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Synthesis of examples and agent-based meta-model

Agents

- The manipulated agents are characterized by a very wide diversity, both structurally and behaviorally.
- From the 'agents defined by a small number of attributes and elementary laws' to the 'consumer agents' of CUBES that possess memory and decision structures
- the term 'agent' serves to qualify entities that seem to possess very variable degrees of complexity. This versatility can also be present within the same model, where agents with different characteristics can coexist

Simple agents, complex agents

1. An agent is either a concept (in the reference model or in the conceptual model) or a temporary or permanent computational structure (in the operational model).
2. An agent is used to group and individualize a set of attributes, mechanisms, and relationships to other entities of the model.
3. An agent whose behavior is partly based on memorizing its past behaviors will thus be considered as more 'complex' than an agent simply reacting to its immediate environment, simply because the modeler had to make a choice in representing this memorization capability.
4. Three factors can be seen as governing the choices of agents used: the scientific context, theoretical choices, and the question at the origin of the modeling.

Simple agents, complex agents

- **Scientific Context**

The dominant scientific discipline in which modeling activity takes place exerts considerable influence on the complexity of the agents.

- **Theoretical Choices**

The pre-existing theoretical choices of the modelers during the establishment of the reference model will thus heavily weigh on the complexity of the agents used. This is especially true as many models are designed to partially validate these various theories.

- **Modeling Question**

The core of modeling activity lies in the question that guided the model's establishment by the modelers, as it largely determines the type, as well as the simplification (or complexification), of the agents used.

Simple agents, complex agents

- Behavioral model agents (Manta) add capabilities for perception, communication, and representation of others. Consequently, their behavior is no longer solely dictated by their internal state or immutable laws imposed upon them, but also by what they can perceive as information, possibly actively, in their physical and "social" environment (other agents).

- Social models of (CUBE) further formalize the relationships between agents by materializing notions (external to agents) such as networks or communication and making them a central determinant of behaviors.

- The agent is no longer conceived as isolated but rather as closely dependent on a larger structure that it both conditions and is conditioned by.

Versatility of models, diversity of agents

- The ability to represent any object of study within a reference system in the form of artificial agents within a model is a significant aspect. Whether the object has a tangible reality in the system (such as the ants in MANTA or consumers in CUBES) or is a more abstract construction, agent-based modeling effortlessly adapts to the languages, theories, or methods existing among modelers.
- **Micro-Macro Relationships**

The choice of agent-based modeling is not solely based on its richness of representation.

It often stems from the desire within a reference system to understand the relationships between different levels of abstraction and the interconnections that bind them.

This results in models with a "micro" level, represented by agents, and various "macro" levels, which often exist only through measurements aggregated locally on the population of agents, or through the emergence of "emergent" structures recognizable and identifiable by their relative permanence.

- **Example**: ants at the micro level and social structures at the macro level in MANTA.
- **Differentiation of Agents**

A third reason often emphasized by model designers to justify an agent-based approach is the ability to represent reference systems composed of differentiated entities, either by the value of their attributes or by their attributes or behaviors themselves.

ENVIRONMENT

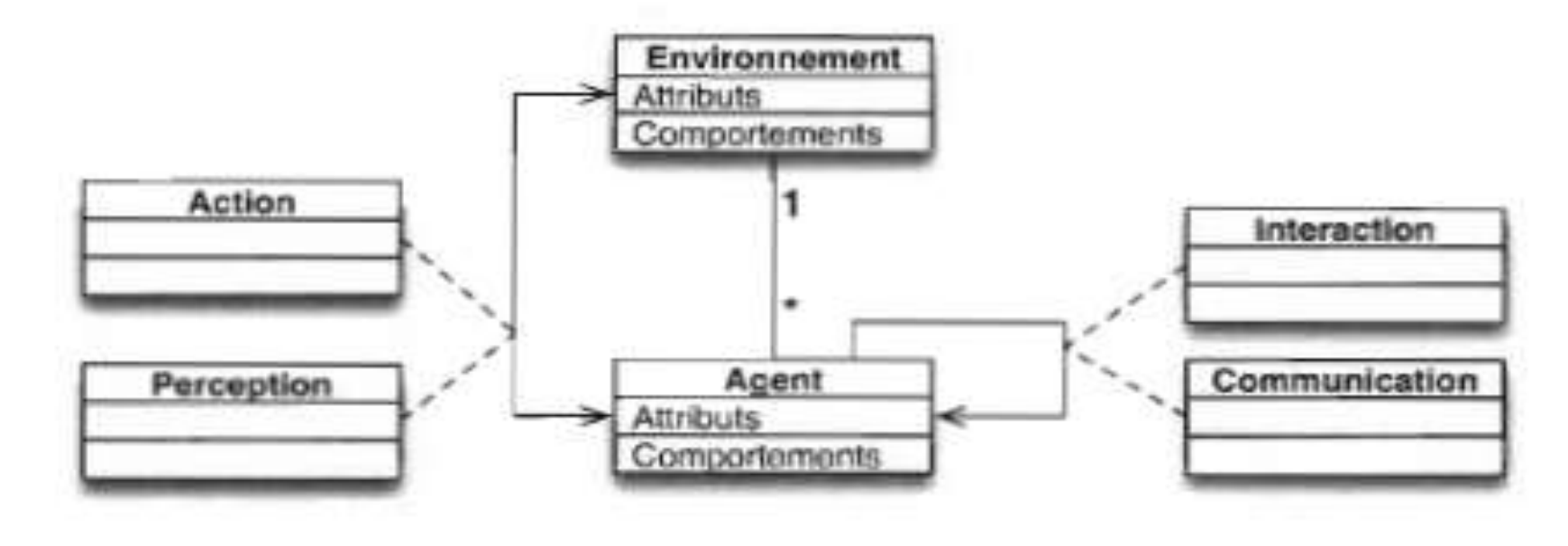
- In agent-based models, the environment can be defined as all information not carried by the agents. This definition, potentially acceptable at an operational level, leaves ample indeterminacy at a conceptual level.

- In the case of real robots operating in the real world, the environment does not need to be modeled because it simply exists. It is the sum of everything the robots experience in their deployment. Only formalized representations of this environment may need to be designed in the programs controlling these robots to ensure they operate correctly.

- In agent-based models, where everything must be modeled: the agents, their environment, and the representation they have of it.

Gaps in the Meta-Model

- The modeling based on agents seems to be applicable to all fields of application.
- This versatility is the positive consequence of the generality of the meta-model. Another, more problematic consequence concerns the apparent lack of coherence between different models and, within each one, the blur of certain definitions (which is often only clarified at the time of implementation on a simulator).
- Historically, this lack of binding formalism undoubtedly favored the adoption of agent-based models in domains resistant to simulation-based approaches, such as sociology or ethology.



Gaps in the Meta-Model

- It does not provide support for representing the structural and behavioral diversity of the types of agents employed in models, which is essential in many works.
- • It does not provide any distinction between behavior and decision mechanisms.
  • It does not easily allow describing agents with individualized behaviors.
- • It does not provide any guidance for describing the structure of the environment, which is free (as are the agents).
- • It does not offer the possibility of describing models comprising multiple environments, neither at the structural level nor in terms of their interrelations.
- • Consequently, it does not provide references to allow agents to manage multiple environments simultaneously.