University of reunion Island

# LIM laboratory and MAS Team

Computer Science and Mathematics Research Laboratory

30 permanent researchers accredited by the French Ministry of Research & high education EA2525

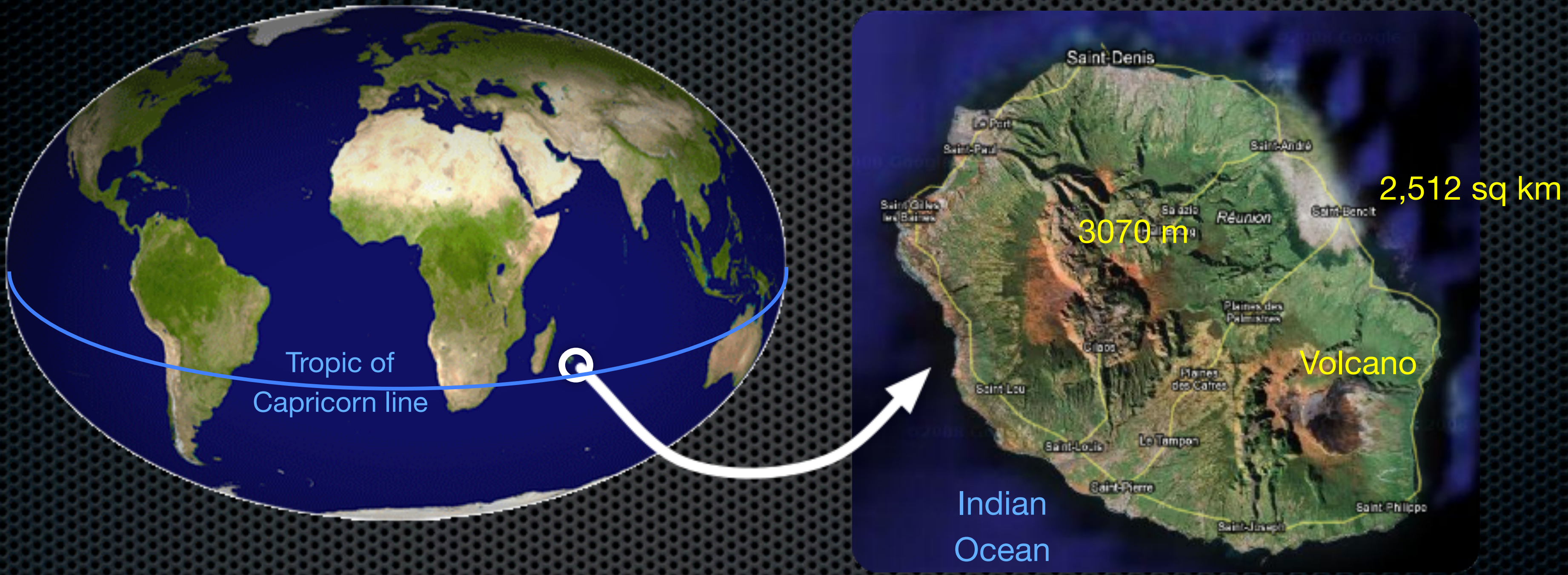
UNIVERSITÉ DE LA RÉUNION
S'ouvrir aux mondes

## Saint-Denis

- Rémy Courdier
- Denis Payet
- Daniel David
- Nicolas Sébastien
- Yassine Gangat
- Zoubida Afoutni
- Maimouna Diagne

The MultiAgent Systems & Applications Group

# Some key figures




- A modern French department, living standards to European levels
- Located on the Tropic of Capricorn line (21° Lat. South, 55° Long. East)
- A relief both complex and varied (an altitude of 3070 meters)
- A multi-racial young population of 800,000 inhabitants in 2008, over 1 million by 2030
- A relative small territory of 2,512 sq km (same surface area as Luxembourg)

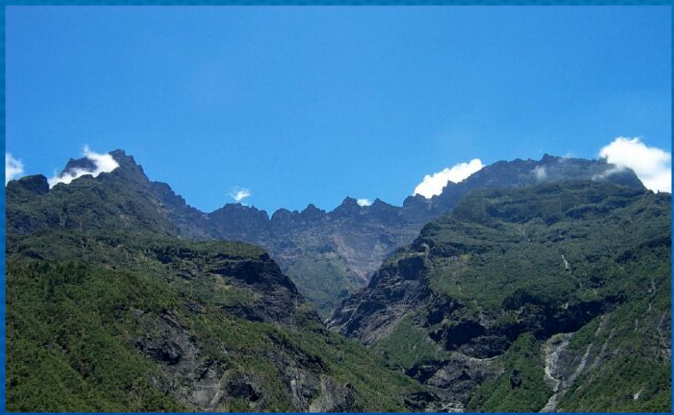
Setting the Scene : Réunion Island Characteristics

# Hot Spot by virtue of its geostrategic position

Marine Sub-tropical biodiversity

Space observation

Tropical Terrestrial UNESCO World Heritage



Created by two volcanoes

**Tropical Biodiversity**

**Geosphere Observation**

# Working on local high-priority issues

**Sustainable Development...** **Territory's economic objectives**

Transport & Road infrastructures

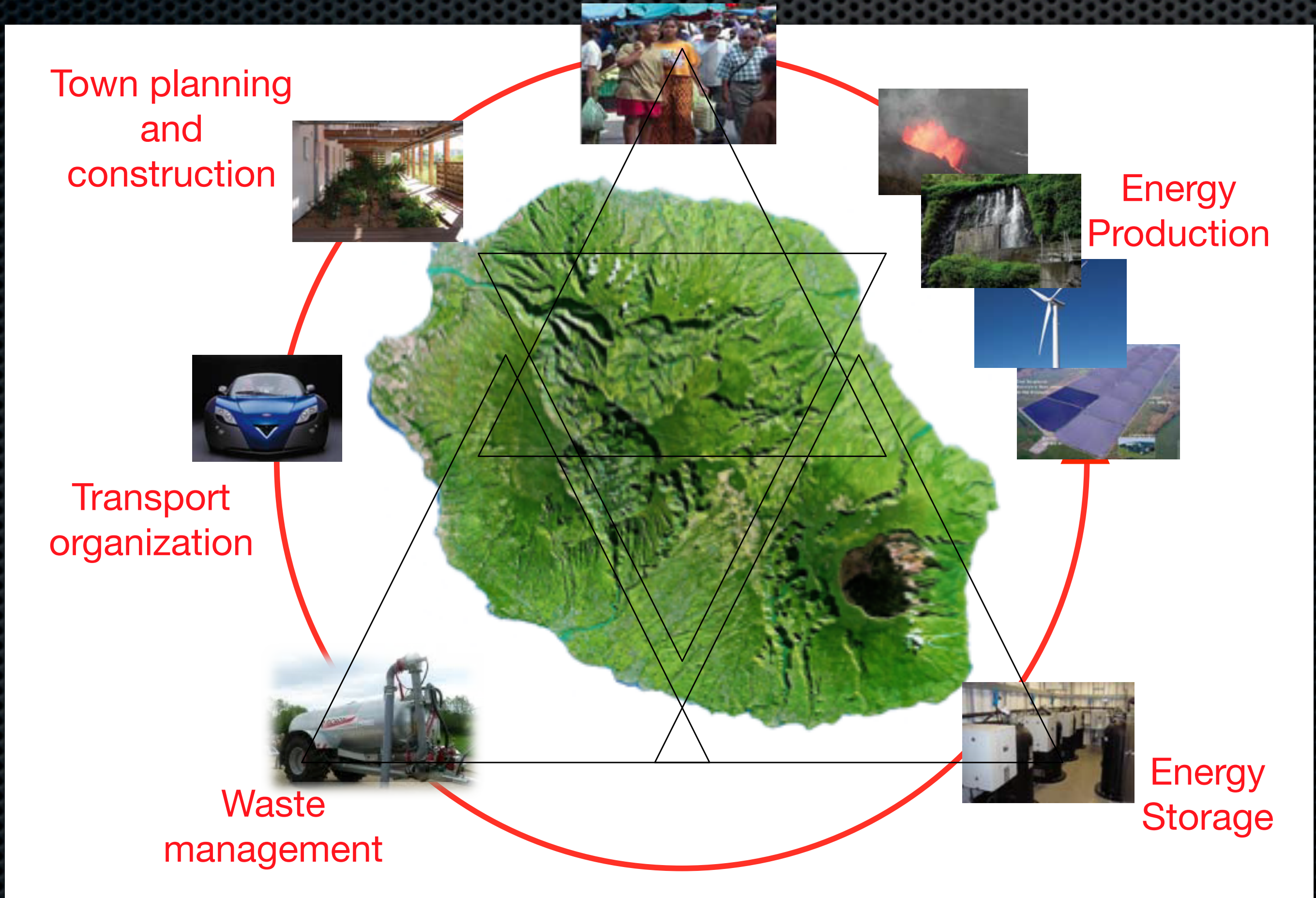
Agriculture & food self-sufficiency

Social changes and city evolution

Energy autonomy & renewable energies

# 'Energy Reunion' Program & Sustainable Dev.

- Steered by the French Government, Regional Council and economic actors
- Aimed at making Reunion Island a demonstration ground for all sustainable development technologies of interest for the society of the future.




**Land-use Planning for Sustainable development**

**A choice for**

*cross-sectional axis which help to manage the process of integration of innovative technologies into society*

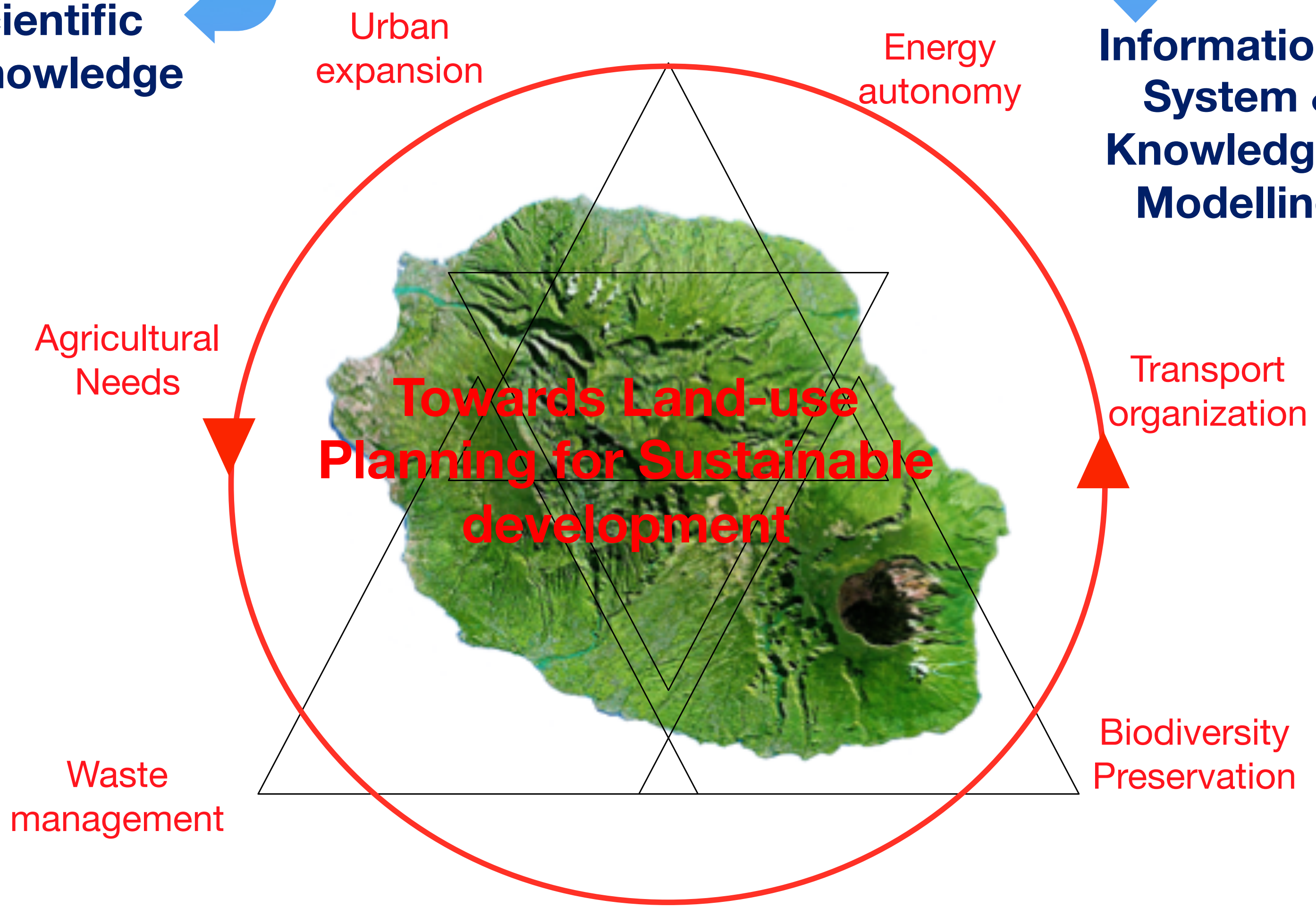
University of Réunion

20 research Labs

Computer Science and Mathematics Research Laboratory (EA2525-LIM)

**Thematic Scientific Knowledge**

**Information System & Knowledge Modelling**



Setting the Scene : Réunion Island Characteristics

# Hot spot for experimenting simulation case studies!

Relevant Case studies

**Geosphere** Observation

Tropical **Biodiversity**

Energy autonomy,
Land-use Planning for
**Sustainable development**

Relative small and
**closed system**

Great **diversity**

**Subtropical context**
with new constraints

Relevant environment

Forces available in terms
of human means

Modern economic organisation &
infrastructure

Existence of many research units
accredited by the French Ministry of
Research & high education

Relevant technical & human context

**Reunion Island is a particularly good candidate for applications on Natural and Social Simulation**

Setting the Scene : Réunion Island Characteristics

# Reason to simulate

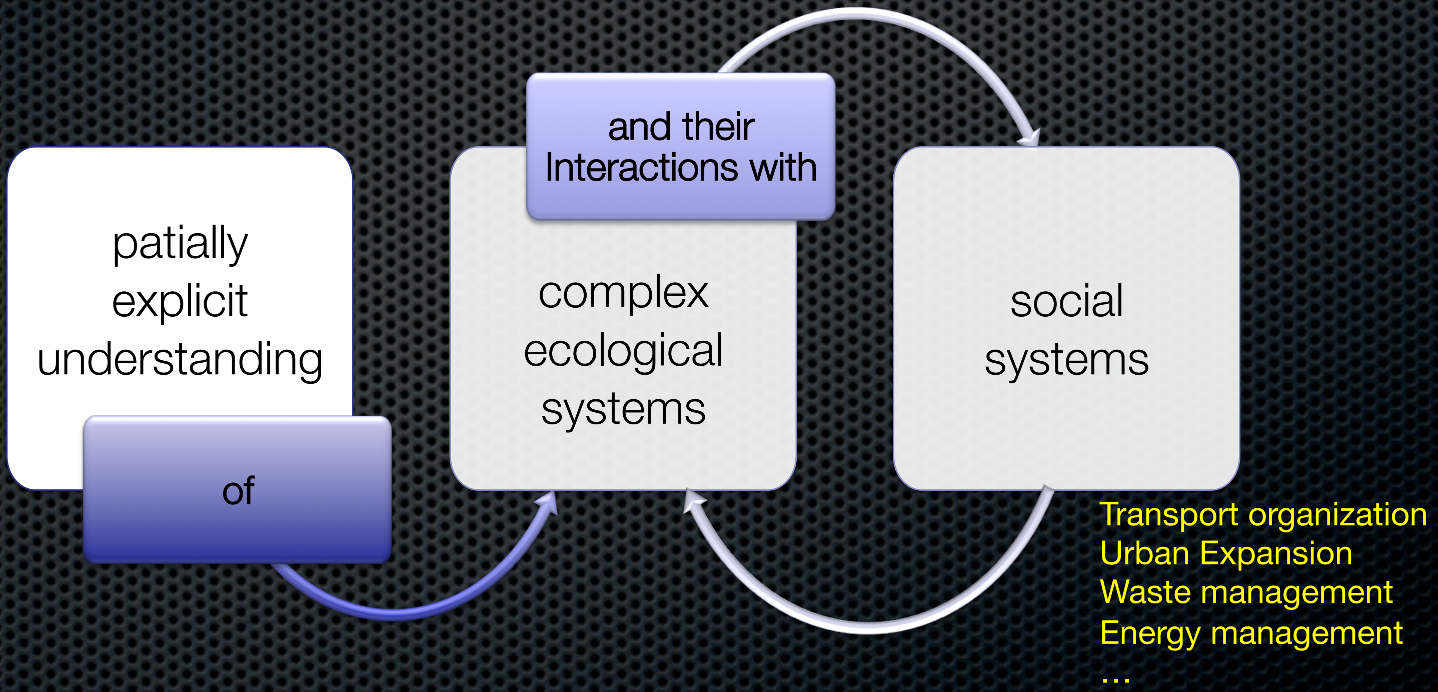
- We believe in a linear fashion, in a complex system, we are not able to understand all the forces at work and how they fit together
- We can not imagine all the possibilities of a complex system
- We are unable in a complex system  to predict all the effects of several cascading events, or a new element that our imagination could conceive

**We need to gain insight into the causes and effects, to allow establish arguments that will predict how events occur**

**We modeled especially for qualitative predictions of the future**

# Land-use planning and sustainable development

- Land-use planning guides the organization of a spatial environment to meet the demands of a society (Ligtenberg & al.,2004)



Setting the Scene : Réunion Island Characteristics

# Land-use planning and sustainable development

Expected impacts (Jiggins and Roling):

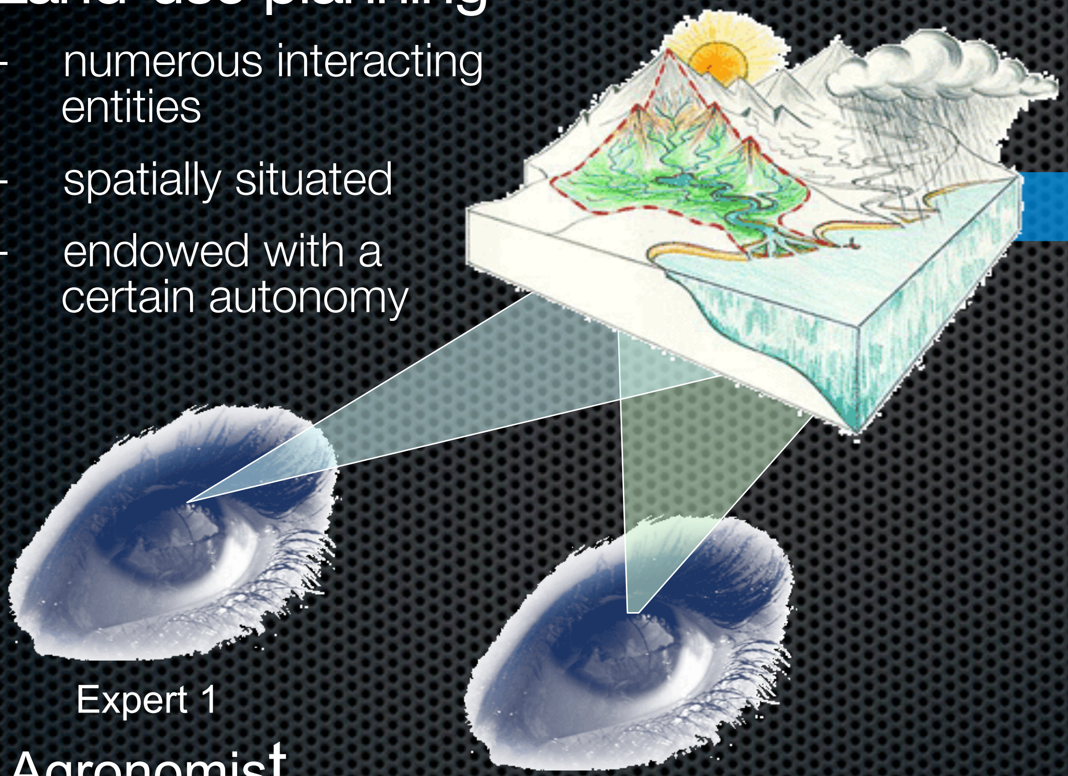
- Generating social robust knowledge for effective and efficient policy-making
- Enhancing social learning and capacity building for practical problem-solving
- Empowering and advocating for socio-political transformation.

**Although each of our Land-use applications combines often several of these objectives.**

# Land-use planning & MultiAgent Systems

## Land-use planning

- numerous interacting entities
- spatially situated
- endowed with a certain autonomy



Expert 1

Agronomist

Expert 2

Economist…

## Multiple formalisms

- ✓ Block diagrams
- ✓ Differential Equations
- ✓ Neural Networks
- ✓ Cellular Automata
- ✓ MultiAgent Systems
- ✓ …

Simulation System

Examples of MultiAgent Simulations

# Main applications developed

**Simulation Platforms**

**GEOMAS SEISMIC**
*Geophysical surveys for simulating seismic bedding planes*

**GEOMAS VOLCANIC**
*Geophysical surveys for simulating volcanic systems*

→ GeOmas Platform (Smalltalk)

**RUNMAGS** Probationary prototype
*Urban Mobility and Trafic Congestion Simulation*

**BIOMAS**
*Biomass flow modelling and organic waste management*

**MUFINS: MUlti Fish INdian ocean Simulator**
*Modelling of behavioural dynamics of fish resources*

→ GEAMAS Platform (Java)

**SMAT & DS**
*Simulation of Land use evolutions for public decision making*

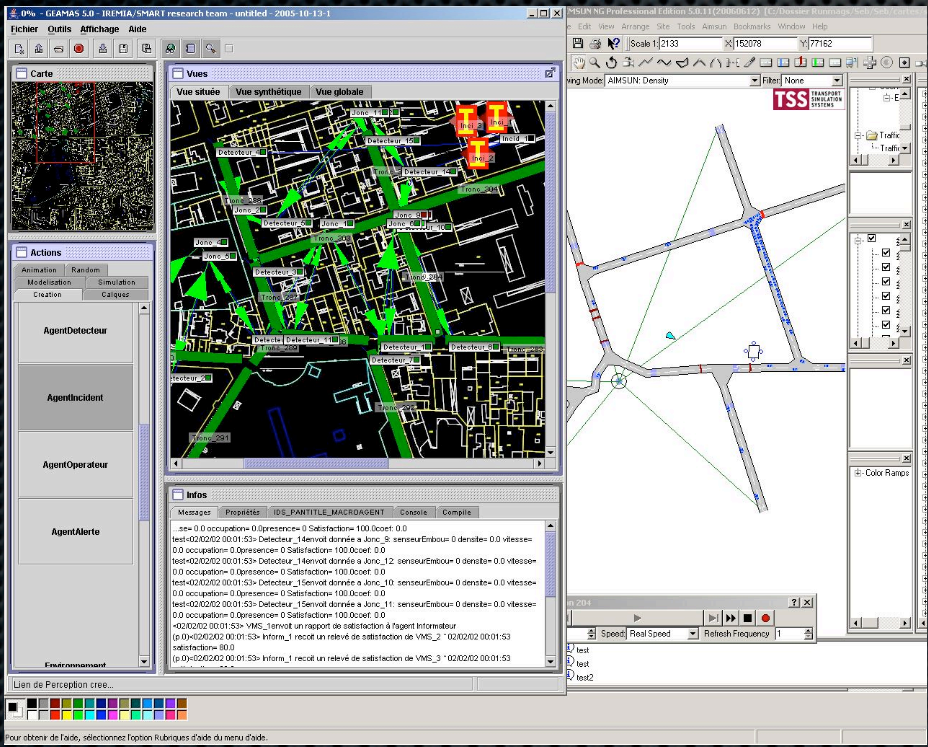
**EDMMAS** Probationary prototype
*Energy Demand Management by Multi-Agent Simulation*

→ GEAMAS-NG Platform (Java)

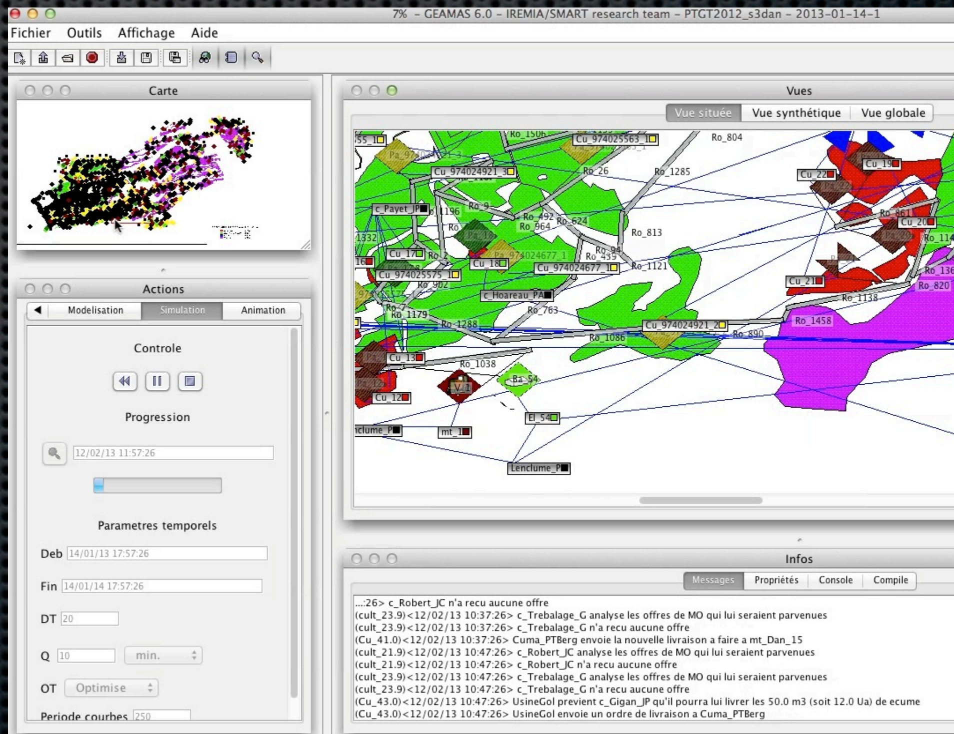
**Reunion Island is a particularly good candidate for applications on Natural and Social Simulation**

# Applications developed with GEAMAS simulation Platform

## RUNMAGS
*Urban Mobility and Trafic Congestion Simulation*




## BIOMAS
*Biomass flow modelling & organic waste management*

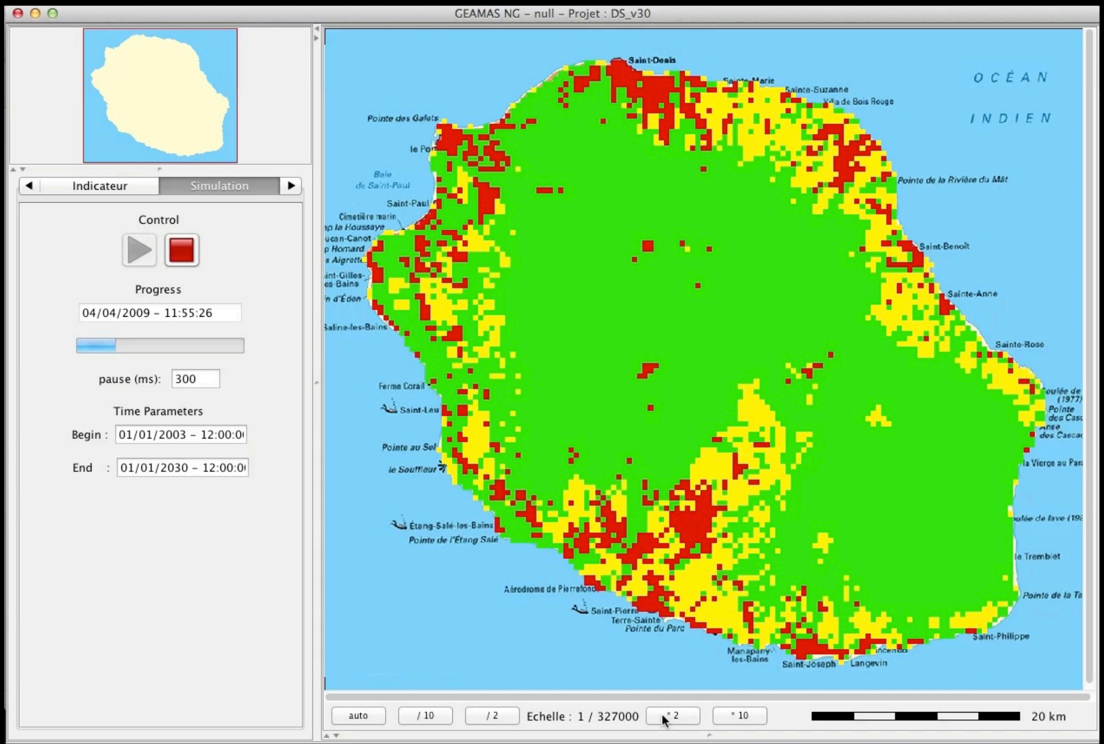


# Examples of Agent-Based Simulations

## Applications developed with GEAMAS-NG

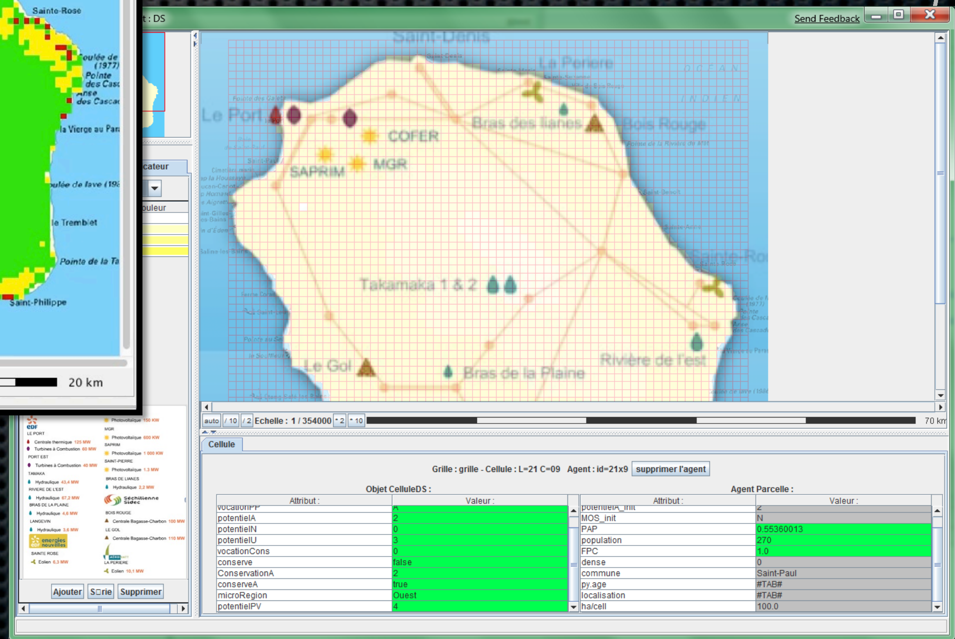
### SMAT & DS

*Simulation of Land use evolutions  for public decision making*




### EDMMAS

*Energy Demand Management by Mu*
*Agent Simulation*



Examples of MultiAgent Simulations

# Main examples of applications developed

## Applications using external simulation platforms

- Use Cases
  Master projects
- TURTLES are the TURTLES
  *Evolution of a green turtles population on several generations in the South-West Indian Ocean*

NetLogo — Northwestern University, Evanston, IL

- Use Cases
  Master projects
- Modelling human activities in farming systems based on the situated action theory

AnyLogic 6 — XJ Technologies

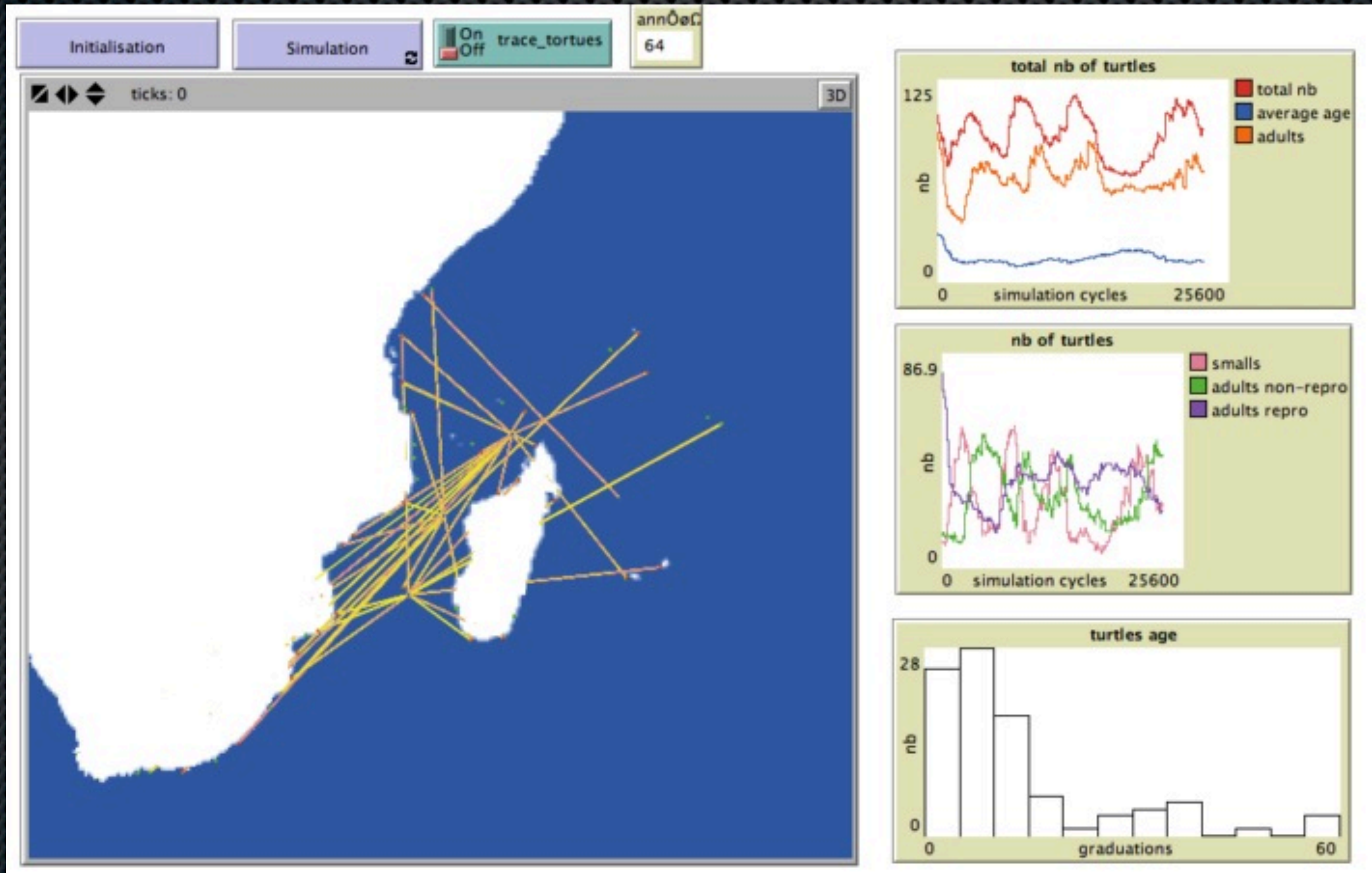
Examples of Agent-Based Simulations

# Example of NetLogo application

Northwestern University, Evanston, IL

TURTLES are the TURTLES

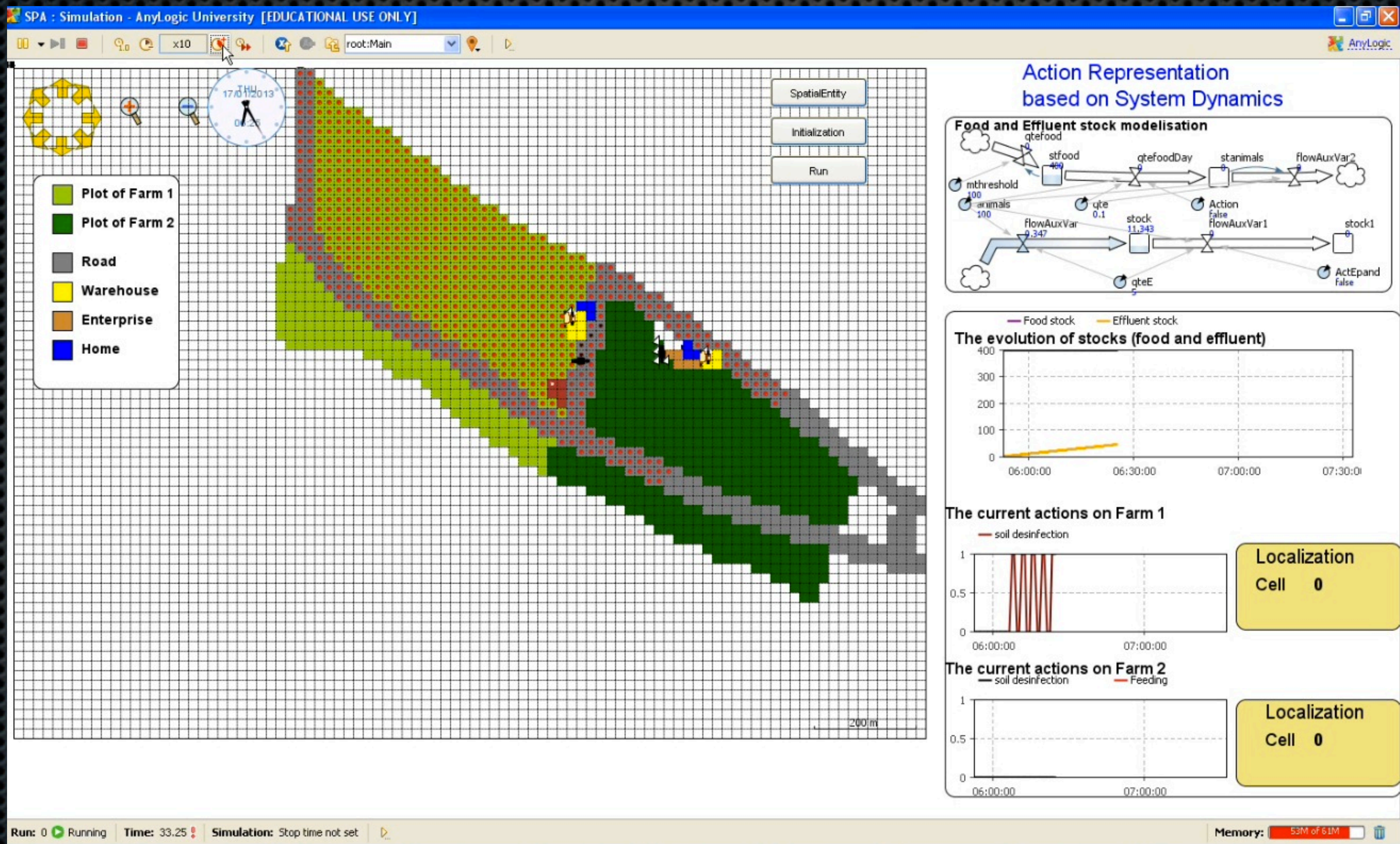
*Evolution of a green turtles population on several generations in the South-West Indian Ocean*



# Example of AnyLogic application


XJ Technologies

Modelling human activities in farming systems based on the situated action theory



# Research orientation

Multiagent Simulation as a tool for
Spatial Planning and Sustainable Development

## Complex Systems

- Large variety of entities having specialized functions,
- Internal hierarchical levels of entities organization,
- High density of interconnections,
- Nonlinear interactions between entities,

…

- Collective phenomena give rise to emergent properties

**MultiAgent System**

## IA technics & Distributed programming

## Simulation

Creates an abstraction of a system as it evolves through time

- Helps with the validation of scientific assumptions
- Helps with the comprehension of system dynamics
- Decision-making aid

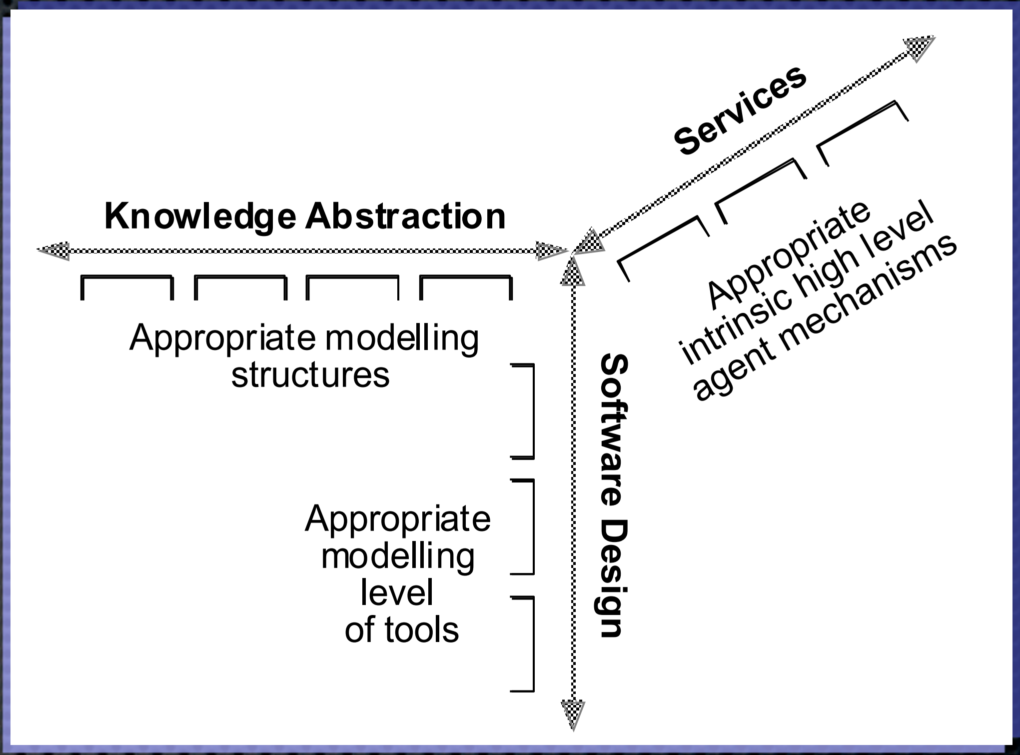
For systems where direct observation and measurement are not possible:

- Cannot be reproduced
- Cannot be experimented with

## Research Orientation

# Research on simulation platform architectures

- ✓ **Knowledge abstraction dimension**
  Appropriate modeling structures that enables the complexity of the tackled systems to be effectively managed (meta knowledge, knowledge, real world)
- ✓ **Software design dimension**
  Appropriate modeling level of tools to design such applications (set of software API)
- ✓ **Services dimension**
  Appropriate intrinsic high level agent mechanisms and services (observation services,…)




Zooming on a multiagent simulation system: from the conceptual architecture to the interaction protocol, IEEE Computer Society Press

Research Orientation

# Main conceptual challenges and issues

Research Key words

**Computer Sciences Contributions**

- How to architecture mutiagent systems for simulation?
- How to represent Agents, Roles, Organisations, Interactions protocols, Emerging phenomena?
- How to distribute a MAS simulation on a network architecture?
- How to represent the Environment and the Time?

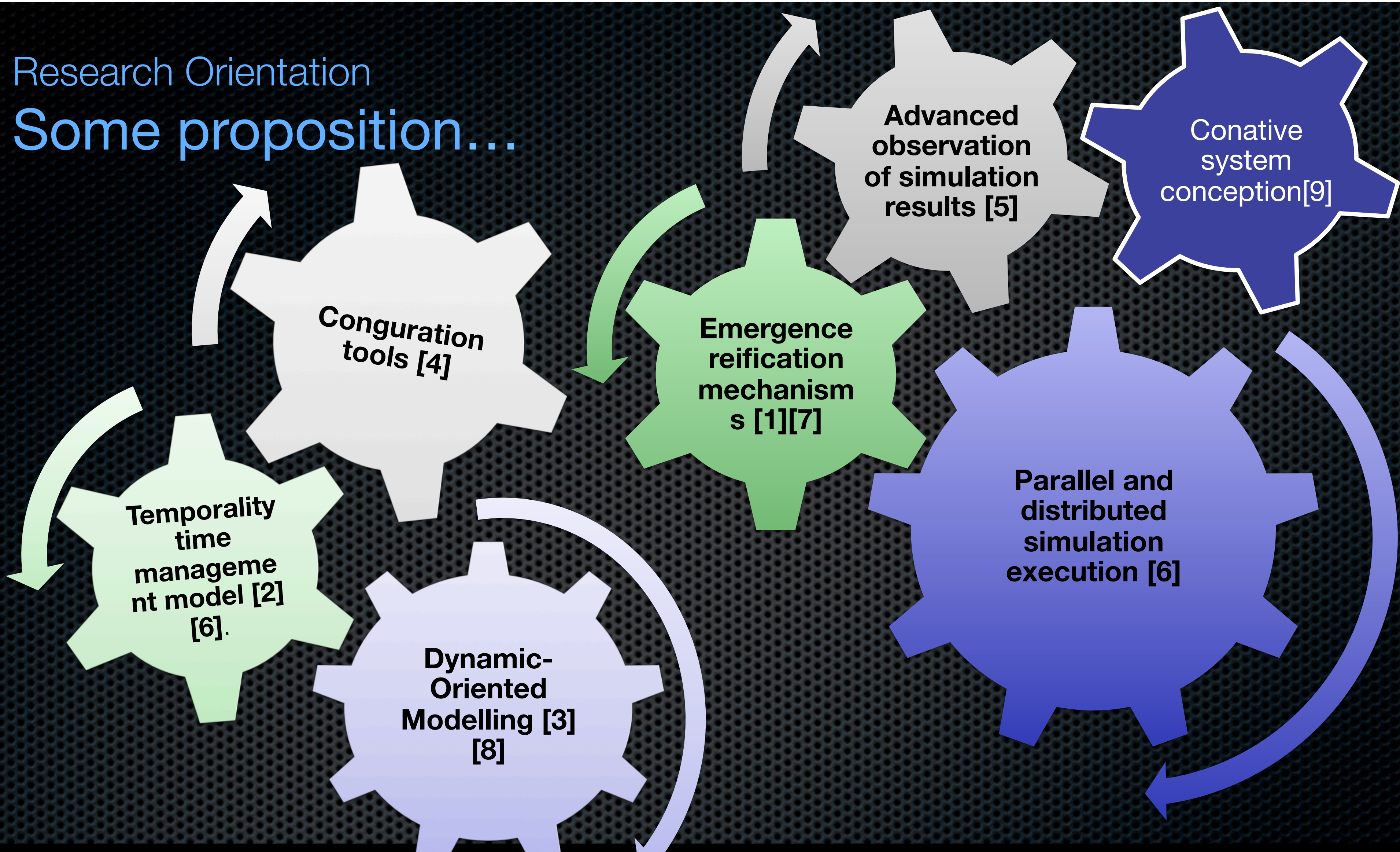
→ Software Engineering AI algorithms

- How to observe the activity and results of a multiagent system?
- How to consider participatory modelling?
- How to reuse dynamics from MAS applications?

→ Methodology

Research Orientation

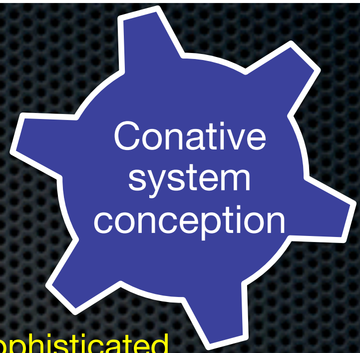
# Some proposition…



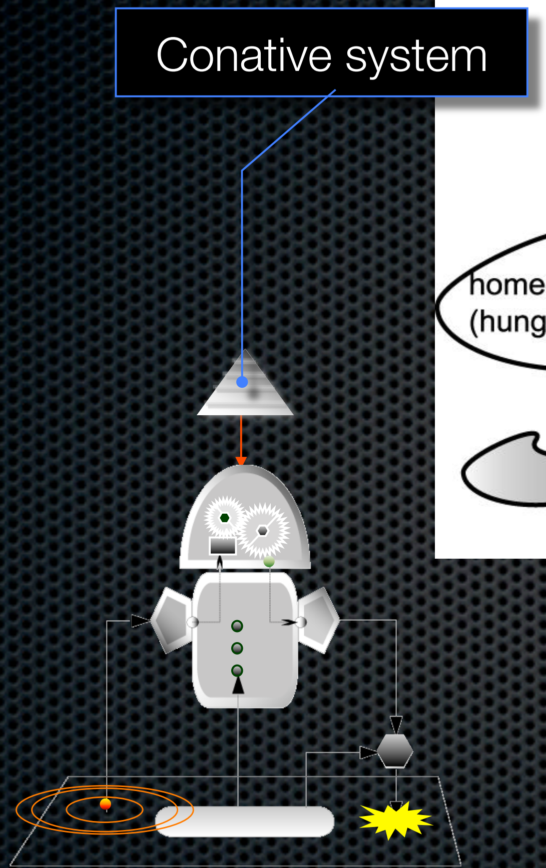

[1] Emergence as Metaknowledge: Refining Simulation Models through Emergence Reification ESM08, 2008.
[2] modele a Temporalite: pour un equilibre entre adequation et optimisation du temps dans les simulations agents, JFSMA06, 2006.
[3] Environment as support for simplication, reuse and integration of processes in spatial MAS, IRI 2006, Hawaii, USA, 2006.
[4] XELOC: eXtensible Editing Language Of Conguration - To facilitate complex systems conguration edition and reuse, EA2525, 2007.
[5] Tools to visualise the structure of multiagent conversations at various levels of analysis Modsim'07, 2007.
[6] Analysis of temporal dependencies of perceptions and influences of the distributed execution of agent-oriented simulations ESM08, 2008.
[7] Modelling Situated Action based on Affordance and Stigmergy, SASO, 2012
[8] Another step toward reusability in agent-based simulation : Multi-behaviors & aMVC," ICTAI 2012…
[9] Generic Motivations in Social Hybrid Agent, RASTA'02 part of AAMAS' 2002

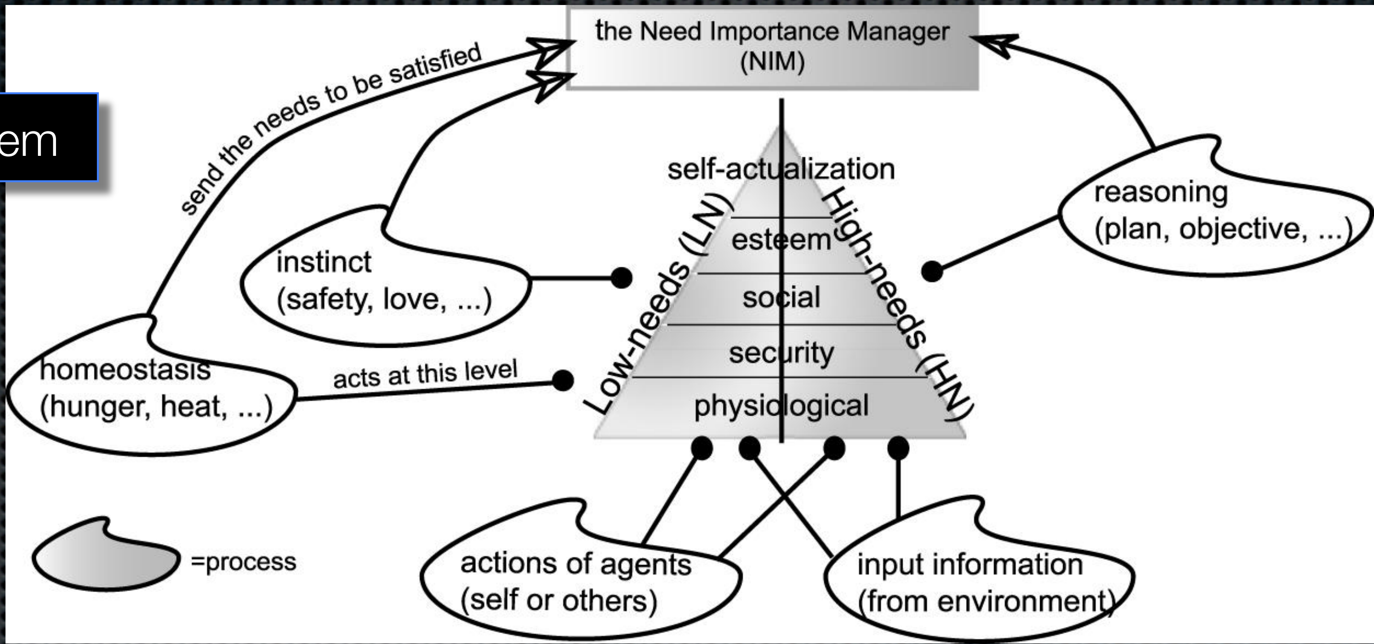
Research orientation

# How to define a conative system?




Depending on the applications the conative System can be more and less sophisticated




Generic Motivations in Social Hybrid Agent, International Workshop on Regulated Agent-Based Social Systems: Theories and Applications (RASTA'02) as part of AAMAS' 2002

The basic instinct of an autonomous cognitive agent: From individual to collective behavior, In International ICSC Congress on Autonomous Intelligent Systems (ICAIS'2002)

Hybrid Model to Design Proactivity and Multi-Agent-Systems, 2002 World Scientific and Engineering Society (WSES) Intern. Conference on evolutionary computations.

# Research orientation
## How to define the environment?

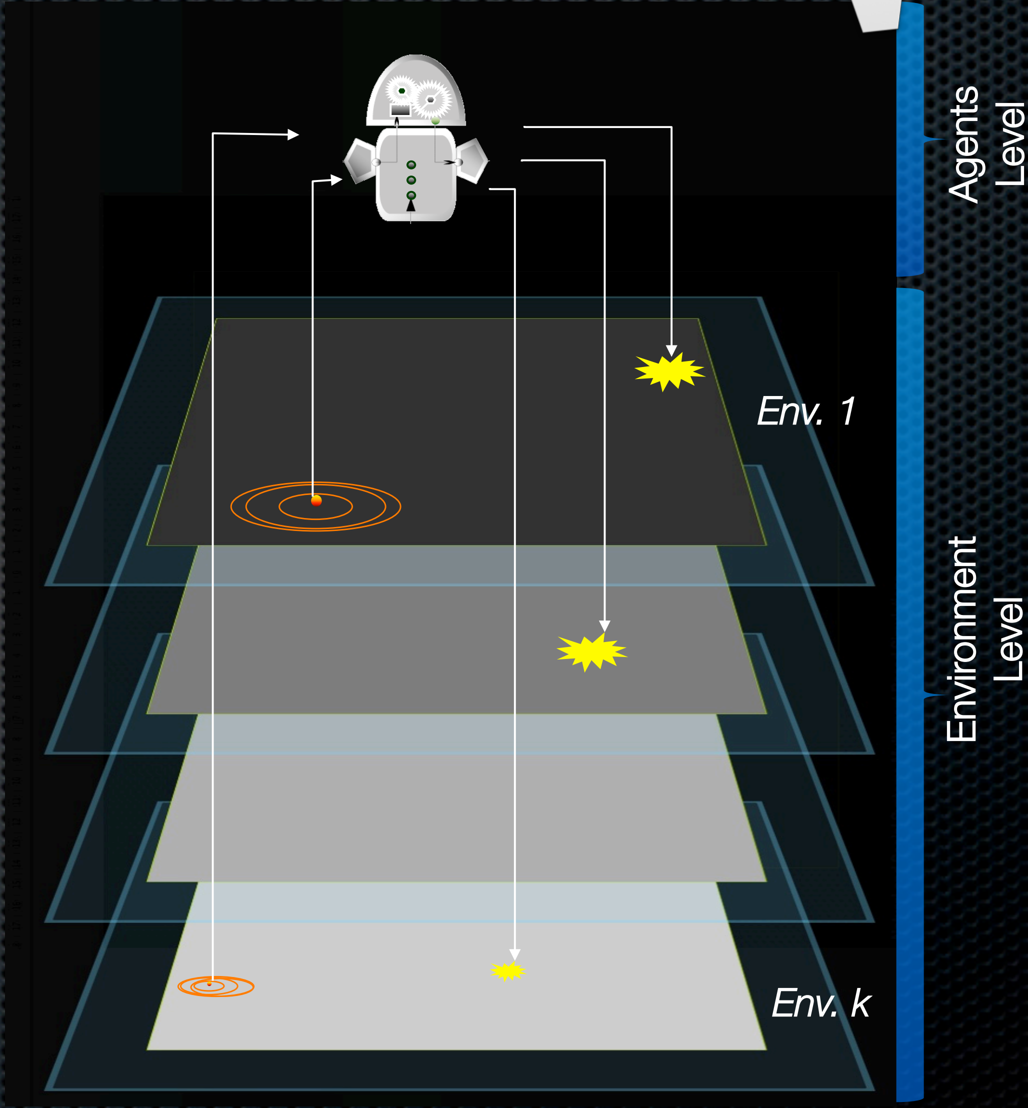
Congura
tion
tools

```xml
<!-- Ajout de l'environnement spatial -->
<addEnvironment  name="ForestWorld"
                 setGlobal="worldName" />
<!--  Configuration de cet environnement -->
<configEnvironment environment="@worldName">
     <multiValue>
          <champ name="request"
                 value="size" />
          <champ name="row"
                 value="@nbRow" />
          <champ name="column"
                 value="@nbColumn" />
     </multiValue>
</configEnvironm
```

```xml
<forMap  name="BiodiversityPotential"
         url="./maps/biodivPotential.bmp"
         resolution="16" >
   <legend name="3classes" >
      <label name="Faible"
             r="255"  v="255" b="128" />
      <label name="Moyen"
             r="242"  v="167" b="46" />
      <label name="Fort"
             r="107"  v="0"  b="0" />
   </legend>
   <cell legend="3classes"
         operator="average" mode="closer" >
      <case label="Faible">
         <!-- suite d'instructions 1 -->
      </case>
      <case label="Moyen">
         <!-- suite d'instructions 2 -->
      </case>
      <case label="Fort">
         <!-- suite d'instructions 3 -->
      </case>
   </cell>
</forMap>
```

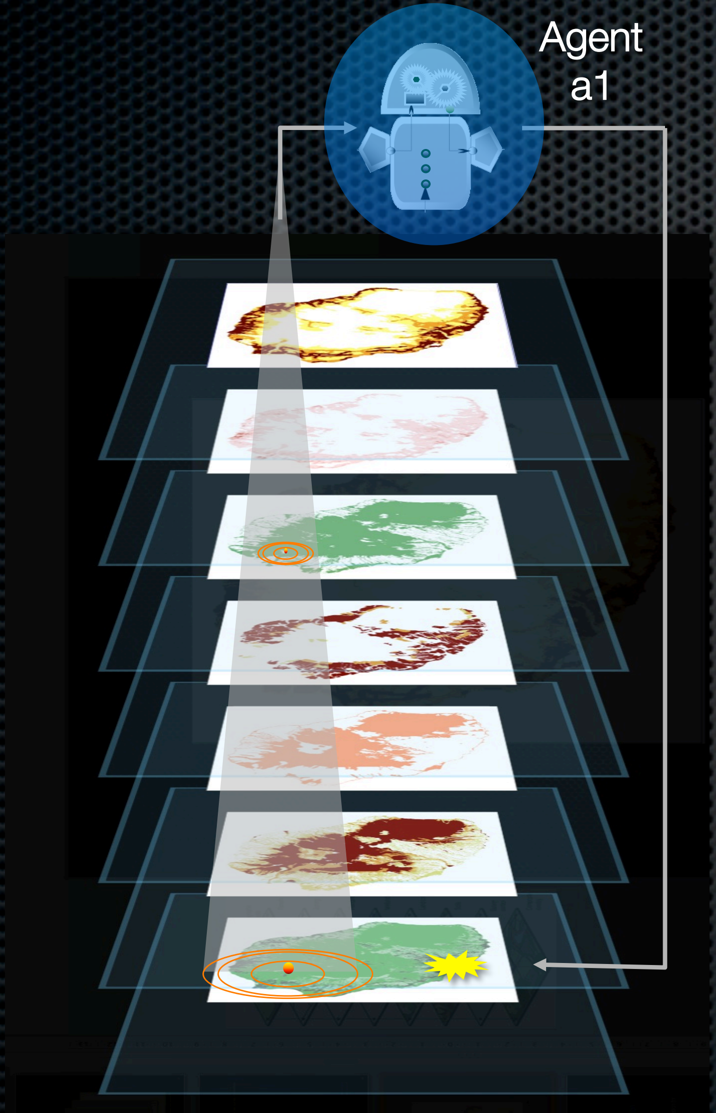
XELOC: eXtensible Editing Language Of Configuration

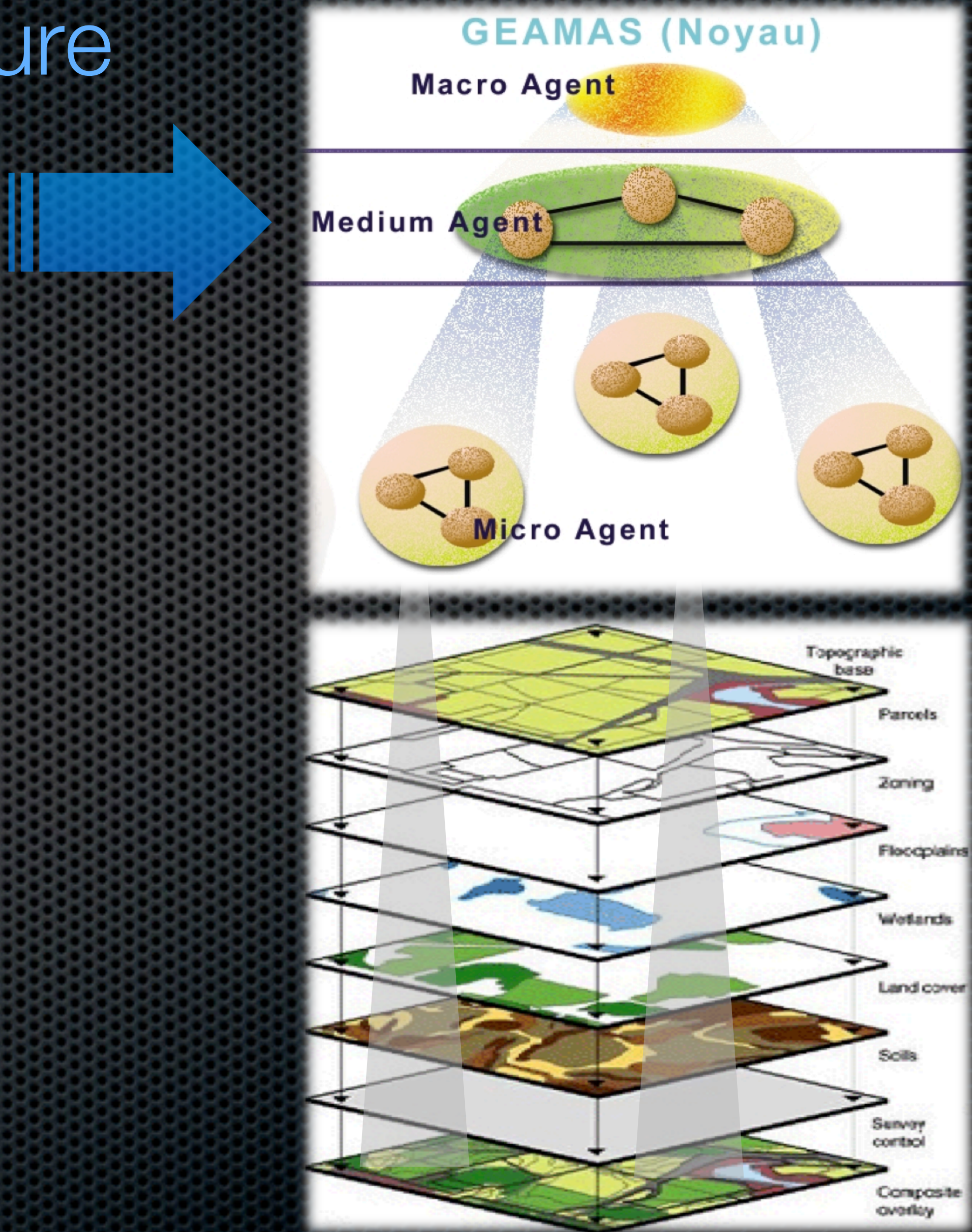
to facilitate complex systems environment configuration edition and reuse



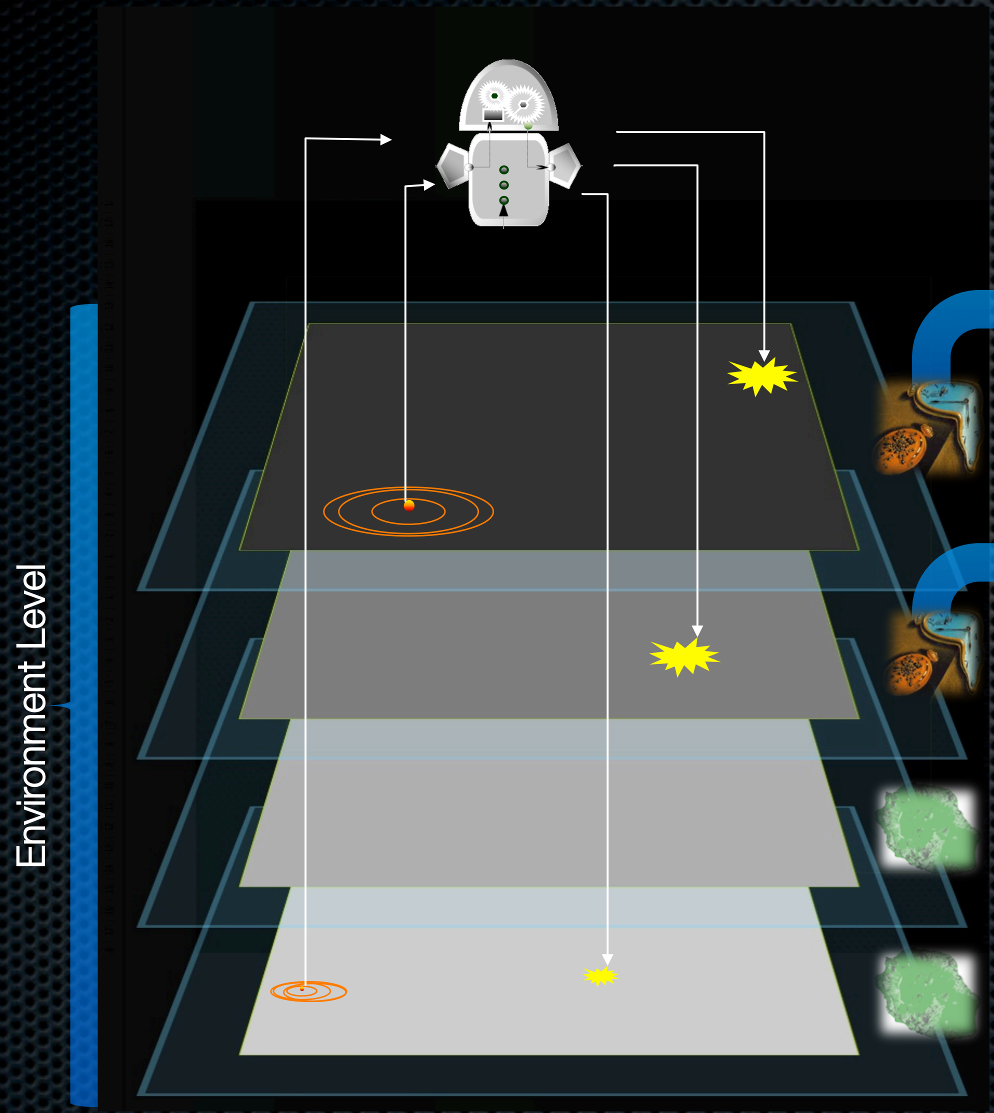

Depending on the applications the environment modelling can be more and less sophisticated

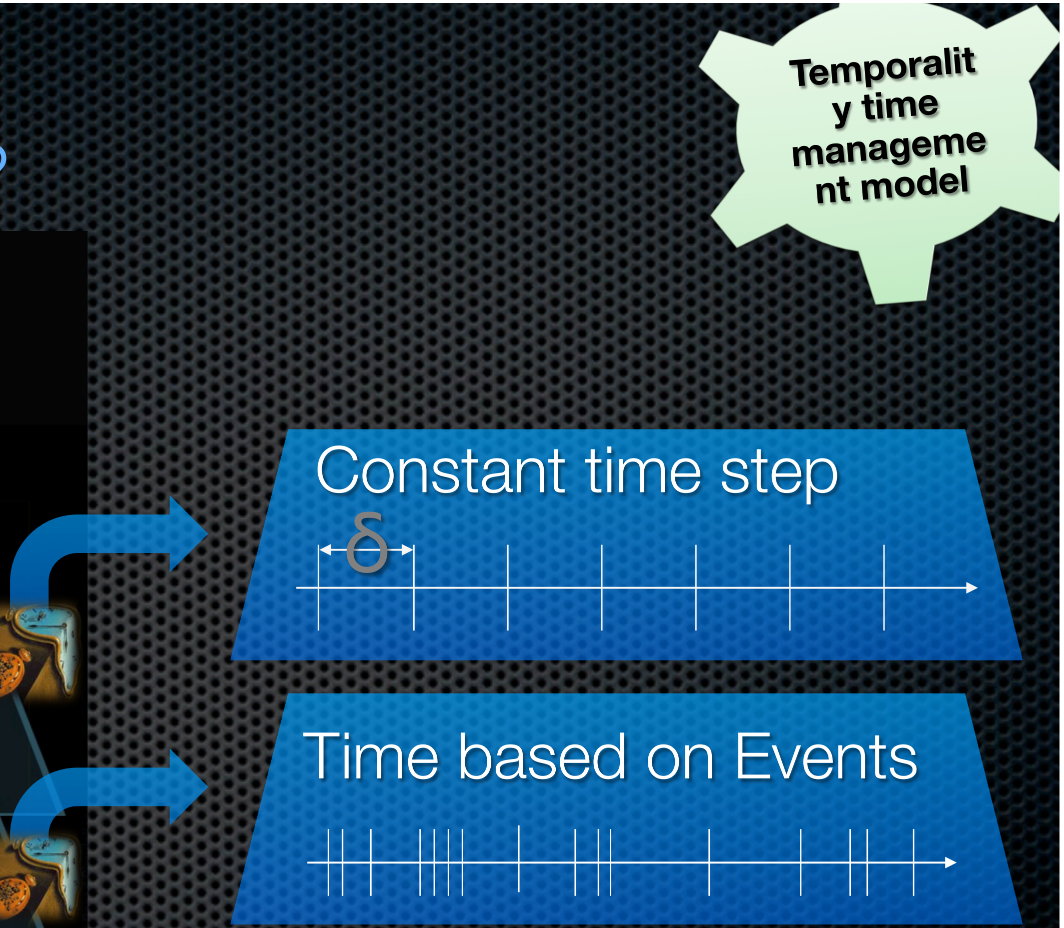
# GEAMAS Architecture



# Research orientation
## How to define the time?



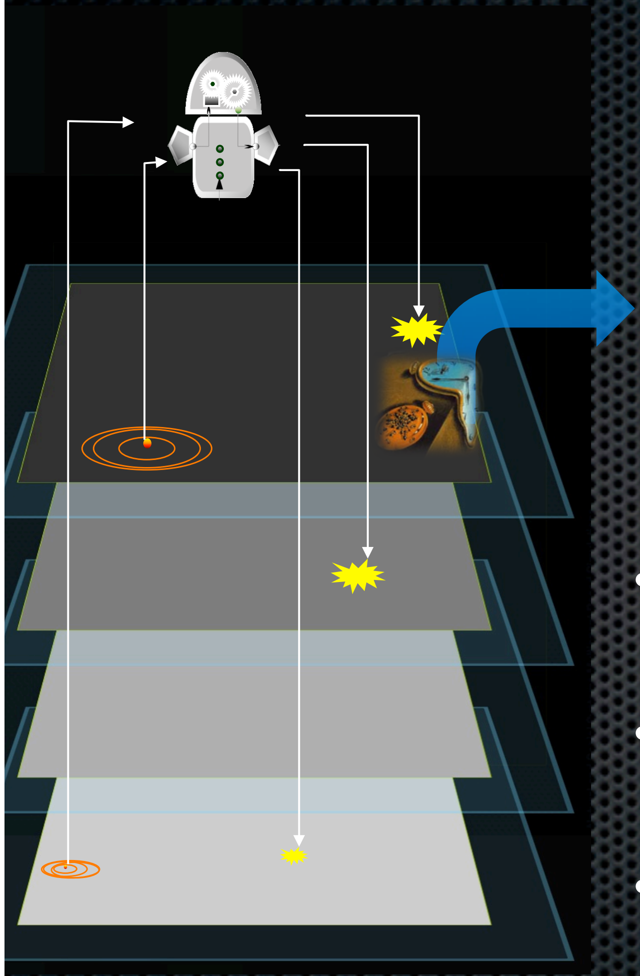

Depending on the applications the time modelling can be more and less sophisticated

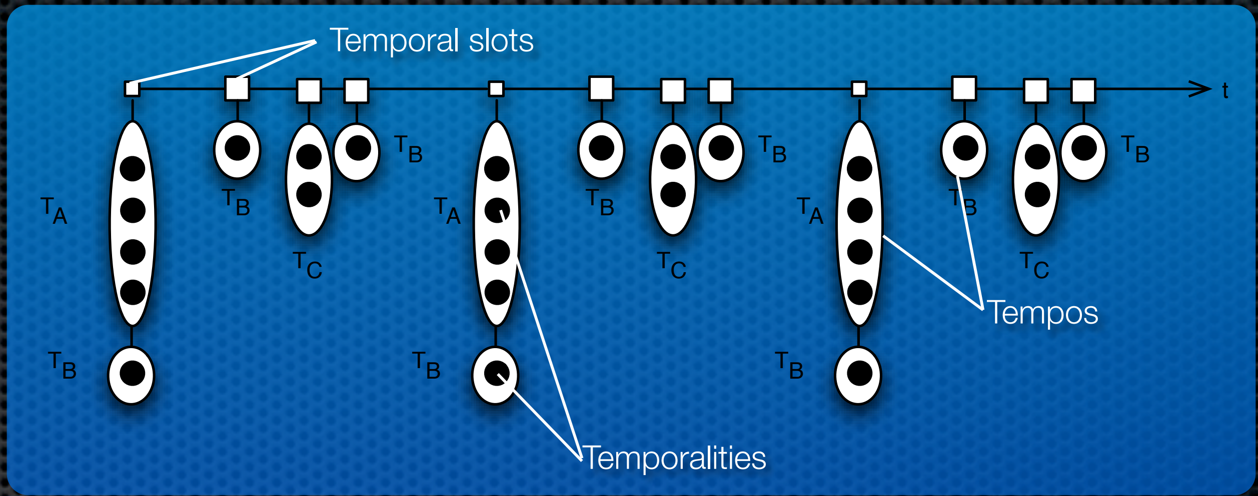
We propose that the time line is viwed by the agent as an environment

**Towards a Multi-temporal simulation systems**
**Not so easy => Temporality Time model**

Research orientation

# The temporality model






- **Temporality**: temporal structure describing triggering of an agent behavior.
- **Temporal slot**: temporal axis' point on which the scheduler trigger a temporality.
- **Tempo** : structure wrapping temporalities sharing same period and a temporal slot.

Research orientation

# The « Temporality Time Model »

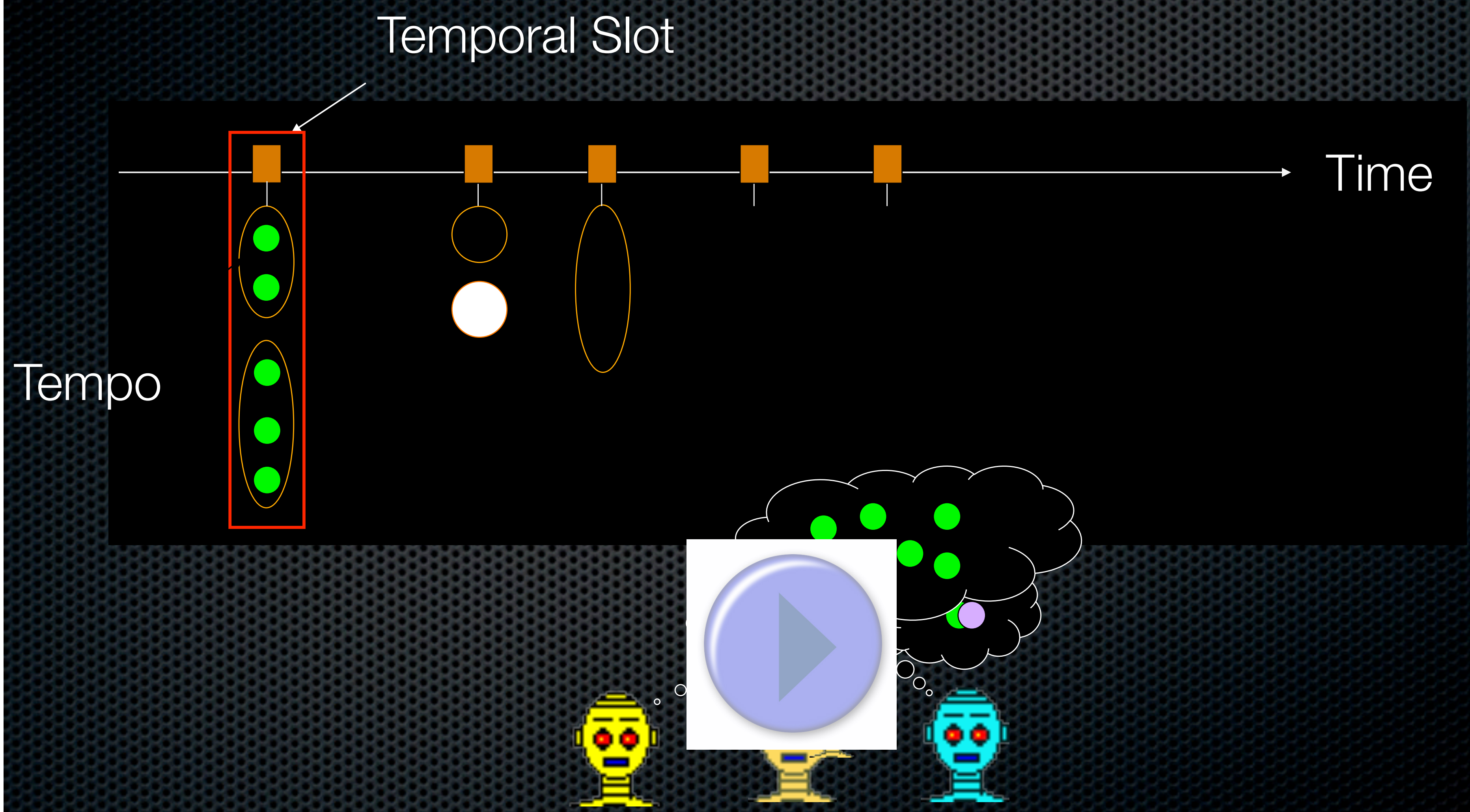
- Temporality : temporality is the description of a temporal time point.


t = {id, d , f, p, v}

- id : temporality ID
- [D, f]: the range of validity
- P: the period that defines the set of points?
- V: variability (tolerance range)

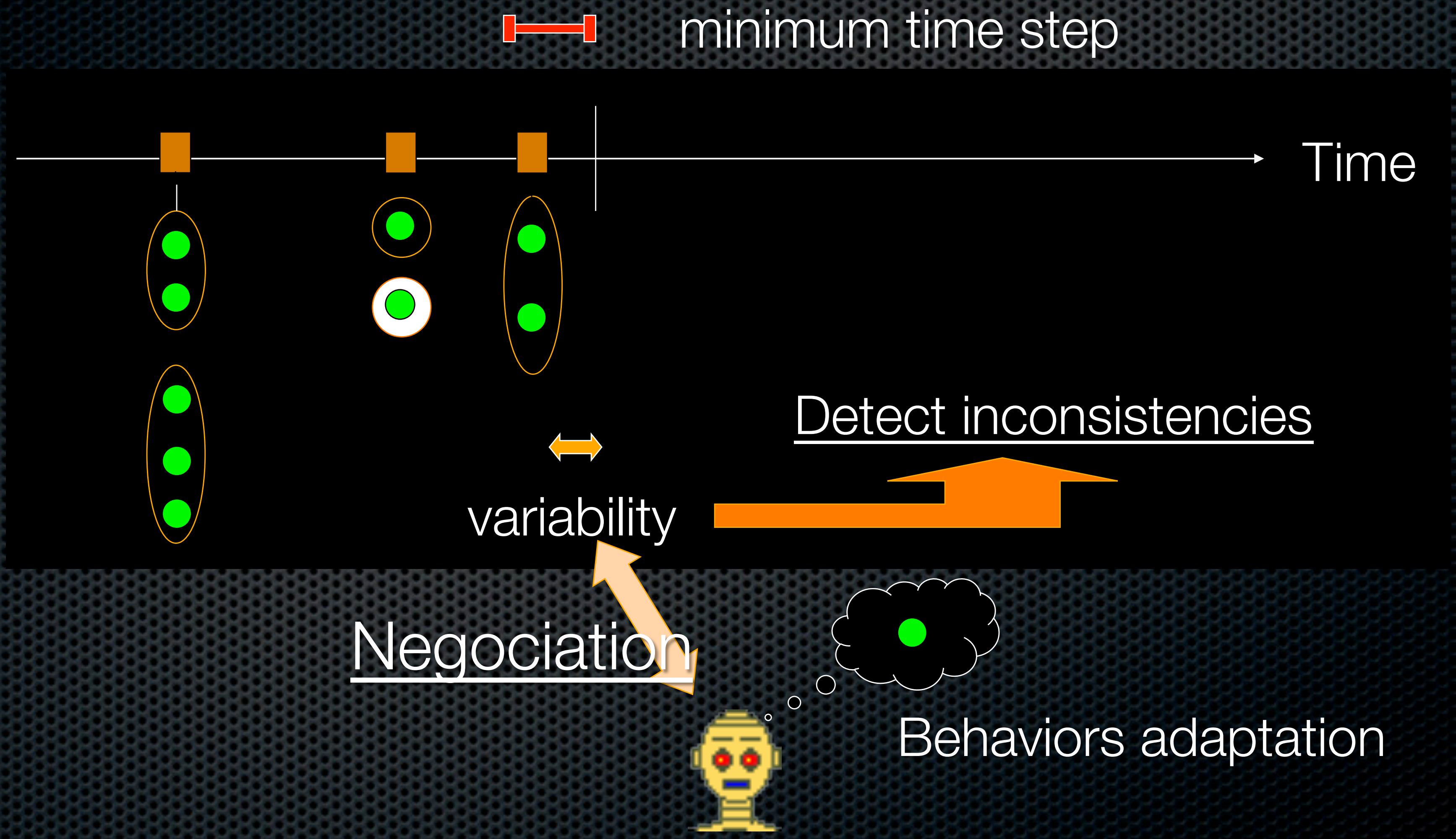
## Research orientation

# The « Temporality Time Model »



## Research orientation

# The « Temporality Time Model »



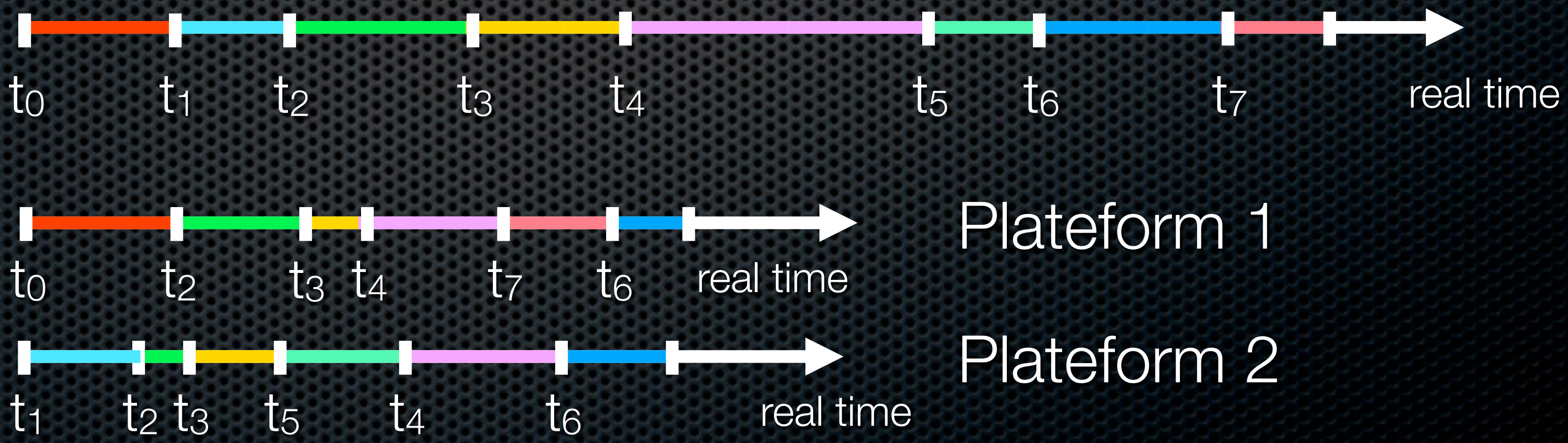
# Parallel and distributed simulation

Parallel and distruted suimulation

Define a scheduler that

- enables parallel simulation of agents being executed at different simulation times,
- takes advantage of simulation model's properties,
- preserves simulation's coherence and integrity.

Simulation execution



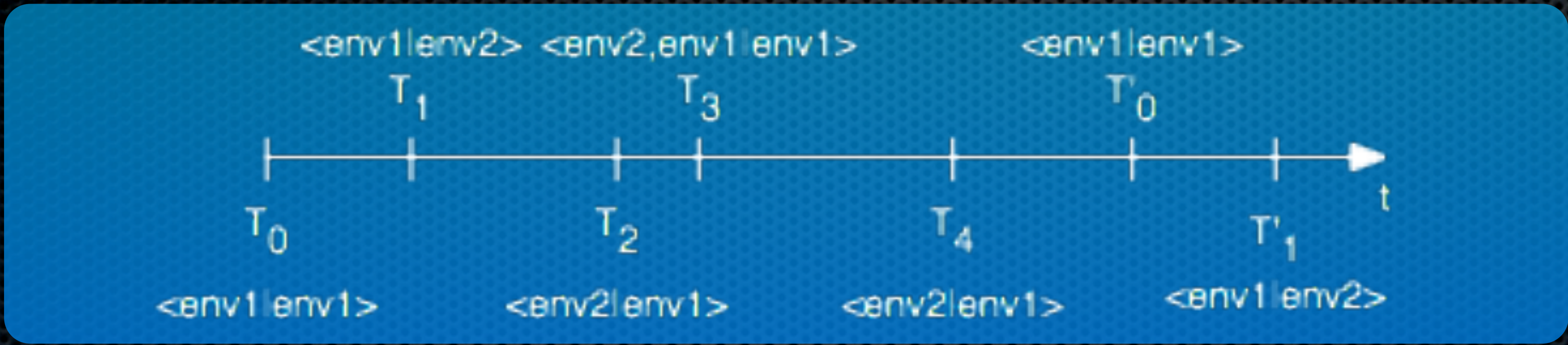
# Optimizing parallelism

- Temporality model provides an *a priori* temporal axis.
- With a classic scheduler, an agent behavior depends on each previous events.


$$t+5 \rightarrow t \wedge t+1 \wedge t+2 \wedge t+3 \wedge t+4$$

**What does “depend on each previous events” mean?**

# Dependencies table - example




$T_0 \rightarrow T_2(P-1) \wedge T_3(P-1) \wedge T_4(P-1)$

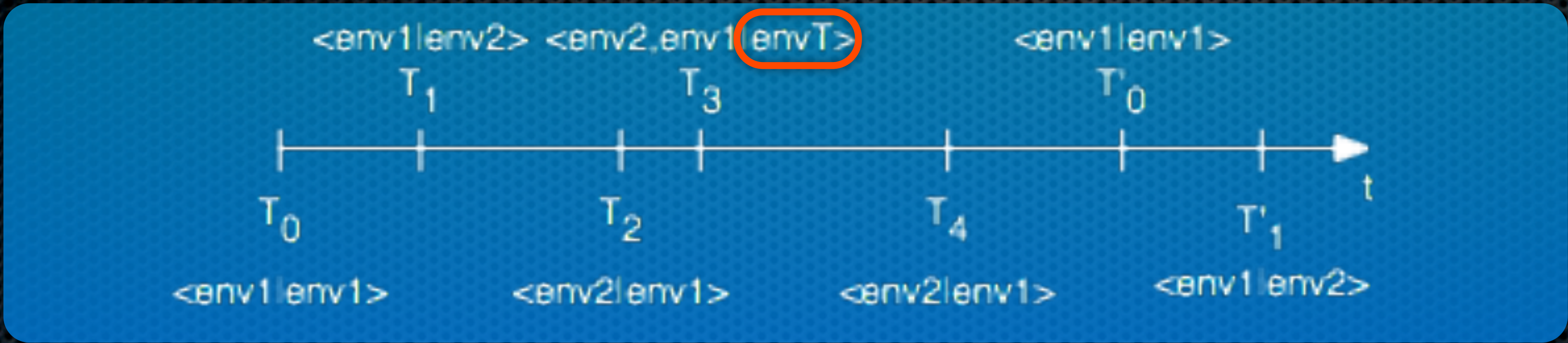
$T_1 \rightarrow T_0 \wedge T_2(P-1) \wedge T_3(P-1) \wedge T_4(P-1)$

$T_2 \rightarrow T_1$

$T_3 \rightarrow T_0 \wedge T_1 \wedge T_2 \wedge T_4(P-1)$

$T_4 \rightarrow T_1$

# Dependencies table - example




$T_0 \rightarrow T_2(P-1) \wedge T_4(P-1) \wedge T_3(P-1)$

$T_1 \rightarrow T_0 \wedge T_2(P-1) \wedge T_4(P-1) \wedge T_3(P-1)$

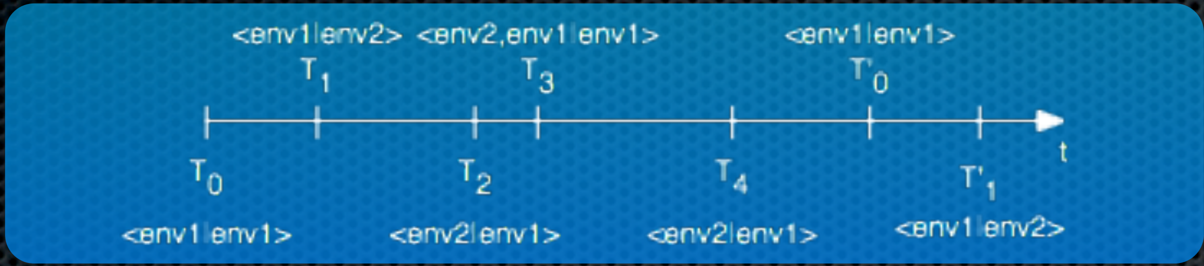
$T_2 \rightarrow T_1 \wedge T_3(P-1)$

$T_3 \rightarrow T_0 \wedge T_1 \wedge T_2 \wedge T_4(P-1)$

$T_4 \rightarrow T_1 \wedge T_3$

# Execution

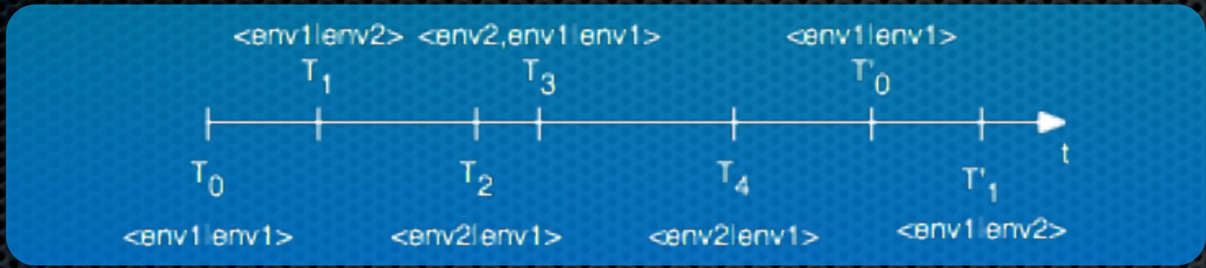
- at $t_{sg}=0$




| | | | | |
|---|---|---|---|---|
| T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) | |
| T1 | T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) |
| T2 | T0 | T1 | T3 (P-1) | T4 (P-1) |
| T3 | T0 | T1 | T2 | T4 (P-1) |
| T4 | T1 | | | |

# Execution

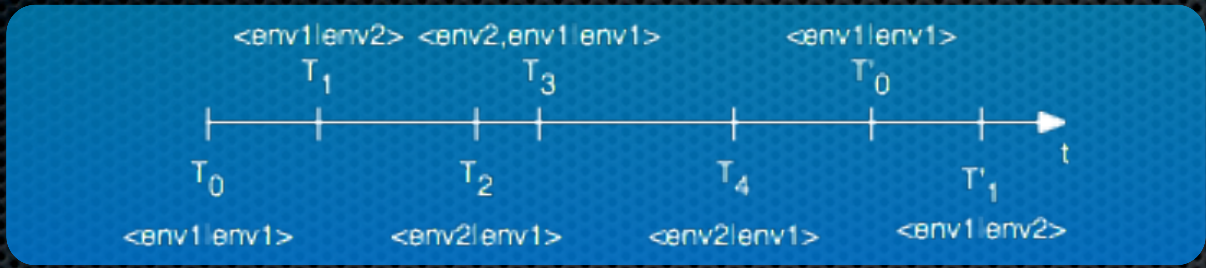
- at $t_{sg}=t_{s0}$




| | | | | |
|---|---|---|---|---|
| T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) | |
| T1 | T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) |
| T2 | T0 | T1 | T3 (P-1) | T4 (P-1) |
| T3 | T0 | T1 | T2 | T4 (P-1) |
| T4 | T1 | | | |

# Execution

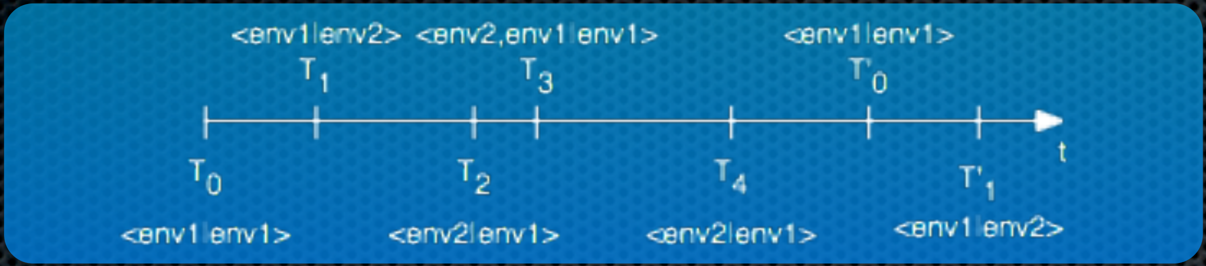
- at $t_{sg}=t_{s1}$




| | | | | |
|---|---|---|---|---|
| T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) | |
| T1 | T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) |
| T2 | T0 | T1 | T3 (P-1) | T4 (P-1) |
| T3 | T0 | T1 | T2 | T4 (P-1) |
| T4 | T1 | | | |

# Execution

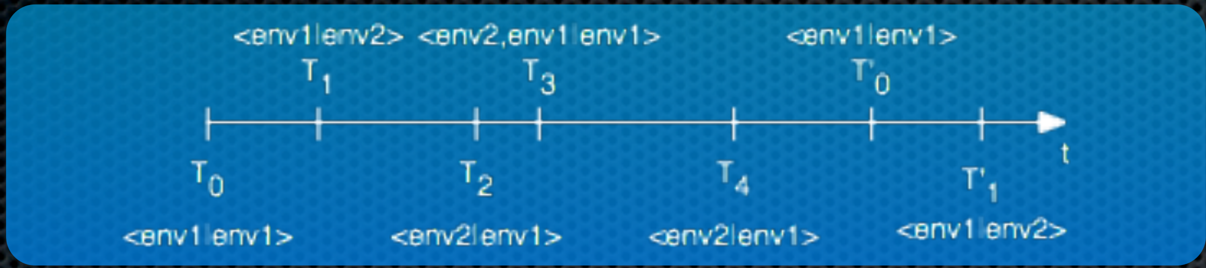
- at $t_{sg}=t_{s2}$




| | | | | |
|---|---|---|---|---|
| T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) | |
| T1 | T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) |
| T2 | T0 | T1 | T3 (P-1) | T4 (P-1) |
| T3 | T0 | T1 | T2 | T4 (P-1) |
| T4 | T1 | | | |

# Execution

- at $t_{sg}=t_{s3}$




| | | | | |
|---|---|---|---|---|
| T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) | |
| T1 | T0 | T2 (P-1) | T3 (P-1) | T4 (P-1) |
| T2 | T0 | T1 | T3 (P-1) | T4 (P-1) |
| T3 | T0 | T1 | T2 | T4 (P-1) |
| T4 | T1 | | | |

# Reification of emergent phenomena?

Emergence reification mechanisms

- Old (but good?) question!
  - **Can we** do it?
  - ....**should we** do it?

- *A priori* always **useful?** But...
  - emergence is the result
  - hardware and software limitations
  - "nature"

➡ **Reification = Detection + Materialization**

➡ **Be careful...**

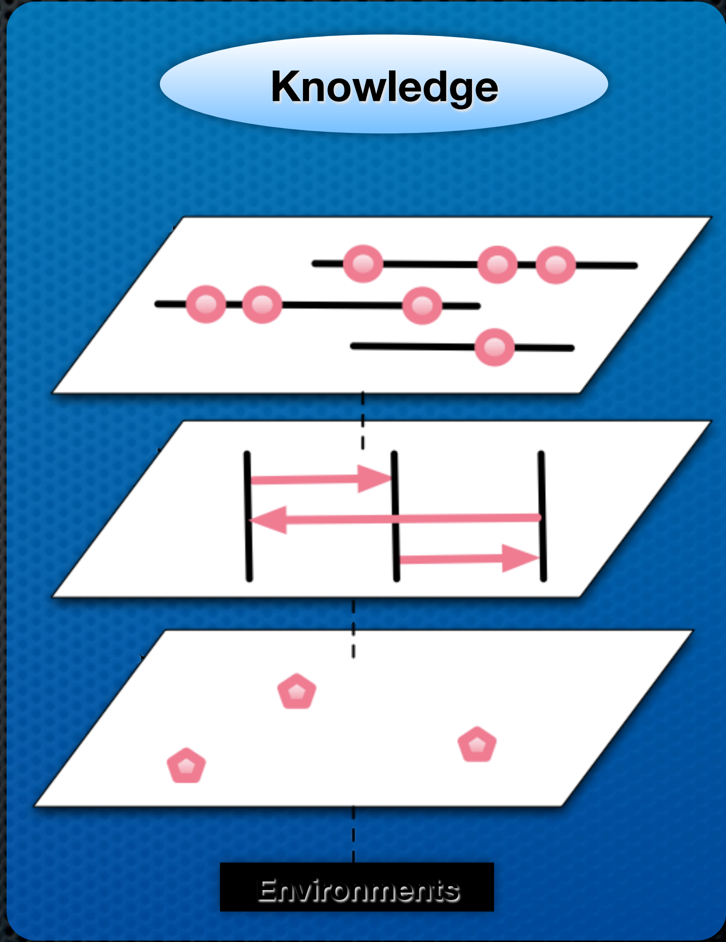
# Many work has been done...

## Definitions

- Emergence Meta-knowledge
- Emergence Laws
- Emergence Revelators

## Formalization

- $R_E = \{ \mathbf{f} : K^n \rightarrow boolean \}, n \in \mathrm{N}$
- $P_E = \{(\mathbf{f},\mathbf{k}) \in R_E \times K^n \,/\, \mathbf{f}(\mathbf{k}) = true\}$
- $L_E = \{ \mathbf{f} : {P_E}^n \rightarrow S_E \}, n \in \mathrm{N}$




## Application

- **Introduction of Emergence Structures in an ABS**

# Emergence Structures

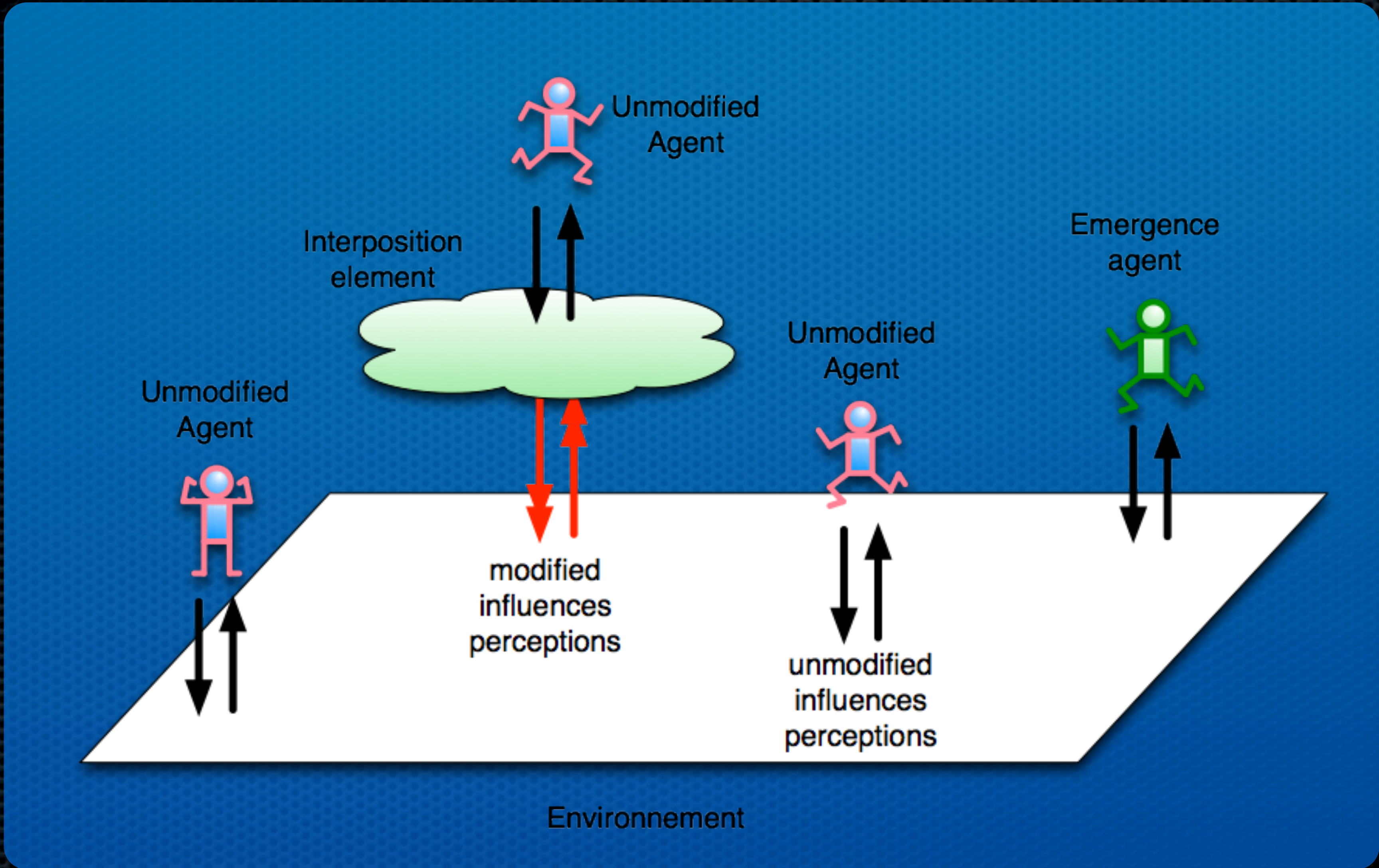
- **Emergence Agent**

  **agent** that runs within an **ABS platform** in the same **environment(s)** than the other agents of the system and **interacts** with them through mechanisms of **influence** and **perception**

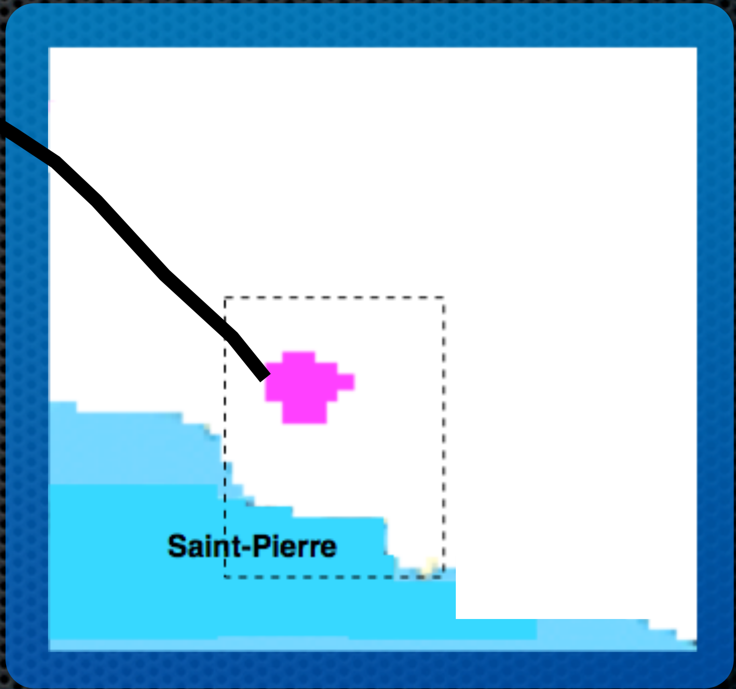
- **Interposition Element**

  structure that allows the **modification** of the **influences** and **perceptions** (by **altering** them, **improving** them, **restricting** them, ...) of one or many agents of the ABS

# Emergence Structures



# Detection and Materialization




- Local phenomena
- Emergence Agents
- Interposition Elements

# Tools for simulation observation

Advanced observation of simulation results [5]

- See Biomas Demo…

# Examples of Multi-Agent Based Simulations

## 1. The Biomas Model

*Biomass flow modeling  and simulation for organic waste management*

# 2. The DS Model

*Simulation of Land use evolutions for public decision making*

# Applications examples

3. Some other large research program examples Integrating MAS simulation conducted Réunion Island

- GERRI Program
- ETIC Program

## Large research program exemples

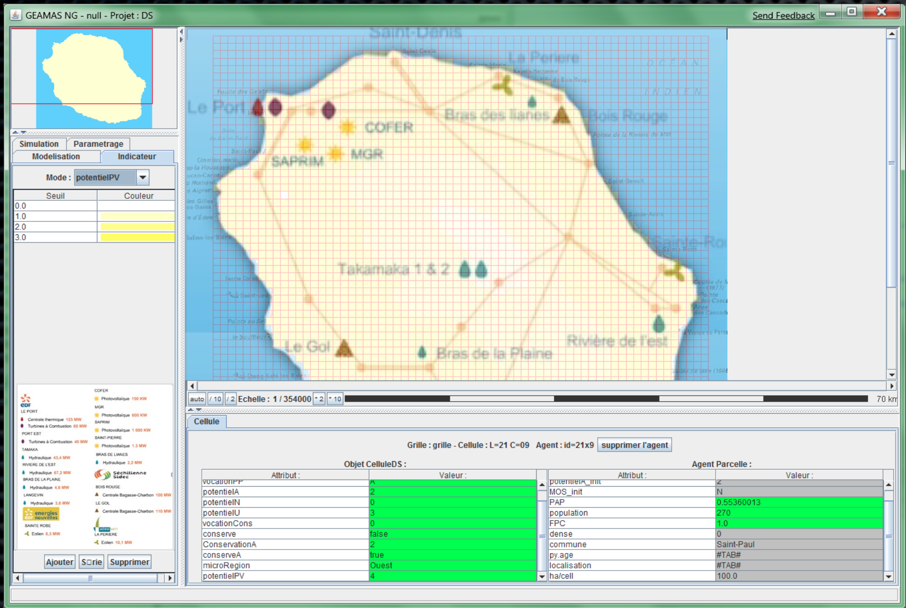
# ‘Energies Reunion’ Program (Gerri Program)

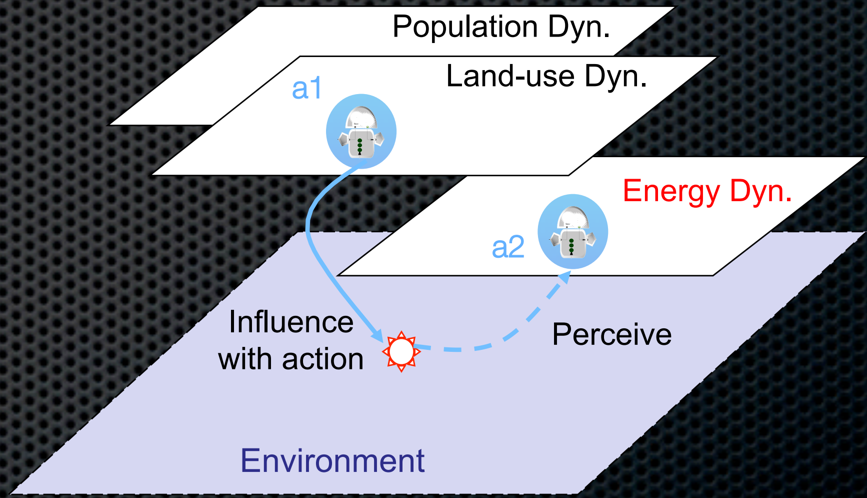
- All the technology required by GERRI already exists, but it is scattered in various locations worldwide.
  => Working with international partner through collaboration
- GERRI has the capacity to bring together and integrate such varied elements of experience in one unique, exemplary place.
  => Reunion Island used as a experimental platform
- A trailblazing scheme and a consistent, global endeavour
  => Involve Researchers, Public Decision-maker and the Industry
- Should provide inspiration for all territories where the concept of energy self-sufficiency makes sense.
  => Particularly in all areas that are remote, landlocked or not connected to a power grid.

# Examples of applications for energy
# DS extention for Energy Simulation

## EDMMAS (DS extention)
*Energy Demand Management by Multi-Agent Simulation*

Environment as coupling element for multi-dynamics modelling




**The aim is to provide a decision-support tool for the energy planning within a territory:**

- ✓ anticipate new energy distribution line and its sizing
- ✓ anticipate of new power plant and its sizing
- ✓ anticipate malfunction or maintenance work.

**PhD : Yassine Gangat**

## Examples of applications

# Multiagent Systems for intermittent renewable forecasting

**Intelligent management of the Reunion Island electrical network with the prediction of solar resource**

Establish, on the basis of a network of sensors scattered throughout the island, the forecasting models of the solar resource that will allow the network manager to anticipate and manage the new operating conditions of the network with high penetration of intermittent renewable.

Link this sensors network to a Multiagent systems used for detecting emergent phenomena (micro-climat,…)

**Ongoing PhD: Mimouna DIAGNE**

**Industrial Partner:**

REUNIWATT, Saint-denis

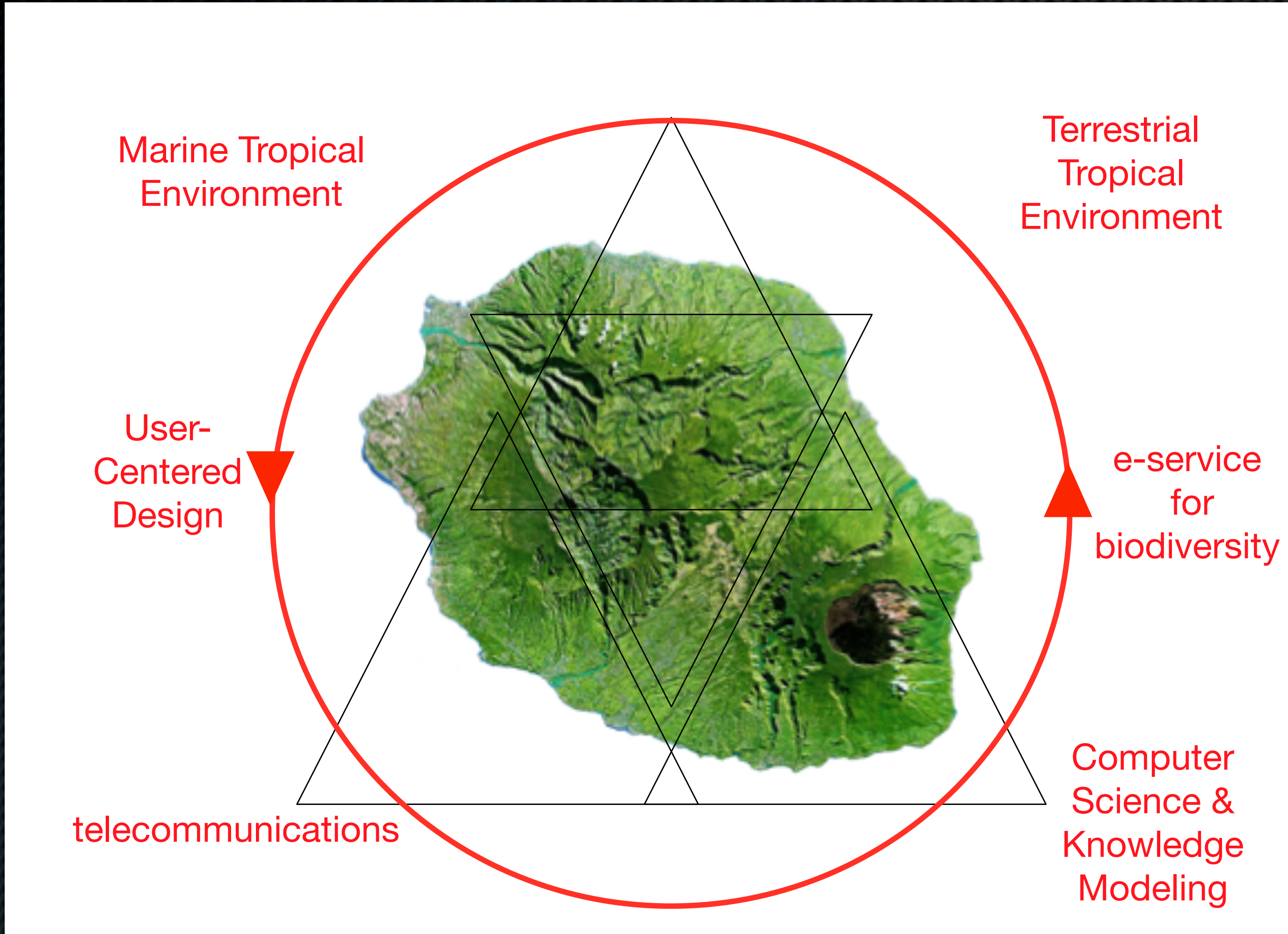
**Research Partner:**

Laboratory of Physics and Mathematical Engineering for Energy and Environment

Laboratory of Computer Science and Mathematics

# Large research program exemples

## ETIC Program




**Land-use & Sustainable development**

**Environnement**
**Tropical**
**Insulaire**

**and**

**Technologies de l' Information et de la Communication**

**Biodiversity Preservation**

**Regional project with European support for digital biodiversity knowledge exchange**

## Large research program exemples
# ETIC Research Program

- **Aim**

  Information System to help to manage insular tropical environment: application to Reunion island

- **Keywords**

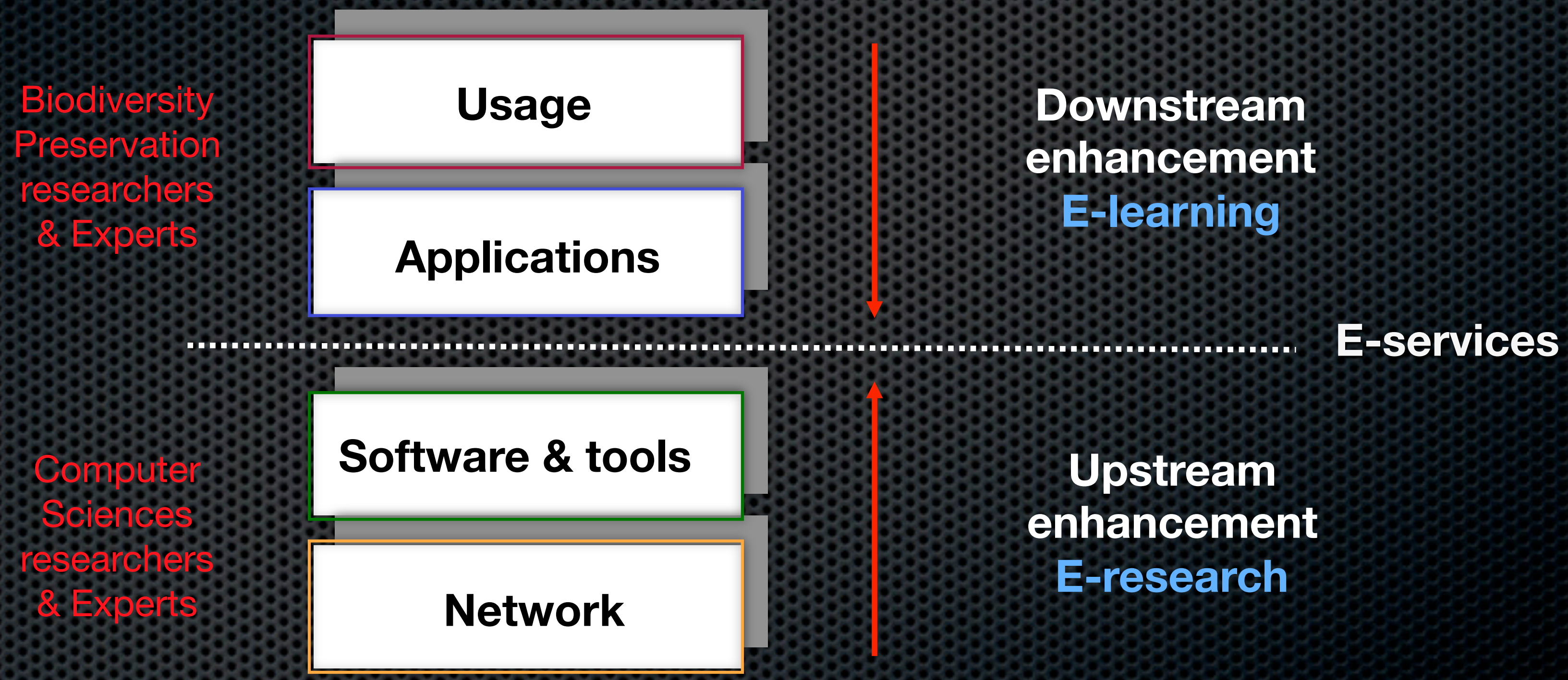
  ETI : natural environment and resources, systematics and ecological diagnosis, spatial management, temporal environmental monitoring,

  TIC : databases, knowledge bases, multi-agents systems, geographical information system, collaborative and collective applications, information and communication strategies

  ETIC : decision making, conceptual modelling, coupling of knowledge representation models, keeping up with technological innovations

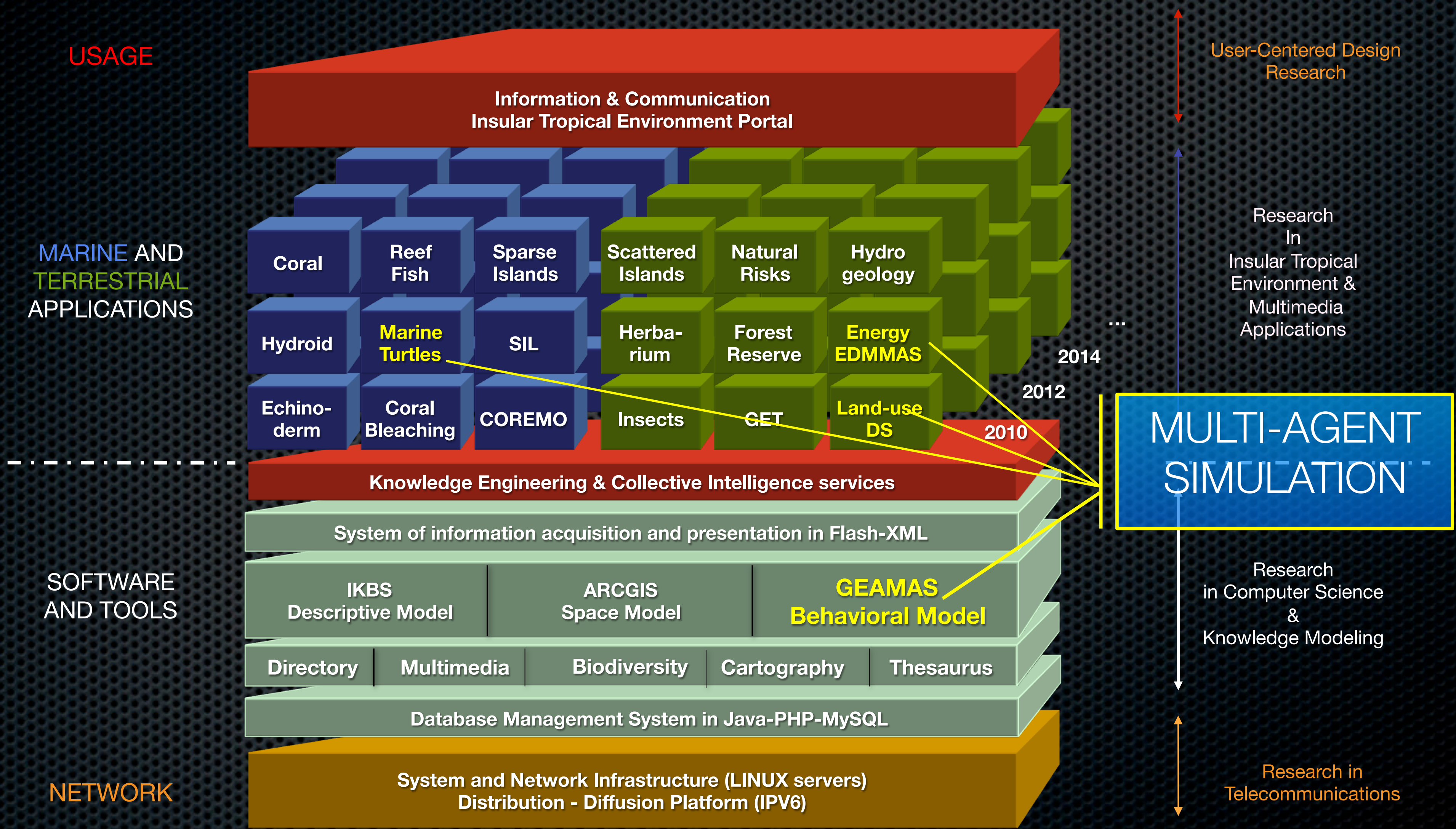
## Large research program exemples

# Methodology



## Large research program exemples

# ETIC Information system architecture



# Lessons from Réunion Island Land-use multi-agents Simulations

- **Advanced interaction analysis tools** of simulations are necessary to understand how situations emerged and to help to the **MAS validation process**.
- **Maps using semantic color codes** are very relevant supports to **build multiagent environments**: easy to manipulate by computing technics and for thematicians too
- In **MAS land-use simulation**, the most important is less the solution but the process leading to it. The  main purpose is then to **enhancing social learning and generating social knowledge** for efficient policy-making
- A **participatory** development of land-use **MAS should be promoted** to explore alternative scenarios **in situation of land-use conflicts**.

**The constitution of a land-use multiagent system is not a simple task. The construction of a methodology necessitates experimentation with theoretical approaches on real applications.**

# Thank you for your attention

# Questions?

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# References


- Yassine Gangat, Denis Payet, Rémy Courdier (2012), Methodology for a new agent architecture based on MVC, 230-239. Lecture Notes in Computer Science, Springer Verlag.
- Yassine Gangat, Denis Payet, Rémy Courdier (2012) Another step toward reusability in agent-based simulation : Multi-behaviors & aMVC, 1112-1119. In IEEE International Conference on Tools with Artificial Intelligence (ICTAI 2012).
- Zoubida Afoutni, Rémy Courdier, François Guerrin (2012) Modelling Situated Action based on Affordance and Stigmergy, 175-180. In IEEE International Conference on Self-Adaptive and Self- Organizing Systems (SASO).
- Daniel David, Yassine Gangat, Denis Payet et al. (2012) Reification of emergent urban areas in a land-use simulation model in Reunion Island, 28-32. In ECAI-2012 workshop on "Intelligent Agents in Urban Simulations and Smart Cities".
- Zoubida Afoutni, Rémy Courdier, François Guerrin (2011) A model to represent human activities in farming systems based on reactive situated agents, 2901-2907. In MODSIM2011, 19th International Congress on Modelling and Simulation.
- Zoubida Afoutni, Roger Martin-Clouaire, Rémy Courdier et al. (2010) Coordination of activities: application of some concepts and formalizations to agricultural systems simulation, 25-31. In Internat. Conf. on Modeling and Applied Simulation (MAS 2010).
- Didier Sébastien, Noël Conruyt, Rémy Courdier et al. (2009) Biodiversity Information Systems evolution: The MABIS model to gather several communities on an adaptable environment, 269-282. In International Journal on Advances in Systems and Measurements 2 (4).
- Nicolas Sébastien, Rémy Courdier, Didier Hoareau et al. (2009) Ordonnancement parallèle de simulations orientes agent : Une approche basée sur l'analyse des dépendances temporelles des influences et perceptions, 673-696. In Revue d'Intelligence Artificielle (RIA) Edité par P. Chevallier et R. Mandiau, Ed. Hermes, ISBN: 978-2-7462-2539-8, pp 673-696 23 (5-6).
- Didier Sébastien, Rémy Courdier, Noël Conruyt et al. (2009) Biodiversity Information Systems: A webservices oriented architecture to face future management's challenges. In Sixth Western Indian Ocean Marine Science Association (WIOMSA).
- Didier Sébastien, Noël Conruyt, Rémy Courdier et al. (2009) Generating Virtual Worlds from Biodiversity Information Systems : requirements , general process and typology of the metaverse ' s models representation : General Steps, 549-554. In International Conference on Internet and Web Applications and Services, ISBN: 978-0-7695-3613-2, Awarded best paper.