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The MASE Design Experience

(Multi-Agent System for Environmental Simulation)

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Agenda

- Introduction
- MASE - AOSE design
- MASE - AOR design
- Case Study
 - Federal District Cerrado (Brazilian Woodland Savanna)
- Discussion
- Conclusions & Future Work

Motivation

- The environment is a global challenge
 - earth's natural processes transform local problems into international issues:
 - global warming, hazardous waste,
 - ozone depletion, acid rain,
 - air & water pollution, overpopulation,
 - **rain forest devastation**
 - **Brazilian Cerrado destruction**
- Land Use/Cover Change (LUCC)
 - important factor in global change!





Brasília LUCC
City Construction (1960)
Federal District of Brazil
Brazilian Cerrado Bioma



Problem

The patterns of change in time & space are produced by the interaction of biophysical and socioeconomic processes – Research question:

How to represent such interaction through computational models?

- Agent-Based Modeling (ABM)
 - natural metaphor to represent patterns of human interaction
 - theories of interactivity in societies (model complex problems)
- Multi-agent simulation
 - contribute to scenario analysis
- Multi-agent simulation (MAS)
 - experimental technique for hypothesis testing and scenario analysis
 - better understanding of real systems (social, economical, environmental aspects)



Environmental Modelling & Software

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A multi-agent model system for land-use change simulation

Célia G. Ralha^a,  , Carolina G. Abreu^{a, b}, Cássio G.C. Coelho^a, Alexandre Zaghetto^a, Bruno Macchiavello^a, Ricardo B. Machado^c



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MASE model

In order to adopt a replicable parameterization process:

1. Systematic & structured **empirical characterization** of the model (Smajgl et al., 2011)
2. **conceptual structure definition** according to the agent-based model documentation protocol - Overview, Design concepts and Details - ODD (Grimm et al., 2006)

Environmental Modelling & Software 26 (2011) 837–844



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journal homepage: www.elsevier.com/locate/envsoft

Empirical characterisation of agent behaviours in socio-ecological systems

Alex Smajgl ^{a,*}, Daniel G. Brown ^b, Diego Valbuena ^{c,d}, Marco G.A. Huigen ^e



Ecological Modelling

Volume 198, Issues 1–2, 15 September 2006, Pages 115–126



A standard protocol for describing individual-based and agent-based models

Volker Grimm ^a,  , Uta Berger ^b, Finn Bastiansen ^a, Sigrunn Eliassen ^c, Vincent Ginot ^d, Jarl Giske ^c,

Paper Goal

Present agent-based techniques to help to define and develop simulation tools, e.g., the Multi-Agent System for Environmental simulation model

- Two design approaches
 - Agent-Oriented Software Engineering (AOSE) methodology
 - Agent Object Relationship (AOR) modeling and simulation conceptual structure

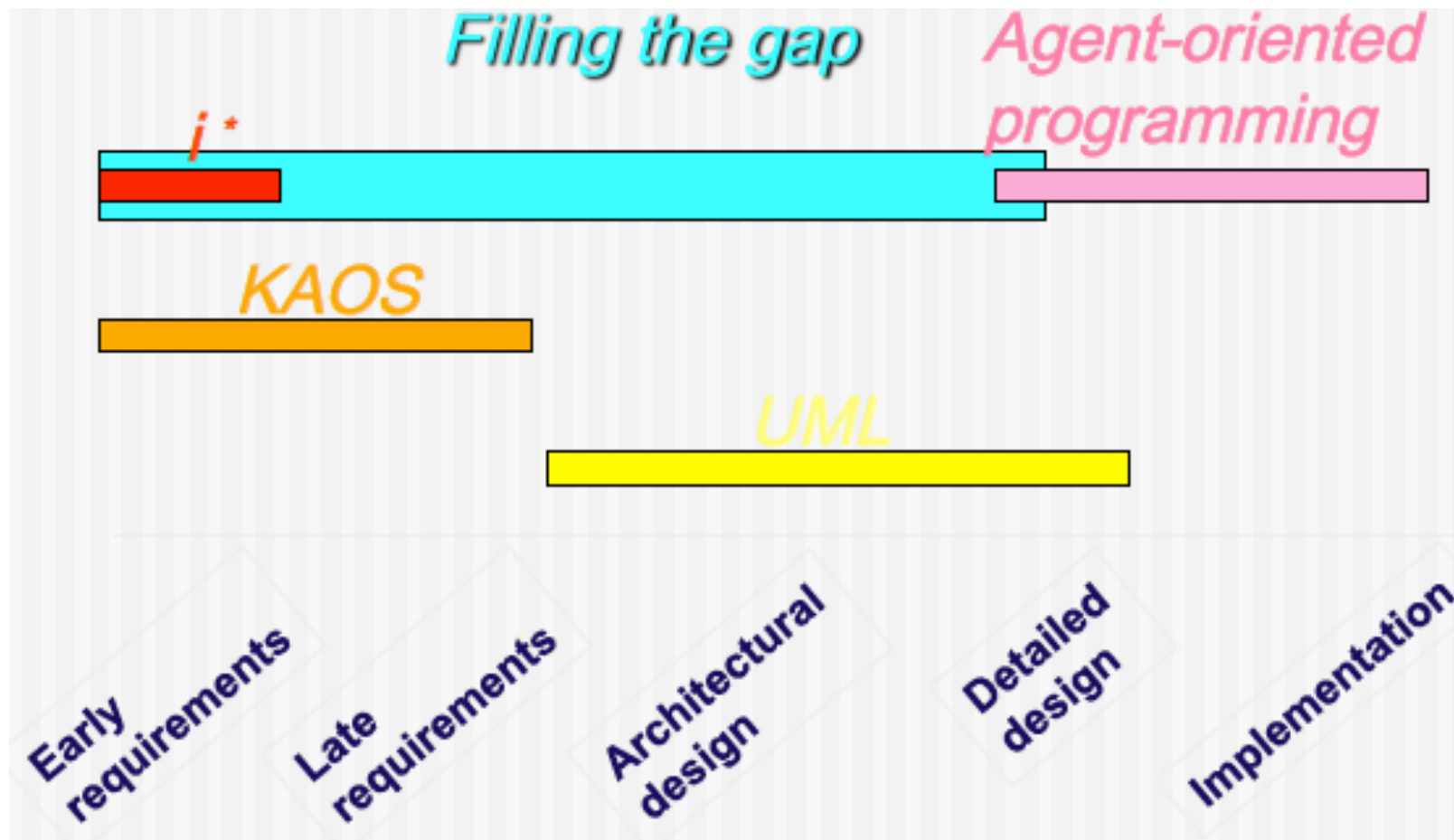
Hypothesis

- different agent-based design experiences can enrich the modeling and development process of environmental simulation frameworks

AOSE methodologies

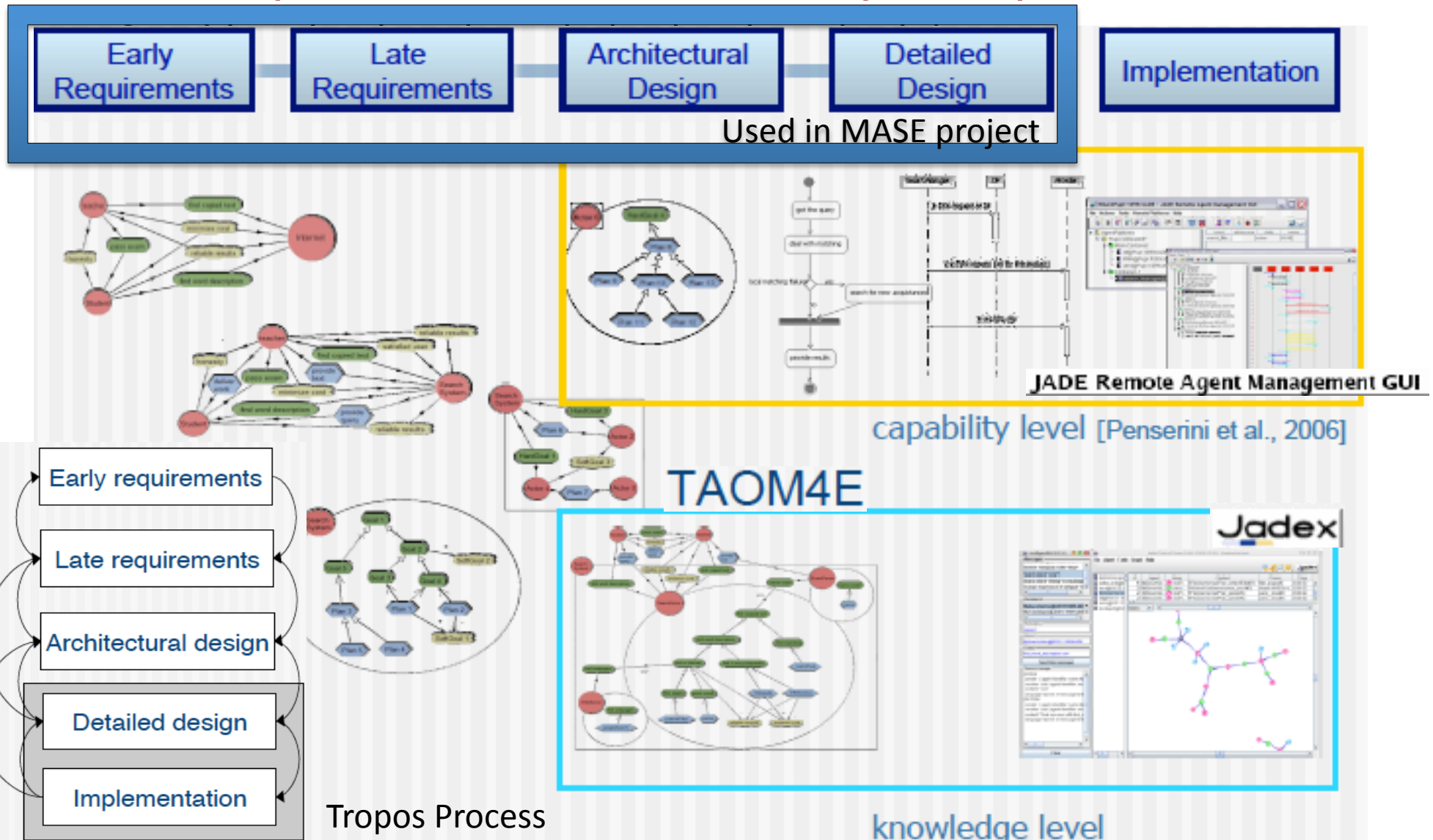
- Agent-Oriented paradigm subsumes the concepts supported by the previous Object-Oriented (OO) paradigm
- Use the Unified Modeling Language - UML (Rumbaugh et al., 2004) & the Agent UML - AUML (Padgham and Winikoff, 2003)
- Many AOSE proposals:
 - **GAIA** – Agent-Oriented Analysis and Design (Wooldridge et al., 1999)
 - Encourages a developer to think of building agent-based systems as a process of **organisational design**
 - **MaSE** - Multiagent System Engineering (DeLoach, 1999)
 - Help a designer take an initial set of requirements and analyze, design and implement a working multiagent system. Works together with the agentTool development system
 - **Prometheus** - A pragmatic methodology for engineering intelligent agents (Padgham and Winikoff, 2002)
 - focuses mainly on the **internal agent architecture**; it is basically a methodology for designing BDI agent systems
 - **Tropos** – Requirements-driven development for Agent Software (Giorgini et al., 2004)
 - founded on the concepts of goal-based requirements adopted from the i* (concepts for modeling social setting by E. Yu) and the Goal-oriented Requirements Language (GRL) - emphasizes the **requirements analysis**

Tropos in Perspective

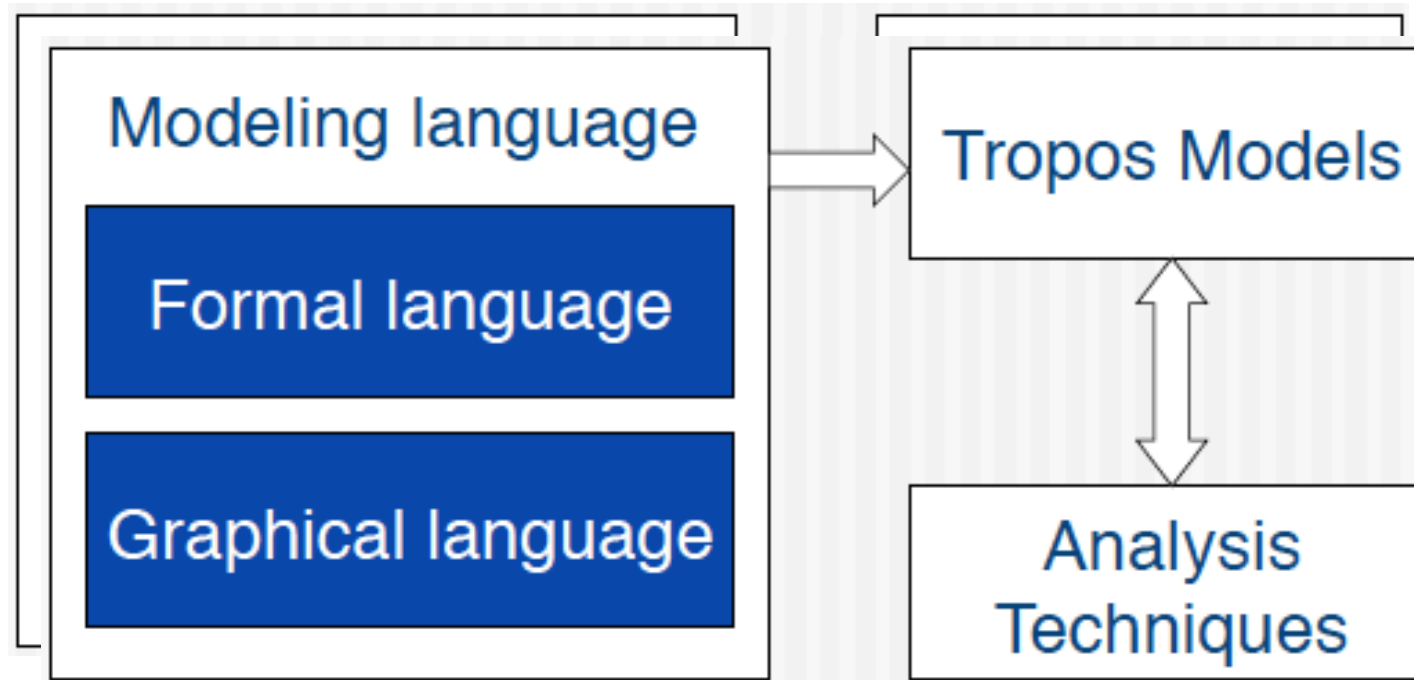


KAOS, a goal-oriented requirements framework that provides a rich temporal specification language

Tropos: A Model-Driven development process

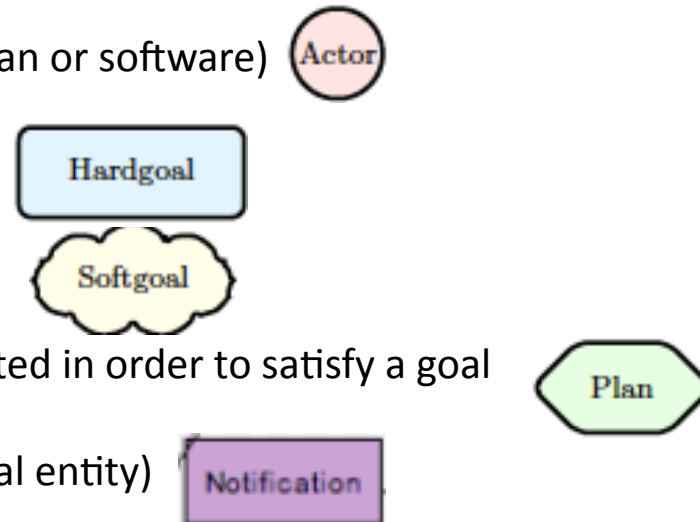


Tropos: Conceptual Framework



Tropos Language: basic concepts

- Actor
 - Intentional entity: role, position, agent (human or software)
- Goal (hard or softgoals)
 - Strategic interest of an actor
 - Hard goal - clear criteria of satisfiability
 - Softgoal - not clear , often used for qualities
- Task or Plan
 - Particular course of action that can be executed in order to satisfy a goal
- Resource
 - Physical or information entity (non intentional entity)
- Social dependency
 - One actor depends on another to accomplish a goal, execute a task, or deliver a resource



Tropos models

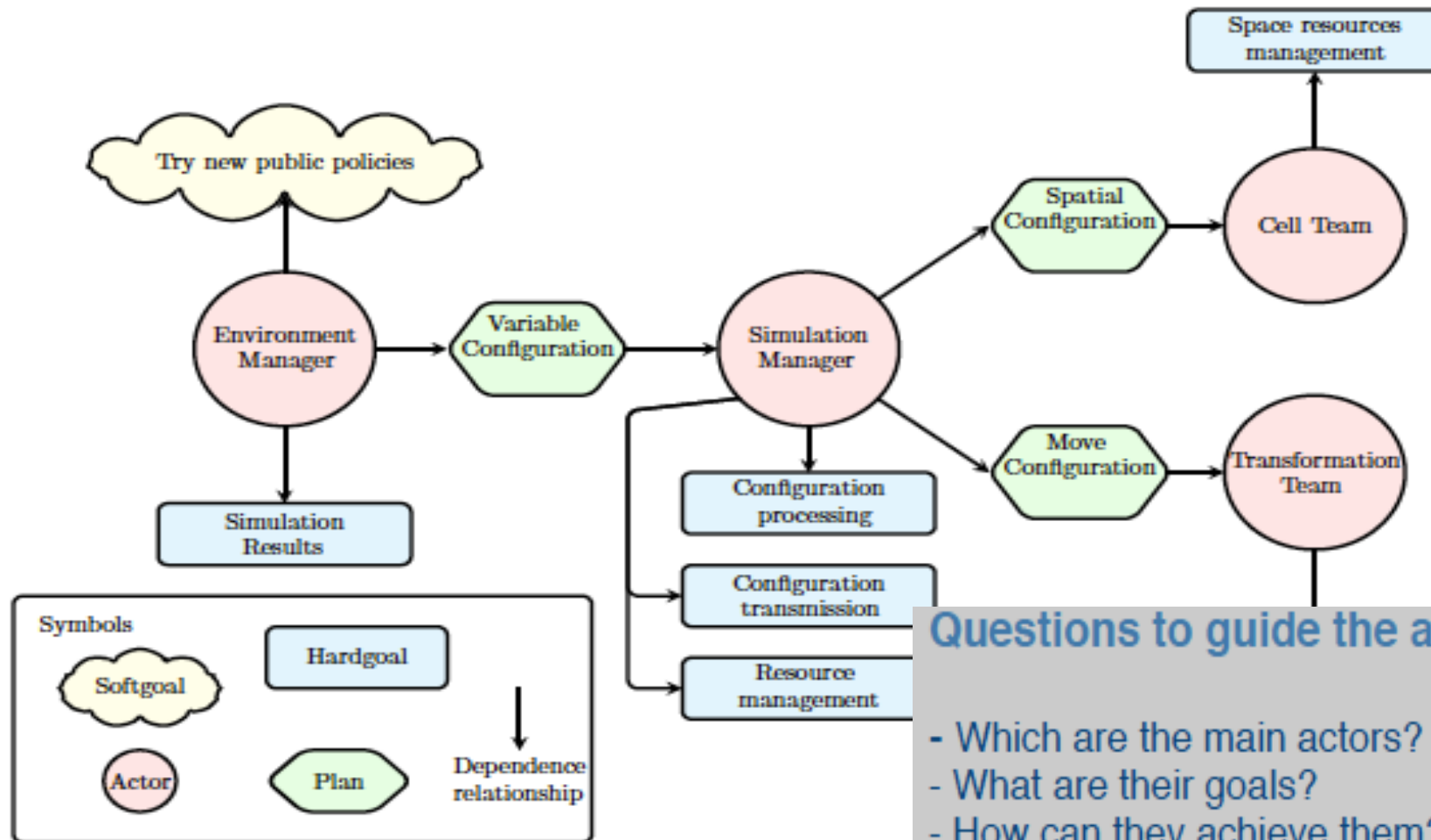
- Actor
 - Goal, task/plan and capability (only for design)
- Dependency – process: actor identification, social dependencies, model refinement
- Mixed
 - Dependency + actor model

Early Requirements

- One question to guide this phase: Which are the main actors?

| Agent Class | Type | No. of Instances | Functions |
|-----------------------------|------------------------|------------------|--|
| GRID Manager (GRIDM) | Goal-based | 1 | Promote interface parameterizations defined by users Manage start, pause and end of agents Receive agents state for the visualization Promote agents state visualization for the user |
| Spatial Manager (SM) | Goal-based | 1 | Instantiate the amount of cells to simulate Get orders from GRIDM and replicates to cells Receive the states of cells and replicates to GRIDM |
| Transformation Manager (TM) | Goal-based | 1 | Instantiates number of TA for simulation Get orders from GRIDM and replicates for TA Receive TA states and replicates to GRIDM |
| Cell Agent (CA) | Reflexive state record | user defined | Perceptions and actions defined in Table 4 |
| Transformation Agent (TA) | Reflexive state record | user defined | Perceptions and actions defined in Table 4 |

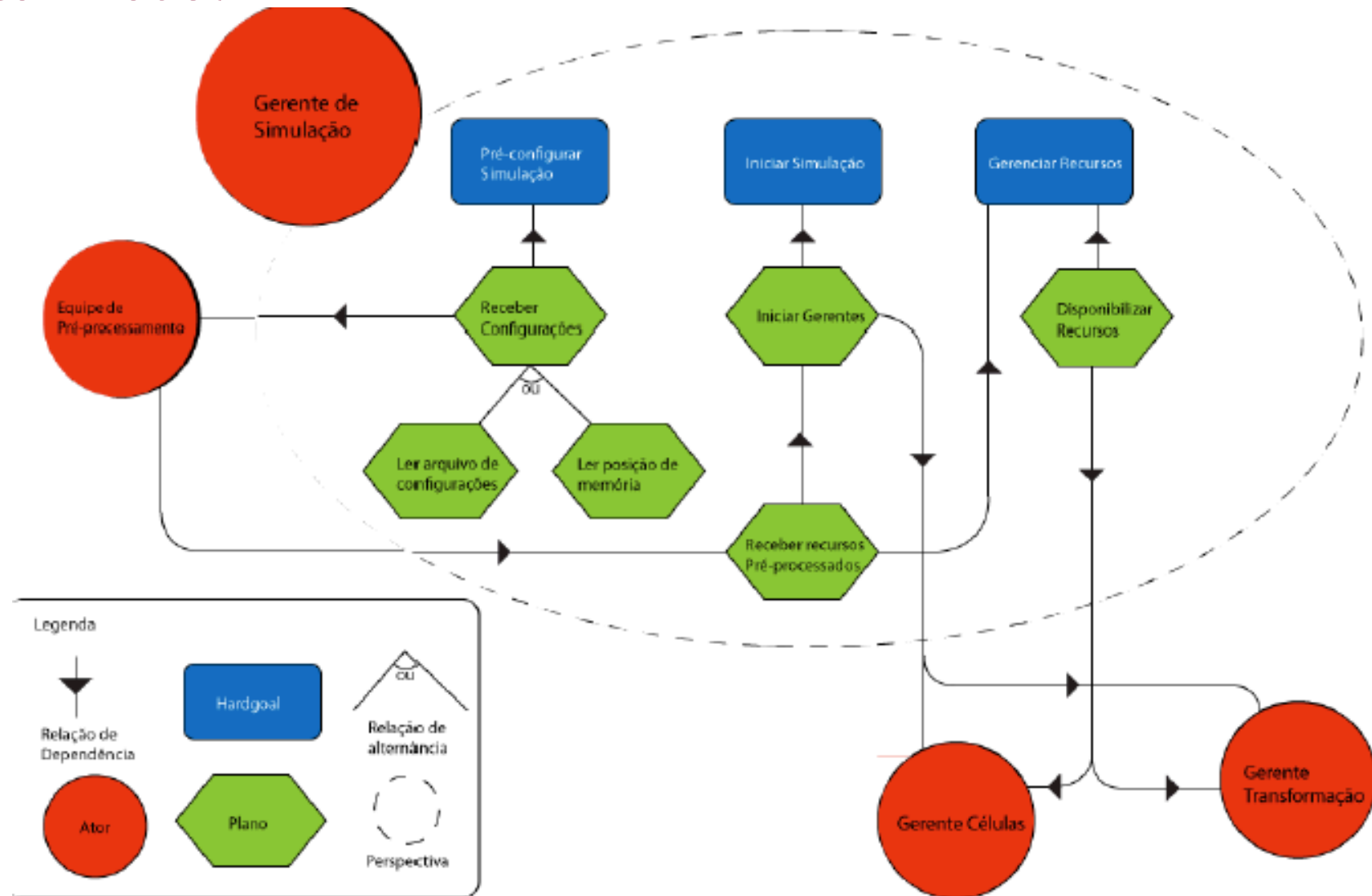
Early Requirements diagram



Questions to guide the analysis

- Which are the main actors?
- What are their goals?
- How can they achieve them?
- Does an actor depend on another one to achieve its goals?

Actor model



Implementation Aspects

- Used Java Agent Development Framework - JADE (Bellifemine et al., 2007) version 4.0, release date 04/20/10
 - Foundation for Intelligent Physical Agents (FIPA) compliant
 - Agent Communication Language (ACL) defined by FIPA
 - Agent Management System (AMS) - white pages
 - Directory Facilitator (DF) - yellow pages
 - Agent Behaviour
 - simple approach - OneShotBehaviour, CyclicBehaviour
 - Composed approach - SequentialBehaviour and FSM-Behaviour
- Library ImageJ to process image files (previously used MatLab)
- Simulation input images - used already classified raster-GIS program images obtained by satellite monitoring LANDSAT EMT (NASA/INPI) - classified by PROBIO software (Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)/Environment Ministry (MMA), Remote Sensing Center (CSR)-IBAMA/MMA)

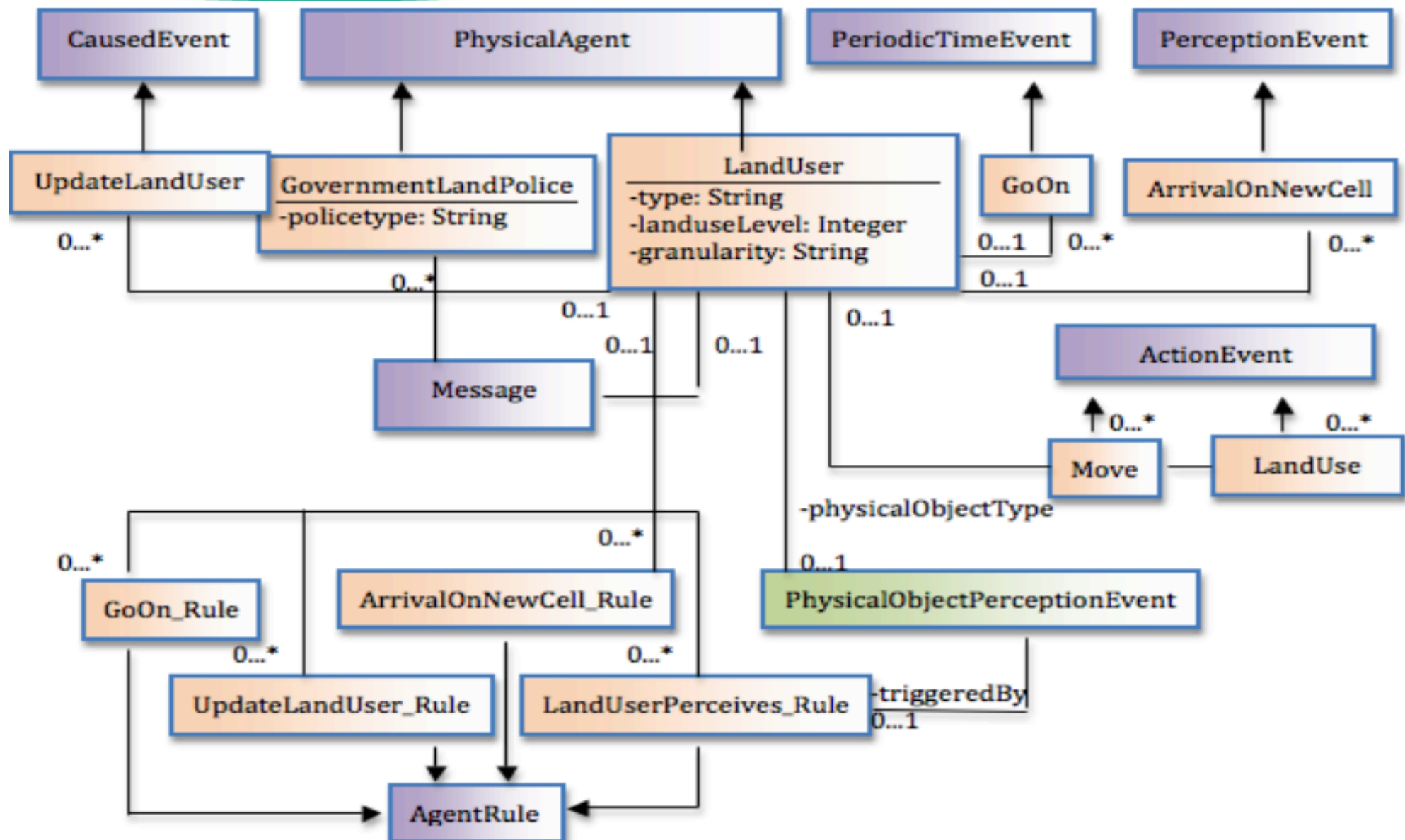
Machine - Intel Core i5 2.27 GHz 4 GB RAM, 64-bit operating system

AOR overview

- Wagner (2004) argues that AOR modeling offers a research perspective to conceptually integrate the static, dynamic and deontic aspects of organizations
- Agent-Object-Relationship (AOR) approach subsumes the concepts supported by Object-Oriented (OO) paradigm with UML, but improve the passive objects with agent concept (active goal directed entities)
- AOR puts together the power of agent-based modeling with multi-agent simulation to extend the classical discrete event simulation paradigm
- Developed a high-level declarative specification language – the AOR simulation language (AORSL) based on a high level ontological framework to define simulation models closer-to-reality (entity-relationship modeling)

AOR overview

- AOR is a discrete event-oriented simulation platform
 - Agents respond to events in the environment, execute actions and interact with each other
 - Two event types:
 - Exogeneous event - external event which does not depend on the actions of agents (e.g. arrival of a new customer)
 - Internal event - like a message exchange, that is the basis of simulation since agents interact sending messages to one another
- AORSL has special constructs to represent agent cognitive aspects based on their beliefs and intentions
 - Entity type, agent rules, environment rules, initial conditions



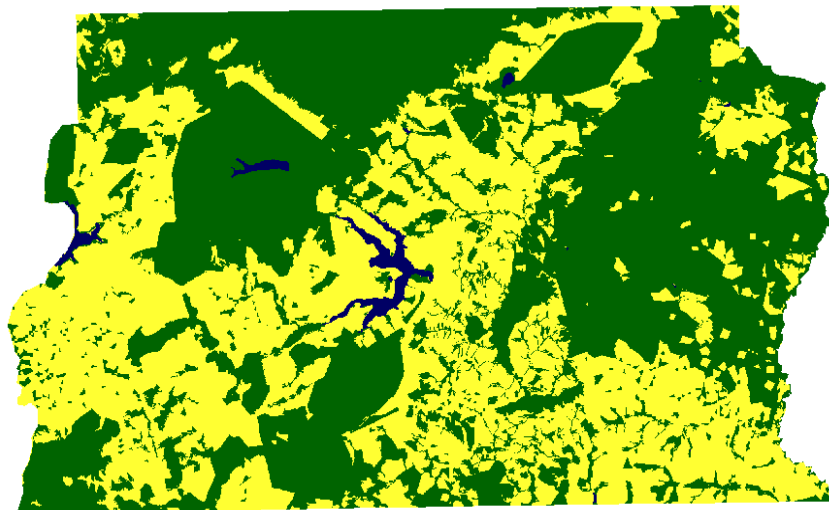
AOR limitation

- There is a AOR Web Simulation Server (AOR-WebSim) that uses the XML-based language and generates Java and JavaScript code to visualize the modeled scenarios
- Environmental land-use simulation tools have to deal with GIS images from satellite images (raster-GIS)
- AOR was proposed to organizational models and consequently is limited to deal with real maps
- Experimentally tested the AOR platform has a limit of 50X50 (grid)

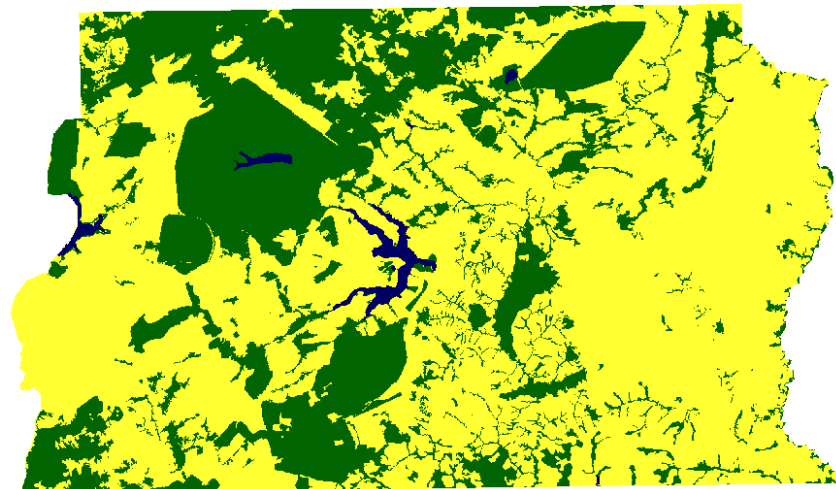
Site: <http://oxygen.informatik.tu-cottbus.de/aor/> and http://www.simurena.de/en/simurena-framework_en

Why the Brazilian Cerrado Case?

- major Brazilian savanna-like ecosystem, the second largest biome in South America
- undergoing rapid transformation to cattle ranching and to soybean production
- requiring urgent action for the conservation of biological richness - recent report of WWK UK presents painful consequences from soya production:
 - in 6 year period, land-use change in the Brazilian Cerrado released 275 million tons of CO₂ per year, more than half the total emissions for UK
- Federal District of Brazil is the single state fully covered by Cerrado biome (578,900 ha)



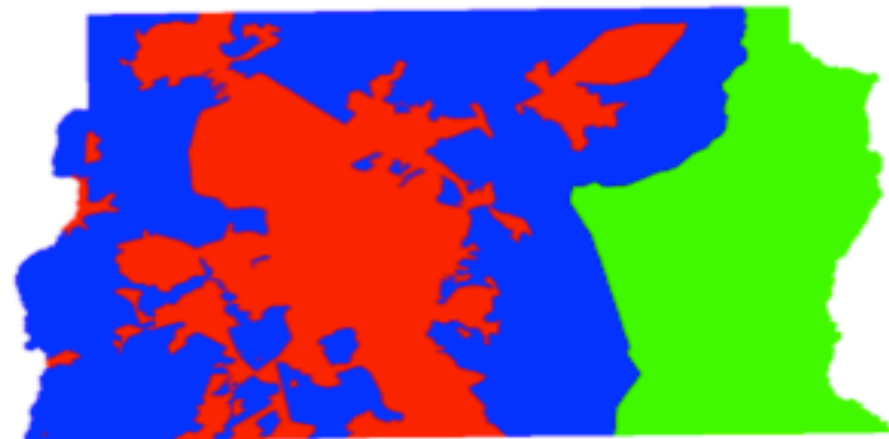
2002

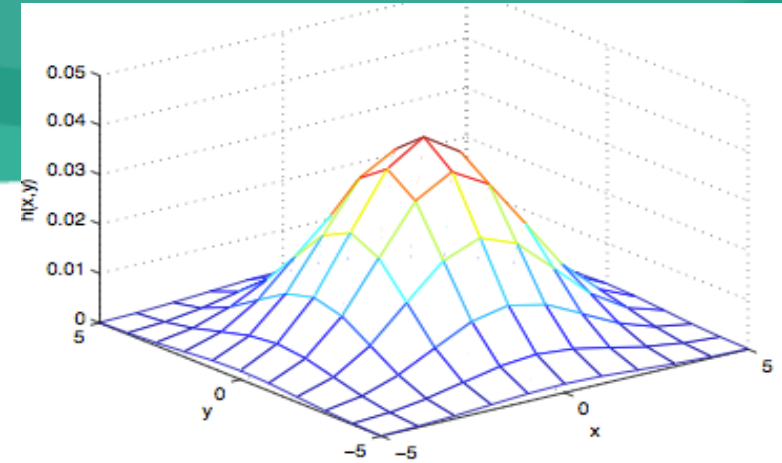


2008

Overview - State variables and scales

- the input map is divided into cells of a simulation grid using two different maps to compare from initial to subsequent time
- in this study case the initial time 2002 and subsequent 2008 (365 time-steps)
- **MASE** temporal and spatial scale models are configurable
- every set of 4 cells represent one hectare in the simulation grid
- each time-step is one week of chronological time
- used satellite images of LANDSAT ETM (NASA/INPE) classified by PROBIO/IBAMA
- physical state of cells use set of real spatial data including 6 proximal variables: water courses (rivers); water bodies (lakes); buildings; highways; streets; protected areas
- used a set of real policy information to land-use exploration (PDOT):
 - Red - urban macrozone
 - Blue - controlled use
 - Green - diversified use

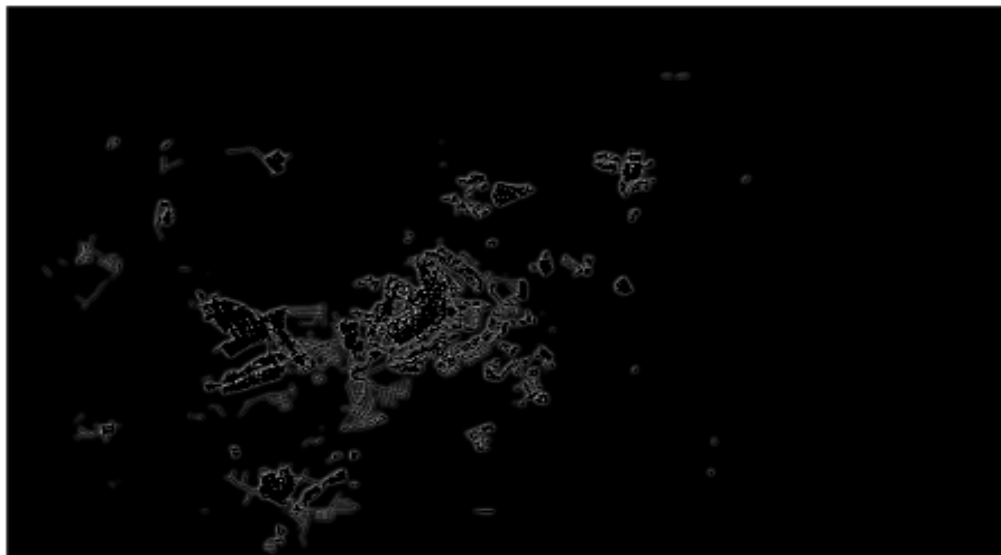




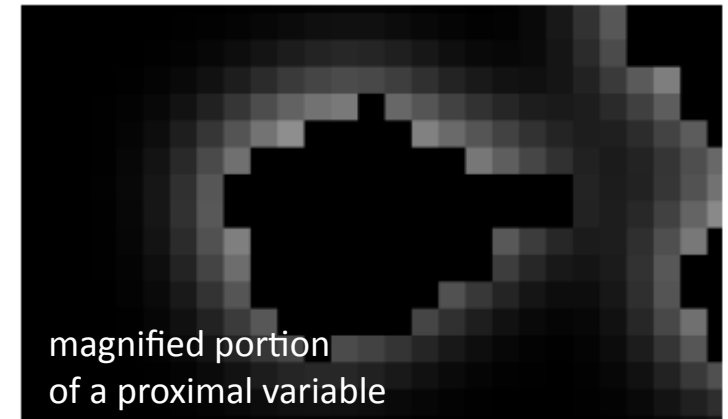
Technical Details

- **Input**
 - Physical environment - use 6 image layers (proximal variables=railways, highways, rivers, lakes, streets, buildings)
 - Images were filtered using Gaussian bi dimensional filter (Equation 1)

$$h(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$



Proximal variables- streets



magnified portion
of a proximal variable

- +p *positive influence*
- p *negative influence*
- 1 *Neutral*

Technical Details

The new destination for the transformer agent is determined - probabilistic manner

- build and normalize a vector of grid cells value $V[i]=[96, 21, 98, \dots]$

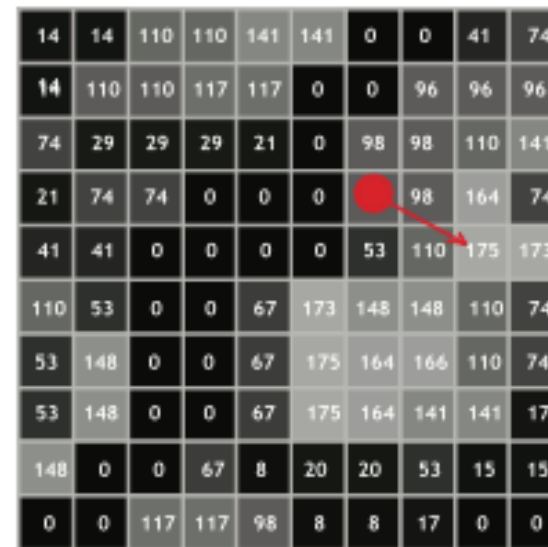
- calculate $C[i]$ function:
$$C[i] = \sum_{j=0}^i V_{norm}[j], \quad i = 0 \dots n - 1.$$

$$V_{norm}[i] = \frac{V[i]}{\sum_{j=0}^{n-1} V[j]}, \quad i = 0 \dots n - 1,$$

- Finally, pseudorandom number N is drawn from the standard uniform distribution open interval $(0,1)$ and searches for the first value of i where $C[i] > N$



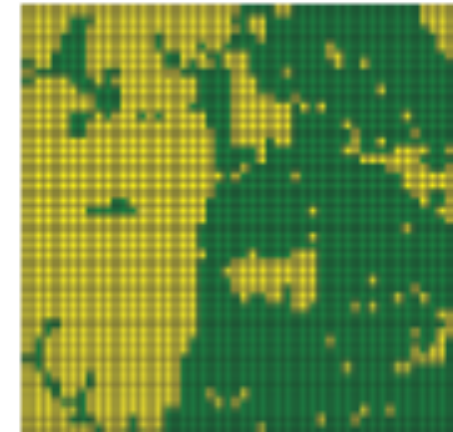
(c)



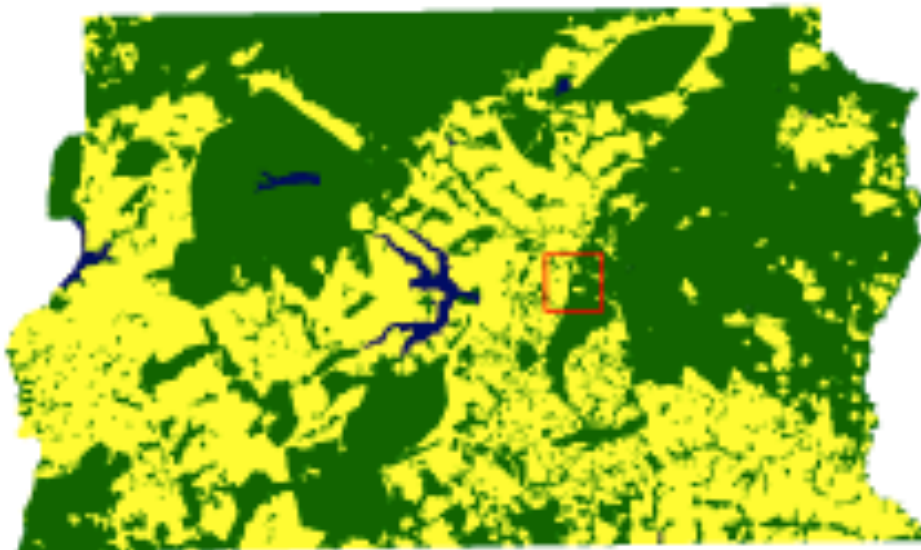
(d)

Two Design approaches: results

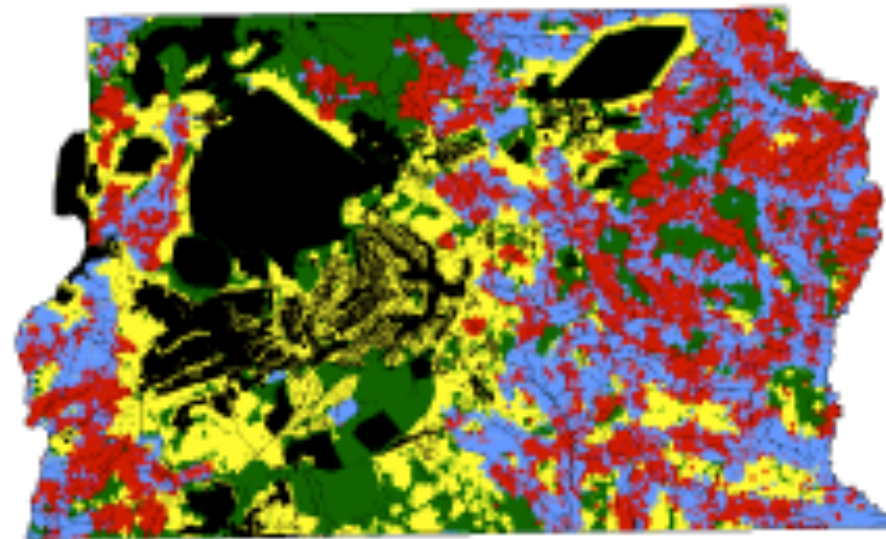
- AOSE with JADE Framework (2002-A, 2008-B)
 - two different land-user agents: farmers (blue) and ranchers (red)
- AOR platform with a 50X50 grid (2002-C)
 - 0,4% of the Federal District area, need 250 image pieces to simulate separated, then put results together in the same map (problem to control movement)



AOR 2002-C



AOSE 2002-A



AOSE 2008-B

Discussion

- Different challenges to design and implement
 - AOSE approach with Tropos & Jade
 - Tropos methodology includes the software development phases from early requirements (analysis) to detailed design - normal system-to-be building
 - allows a deeper understanding of the environment where the software must operate, agents communication and interactions, agents goals and action plans - focus the agents definition
 - Can be implemented in OO language, but the use of JADE would help, however JADE has to be learned
 - AOR approach with AORSL & AOR-WebSim
 - based on a discrete event paradigm that integrates objects to agents
 - great semantic power to represent different models, but the simulation metamodel definition for a real case is very consuming - design and implementation in the declarative AORSL
 - not recommended for real image dealing

Conclusions & Future Work

What we done so far:

- defined the conceptual model in a systematic and replicable way
- modeled with an AOSE and AOR design approaches
- implemented MASE & developed a case study (validate model)
- analysed the simulation results (Pontius et al., 2008)

Where are we going?

Improve agents rationality (most challenging part!)

- MASEX - using Belief-Desire-Intention Model, theory of human practical reasoning (Bratman, 1999)
- apply qualitative expressivity to make easy to ecologists to model
- represent space using topology to automatic reason about geographical aspects (sptatio-temporal reasoning)



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Simulation video - 20 farmers(blue) & 20 ranchers(red)





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Thank you for your attention!
Questions?

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