Towards a Generic Approach for Multi-level Modeling of Renewable Resources Management Systems

(Extended Abstract)

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ABSTRACT

Multi-agent systems are widely used in renewable and natural resources management. Multi-agent systems are able to manage the complexity of such systems characterized by a large number of interacting entities with different levels of granularity and including dynamics of different contexts (ecological, economic, social). In this work, we propose a generic multi-level architecture for renewable and natural resources management.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multi-agent systems; I.6.5 [**Simulation and Modeling**]: Model Development

Keywords

Complex systems, renewable resources management, multi-agent systems, multi-level modeling

1. INTRODUCTION

Renewable and natural resources management systems are complex systems involving a large number of interactions between several stakeholders with different objectives. Since 1990, there has been a striking increase in the use of multi-agent systems to study renewable and natural resources management. The studies presented by Anxtell and Epstein in Their book ”Growing artificial society” can be considered as founders [3], appeared subsequently other models to accommodate different situations:pastoralism [2], hunting [1], water management [4]. Note that most models in this field focus on decision making using macro-level empirical data or making assumptions which can lead to biaised results.Taking into account dynamics from different levels makes the system modeling difficult. The challenge is to propose a generic approach for renewable resources management modeling aiming modeling simplicity and results accuracy. In this work, we opted for a multi-level architecture for the following reasons:

- A multi-level architecture implies simple modeling. In fact, each level of granularity can be designed and modeled on its own.
- Modeling the lowest level of granularity provides accurate data transferred to the upper layers which implies accurate global system results.
- A multi-level architecture makes integration of GIS (Geographic Information Systems) easier as each layer may correspond to one or more GIS layers. The use of GIS anchors the system in its effective environment: displacement spatiality, ecological and pedological information (surface state, soil texture, slope, etc.).
- The complex nature of renewable resources management systems requires a multidisciplinary work. A multi-level architecture allows the assignment of each layer to a group of experts which facilitates collaboration between experts from different fields.

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2. MULTI-LEVEL ARCHITECTURE FOR RENEWABLE RESOURCES MANAGEMENT

We propose an indicator-oriented reasoning.To identify our system layers, we proceed as follows:(1)Define a sufficient set of indicators for the system state inspection(2)Define layers which may affect the system degradation that is the indicators values(3)If the indicator value can be derived directly, the underlying layer is not modeled. We identify two dynamics within a system of renewable resources management: Risk management dynamic(see section 2.1) and Operative dynamic(see section 2.2).

2.1 Risque management dynamic

In order to follow layers evolution, we define Observer agents. An Observer agent is an aggregation of agents of the underlying layer. It calculates the value of macroscopic variables and detects the appearance of emergent properties. It compares the indicators values with thresholds indicating the alarm level and reports the situation to the Strategic Decision Maker agent. The latter makes decisions using positive or negative feedback. Decisions taken by the Strategic Decision Maker agent affect layers local dynamics.

2.2 Operative dynamic

We identify three types of layers:

- RL(Resource Layer): layers that can only be considered as resource layers for example the ecological layer (soil-vegetation) in the pastoral system.
- CL(Consumer layer): consumer, protector or manager layers for example socio-economic stakeholders layer in the pastoral system.
- CRL(Consumer and Resource Layer): layers that can be considered as consumer or resource layers for example Animal layer in a pastoral system.

Note that, in this paper, we concentrate our study on layers which can be considered as resources $\{layer\ i, i \in RL \cup CRL\}$.

2.2.1 Inter-layer dynamic

Until now, we are interested in the exploitation relationship. An exploitation relationship is expressed by two clauses:

- uses(i,j),$\{i \in CRL \cup CL, j \in RL \cup CRL\}$ Which denotes that i layer uses j layer resources.
- und-dis(j,i),$\{j \in RL \cup CRL, i \in CRL \cup CL, \exists uses(i, j)\}$ Which denotes that j layer undergoes disruption induced by the use of its resources by the i layer.

Coherence must be established between the defined clauses in terms of:

- Time: concerns two aspects:
  - When the clause is considered: this aspect concerns the synchronization between the consideration of the effects of the clause and the local dynamics. Two alternatives are identified:
    - disturbance: the clause occurence is an interrruption, in this case the effect of the clause is calculated immediately.
    - stress: the effect of the clause is not immediate and can be calculated among the underlying dynamic.
  - The clause duration: concerns the quantification of the clause effects on the local dynamic.
- Space: Spacial coherence implies the clause anchoring in its spatial context especially when using GIS.
- Scope of the clause: Multi-level architecture enables the construction of each layer by specialists of the underlying domain. Therefore, it is to make a correspondence between clauses. Correspondance concerns conceptual, quantitative and qualitative aspects. For example, the result of a formula in a field may lead to a system of equations in another domain or be converted to another unit. Qualitatively, a clause may involve a subset of resources, for example, consumption of the most palatable plant species criterion.

2.2.2 Intra-layer dynamic

Each resource layer (i) is a multi-agent based system composed of the triplet $< Ai, I_i, E_i >$:

- uses resources Re_i

$$Re_i = re_i + \sum ru_{i,j} \quad j \in [1, i-1]$$

- undergoes perturbations Pe_i

$$Pe_i = \sum ru_{k,i} + \sum rc_{k,i} \quad k \in [i+1, n]$$

- A_i: the set of agents in the resource layer i.
- I_i: the set of interaction among i.
- E_i: the environment of i.
- re_i: local resources of i layer.
- $ru_{i,j}$: resources acquired by i layer outcome of utilizing the lower layer j
- $rc_{k,i}$: resources aquired by i outcome of restoration and rehabilitation(correction) performed by k on i.

The interaction dynamic of the resource layer may be accelerated by catalysts. We define two types of catalysts:

- Degradation catalyst: accelerates the ressources degradation. This catalyst is triggered by degradation thresholds such as wind erosion.
- Promising catalyst: improves the resource layer state. This catalyst is triggered by rehabilitation actions.

3. CONCLUSIONS AND PERSPECTIVES

We proposed a generic multi-level architecture of renewable resources management systems. Multi-level architecture facilitates complex systems design as each layer is designed and validated on its own. It ensures collaboration between experts from different disciplines and makes results more accurate. We defined three types of layers within our architecture: RL, CL and CRL. In this paper we focus on RL dynamic. In future works, we intend to build the generic architecture of the CL and CRL layers.Thereafter, we aim to validate our approach by applying it on the Tunisian pastoral system.

4. REFERENCES

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