary collaborations
- Performances problems
  - Local optimizations
  - Metaprogramming
  - Parallelism : Grid Computing / Metacomputing etc…
- Problems of independent random streams for distributed computing
- Modelling and formalization problems

65

Towards a more modern « approach » ?

- Enlarge the application spectrum
  - True parallel applications ?
- Construction of applications thanks to components (why not distributed objects ?)
  - Application structuration
  - Encapsulation of parallel codes
- Coupling of parallel codes
- Two opposite aspects
  - Hide the complexity in a component
  - Connecting components with multi-scales communications



66

Agents & computing grids

- D-Agent project for Meta-Computing
  - Mobile agents buying access right to the computing resources and establishing a computing market.
  - http://agent.cs.dartmouth.edu/papers/#market
- Echelon project : Agent Based Grid Computing Architecture
  - http://www.geocities.com/echelongrid/
- Agent Based computational Economics
  - http://www.econ.iastate.edu/tesfatsi/ace.htm

67

Bioinformatics and Multi-Agent Systems
BIXMAS 2002 Workshop

Agents in bioinformatics

- Analysis and autonomous annotation of genomes : BioMAS, RETSINA (http://citeseer.nj.nec.com/445758.html)
- MAS Architectures for genomic applications
- Multi-agent approaches for the classification and the treatment of EST (Expressed Sequence Tags)
- Learning & discovery of knowledge in an autonomous way
- MAS approaches for the analysis of gene expression (using microarrays – DNA Chips)
- Coordination and Control of MAS to collect distributed bioinformatics data (http://www.cs.iastate.edu/~honavar/ailab/projects/control.html)
- Simulation of multi-agents for the interaction of molecular proteins in cancer mechanism

Complex agents are not "just programs" (1/2)

- An agent in the context of Distributed Artificial Intelligence is a member of a multi-agent community, where its behavior and logic behind reasoning has to bee seen from the multi-agent perspective
- An agent freely interact, interaction among agents is emergent
- Agents can group into coalitions, teams, they can benefit from this
- Agents do not have to be benevolent, have free will, can cheat, etc.

Complex agents are not "just programs" (2/2)

- Agents can leave/join the community
- Agents can adapt and improve their social role

However there are also other agents such as migrating agent, viruses, information seekers … who are not members of multi-agent community in the above sense

Some organisations & standards

- FIPA : The Foundation for Intelligent Physical Agents : standards for heterogeneous software agents interoperability (www.AgentLink.org)
- SISO : Simulation Interoperability Standards Organisation
  - Evolution of DIS techniques : Distributed Interactive Simulation
  - HLA Development : High level Architecture
  - FEDEP : Federal Development and Execution Process,
  - FDMS : Functional Description of the Mission Space, DS: Data Standard, ALSP : Aggregated Level Simulation Protocol, OMT : Object Model Template
- OMG : Object Management Group
  - MDA : Model Driven Architecture « melting pot » of methods
  - Production of PIMs Platform Independant Model in UML (Unified Model Language) and PSM Platform Specific Model
    - MOF : Meta Object Facility (universal support to describe concepts) seen as metamodels specified in UML
    - CWM : Common Warehouse Metamodel, JMI : Java Metadata Interface
    - UPM : Unified Process Model, XP eXtreme programming, AGILE,…
  - OMA : Object Management Architecture (old Arch. before Y2K)
    - CORBA, (DCOM et .NET, EJB,…), XML et XMI, SOAP (XML based protocol)

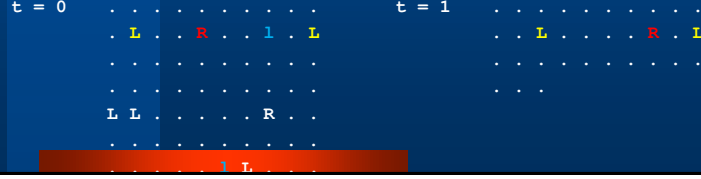
71

MAS : Multi-Agent Lab specs.

Propose a software that will create two categories of agents of your choice (cognitive / reactive).

Some Constraints (see details in the lab subject):

- Agents will evolve in a 2 D space
- The behavior of agents is stochastic
- At least two 2 categories of agents are competing and the software should first propose a textual output to give the main focus to the artificial intelligence (rather than spending to much time on GUI development) – This GUI development phase can be achieved in a second time and is not mandatory.
- The documentation will use the « Doxygen » tool
- Other Software Engineering tools will be used



72

More examples locally for the MAS lab (**free** e-books)

http://pubp.univ-bpclermont.fr/public/Informatique_Modelisation.php

Thats'all falks…

Benny Hill
21 Janvier 1924 – 18 Avril 1992

74