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An Interaction-Oriented Model for Multi-Scale Simulation

1 – DESCRIPTION OF NESTED SPACES

The structural side of the PADAWAN model relies on two relations:

**SITUATION:** \( a \prec e \)

An agent \( a \in A \) is situated in an environment \( e \in E \), denoted by: \( a \prec e \), if \( a \) can perceive, be perceived, act, or undergo actions, in \( e \).

**ENCAPSULATION:** \( a \sim e \)

An agent \( a \in A \) encapsulates an environment \( e \in E \), denoted by: \( a \sim e \), if \( a \) contains \( e \).

- An agent can encapsulate one environment at a time.
- An environment can be encapsulated by only one agent.

**JOINT USE OF BOTH RELATIONS**

**Environment inclusion**

\( e_1 \subset e_2 \) \( \iff \exists e \in A \left[ a \sim e \land a \prec e \right] \)

\( \implies \) oriented graph describing environment nesting

**Agent hosting**

\( a_1 \subset a_2 \) \( \iff \exists e \in E \left[ a_2 \sim e \land a_1 \prec e \right] \)

\( \implies \) oriented graph describing entity composition

+ permanent constraint: no directed cycle in inclusion / hosting graphs

**A SHORT EXAMPLE**

The sodium-potassium pump in cells:

- 3 sodium ions (\( Na^+ \)) enter the pump and bind inside
- an ATP molecule changes the conformation of the pump
- sodium ions are released outside the pump
- 2 potassium ions (\( K^+ \)) bind inside
- the conformation of the pump changes back

Associated structure in PADAWAN (inclusion+hosting graph, simplified)

Associated interaction matrices

Each environment is endowed with a specific interaction matrix

**CONCLUSION**

The PADAWAN model for multi-scale simulation:

- provides relations to represent nested environments and dynamic structures
- allows a local specification of behaviors, using IODA interaction matrices

Several advantages:

- uniformity of concepts and algorithms
- entities + behaviors + spaces = agents + interactions + environments
- incremental and modular design of:
  - the structure of a system (environments inclusion)
  - its function (level-dependent behavior patterns)
- automated implementation (JEDI IDE and platform)

**FURTHER WORK**

Work in progress:

- integration within a Serious Game (FormatStore project)
- adaptation to problem-solving in cartography (with IGN)

Long-term issues:

- constitution of environment libraries
- automatic agents aggregation (structural + behavioral)

**REFERENCES**
