Multiagent Meta-model for the Description of Socio-cognitive Processes:

An Enactive perspective of Language in Artificial Agents

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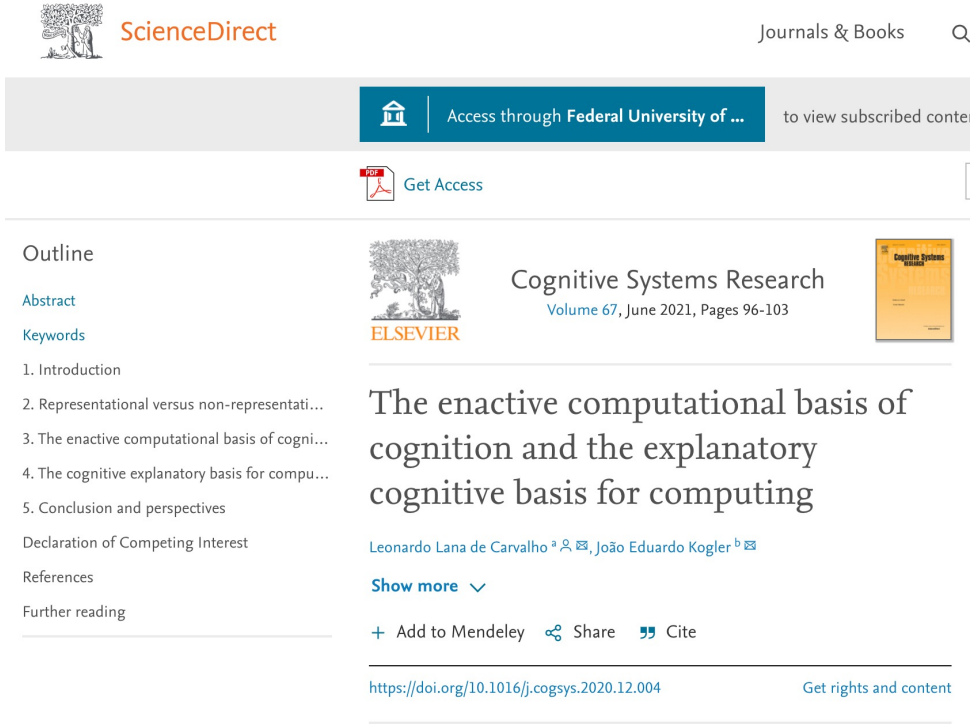
Topics of interest:

- Computational Theory of Mind;
- Enactive Cognitive Science; Enactive Computing;
- Self-organization, Complex Systems and Cognition;
- Agent based Modeling and Simulation;
- Cognitive process: language, consciousness, experience, cognitive development

Current projects

Enactive Computing; computing as an enactive system and cognition as enactive computing

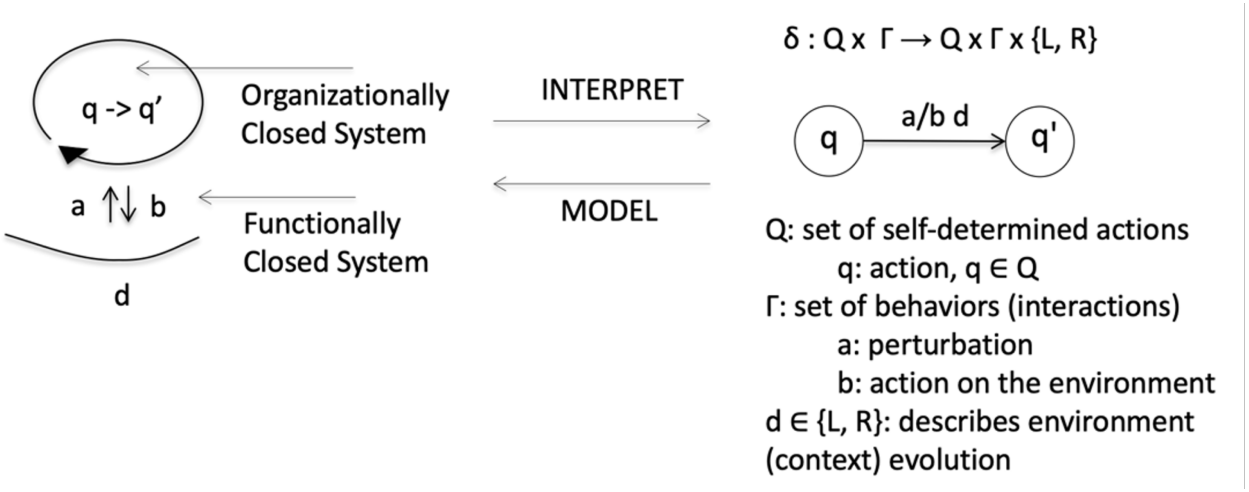
- In the case where cognitive systems are described as non-representational systems but computing are supported as representation-based systems, computing and enactive cognition are assumed to be incompatible. However, several non-representational theories of computing lead to non-representational computational theories of cognition.



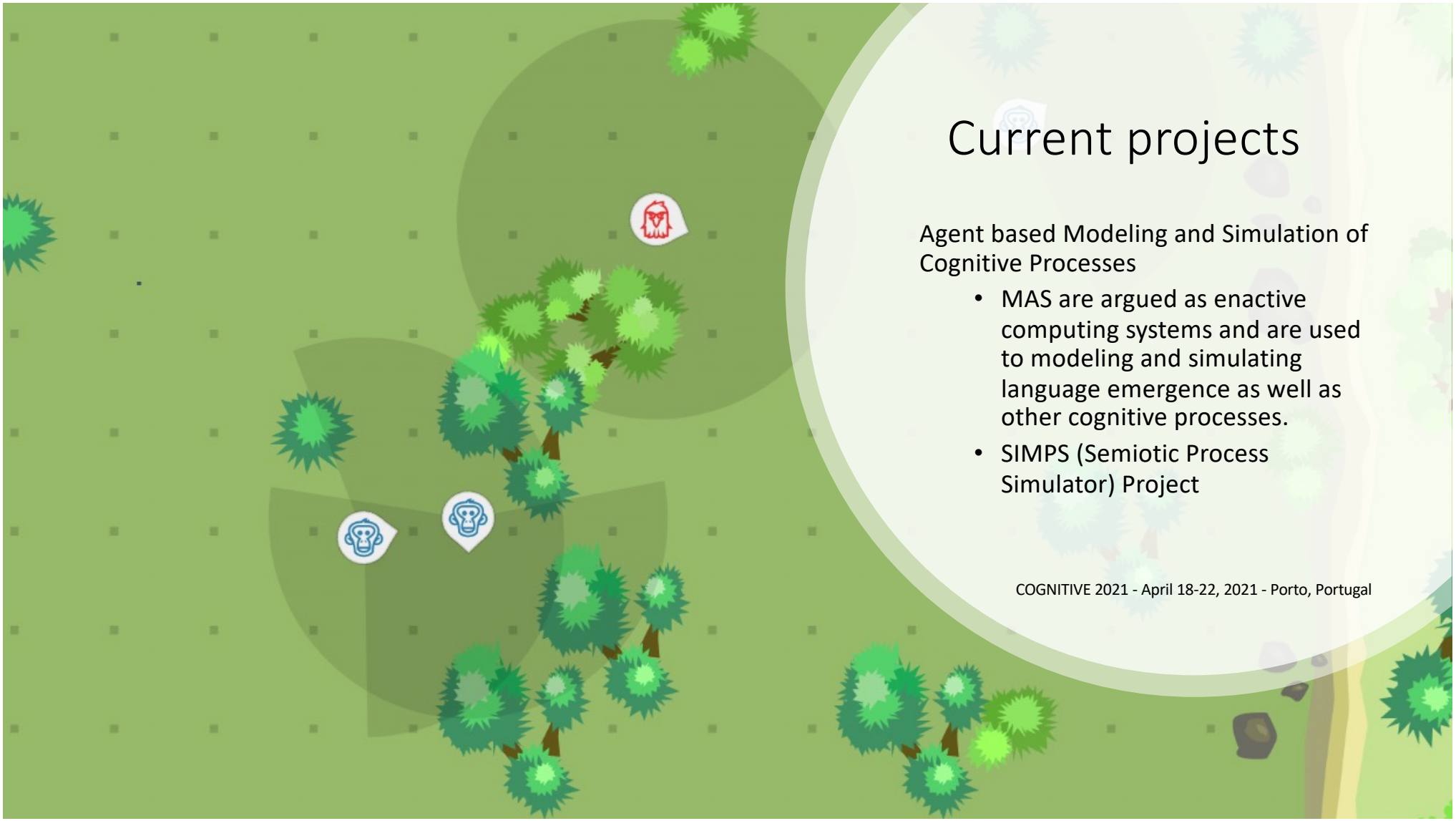
Current projects

Machine experience: enactive and autopoietic perspectives

- Enaction is bring forth a world, an experiential world. We argue that the realization of the experience occurs within the organizational and functional closure in living and artificial machines.



Carvalho, L. L. (no prelo). Modeling enactive and autopoietic systems using Turing Machine: An enactivist point of view. In 11th International Meeting on Information, Knowledge and Action, Diamantina - Brazil, March 16-19, 2021.



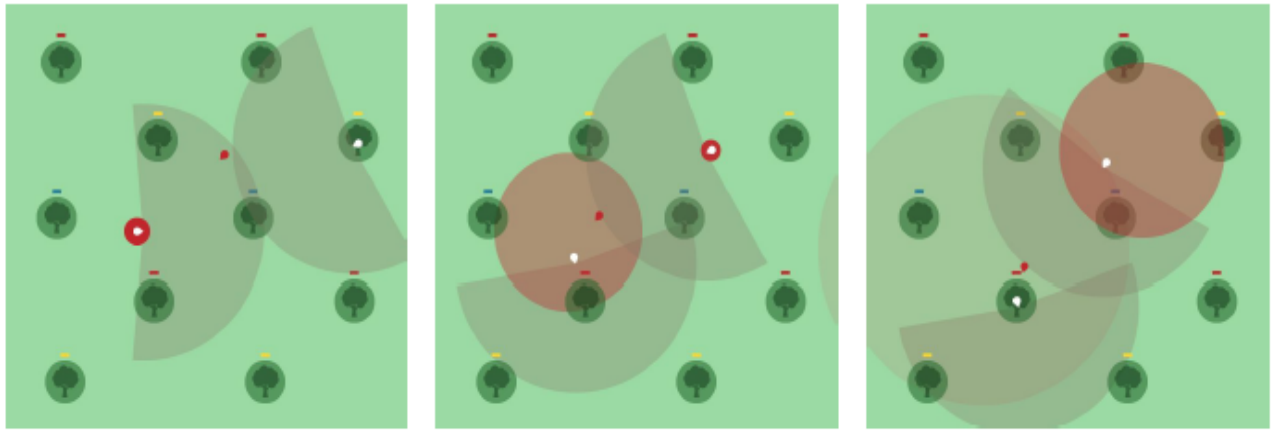
Current projects

Agent based Modeling and Simulation of Cognitive Processes

- MAS are argued as enactive computing systems and are used to modeling and simulating language emergence as well as other cognitive processes.
- SIMPS (Semiotic Process Simulator) Project

Current projects

Agent based Modeling and Simulation of Cognitive Processes



In (a), prey p1 triggers an alarm to indicate the approach of a predator sighted by it; heading to the nearest hideout (b). In (c), the alarm emitted by p1 is heard by another prey (p2), which associates the signal with the predator. (SILVA, FERREIRA, CARVALHO, 2019, p. 99).

MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES:

An Enactive perspective of Language in Artificial Agents

- **Objective** - We propose here a meta-model based on the enactive and autopoietic theory for the description of social and language processes in Multiagent Systems (MAS).
- **What we propose?**
  - We propose here a meta-model based on the enactive and autopoietic theory for the description of social and language processes in Multiagent Systems (MAS).
  - Our meta-model is a four-quadrant map, which describes, according to the concepts of structural couplings and, organizational and functional closure, the architecture of the agents, as well as their social practices and the formation of social organizations.

MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES:

An Enactive perspective of Language in Artificial Agents

- **How was it conceived?** From two sources:
  a) The enactive and autopoietic theory of cognition, with an emphasis on social phenomena and the linguistic domain;
  b) A four-quadrant map, which describes MAS from an integral view.
- **Motivation:**
  - The motivation for the proposal of a new meta-model for the description of MAS and the emerging language in agent-based systems was the incompatibility between Wilber's integral view and that of the enactive theory about psychosocial processes.
  - The central features of the enactive criticism that we carried out here were the concepts of interiority and individuality present in Wilber's theory.

Introduction

- The purpose of this article is to introduce a meta-model for the description of MAS and the emergence of language as social process in artificial agents.
- The proposed meta-model is derived from two other meta-models:
  a) That of the enactive and autopoietic theory of cognition of Maturana and Varela, which describes language as a social phenomenon and the linguistic domain as coordination of behavior and consensual coordination of behavior [12]; [13];
  b) The four-quadrant map based on the theory of Wilber [18], where each quadrant of the meta-model indicates a perspective in which artificial agents, their practices, collective actions and social organizations can be described and discussed [1] [6] [7] [15].

Introduction

- The meta-model described by Maturana [12] and the meta-model describing an integral view on MAS, proposed by Ferber [6] both emphasize a description of language and other cognitive processes as emergent social practices in complex social organizations.
- However, the differences between the enactive and autopoietic view compared to Wilber's integral view [18] cannot be made compatible.
- The central point of our conceptual analysis rests here on the concepts of interiority and individuality present in Ferber's meta-model [6] that demanded an intense conceptual review from the enactive perspective, which resulted in the proposal of our meta-model for describing socio-cognitive processes, from a strictly enactive perspective.

ENACTIVE AND AUTOPOIETIC THEORY OF SOCIAL AND LANGUAGE PHENOMENA

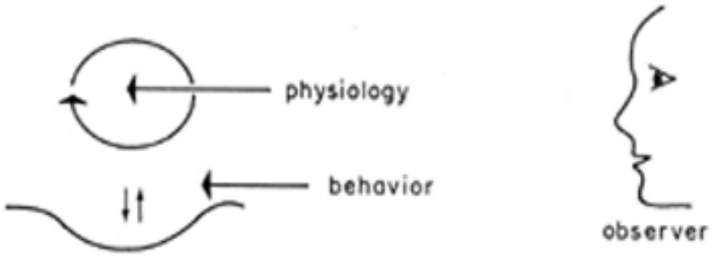


Fig. 0. The physiological and behavioral domains in autopoietic systems (Maturana and Mpodozis, 2000)

- The physiological and the behavioral domains:
  - "The physiological domain is the domain in which the living system exists in the operation of its components as a **closed molecular autopoietic system"**.
  - "The behavioral domain is the domain in which the living system encounters the medium in the realization of its niche, and in which the behavior takes place in the interplay of the structural dynamic of the living system and **the structural dynamics of the medium**."
- "So, the physiology involves the dynamic structure of living system only, while the **behavior involves both** the dynamic structure of the living system and the dynamic structure of the medium in the niche."

ENACTIVE AND AUTOPOIETIC THEORY OF SOCIAL AND LANGUAGE PHENOMENA

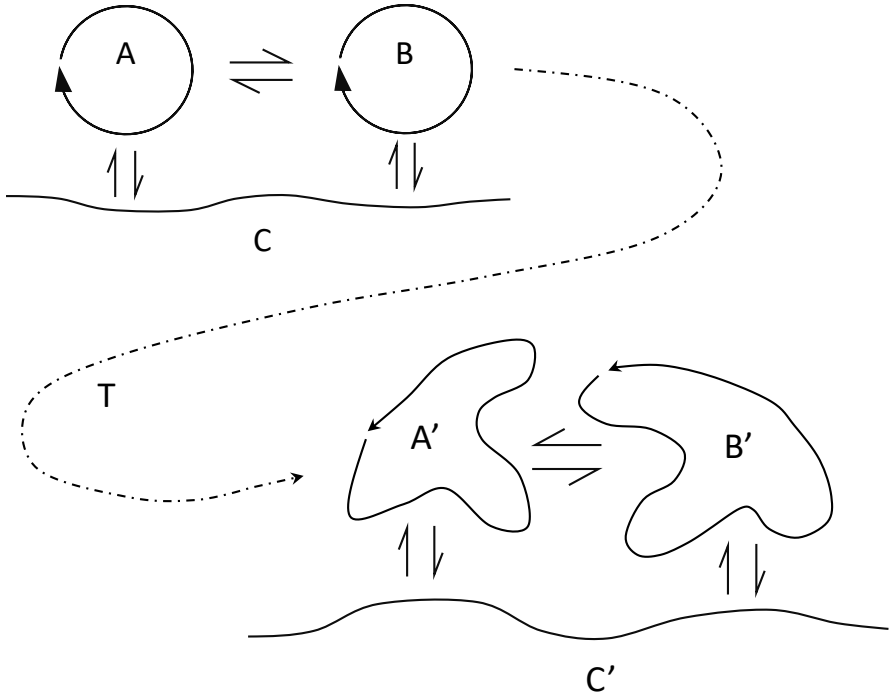


Fig. 1. History of interactions in the medium (adapted from Maturana, 2014)

- A, B and C named as different systems by an observer change depending on their recurring interactions while remaining congruent with themselves in the forms A', B' and C'.
- They are enactive systems. A and B are organizationally and functionally closed.
- A and B are structurally coupled, which characterizes a social level of interactions.

ENACTIVE AND AUTOPOIETIC THEORY OF SOCIAL AND LANGUAGE PHENOMENA

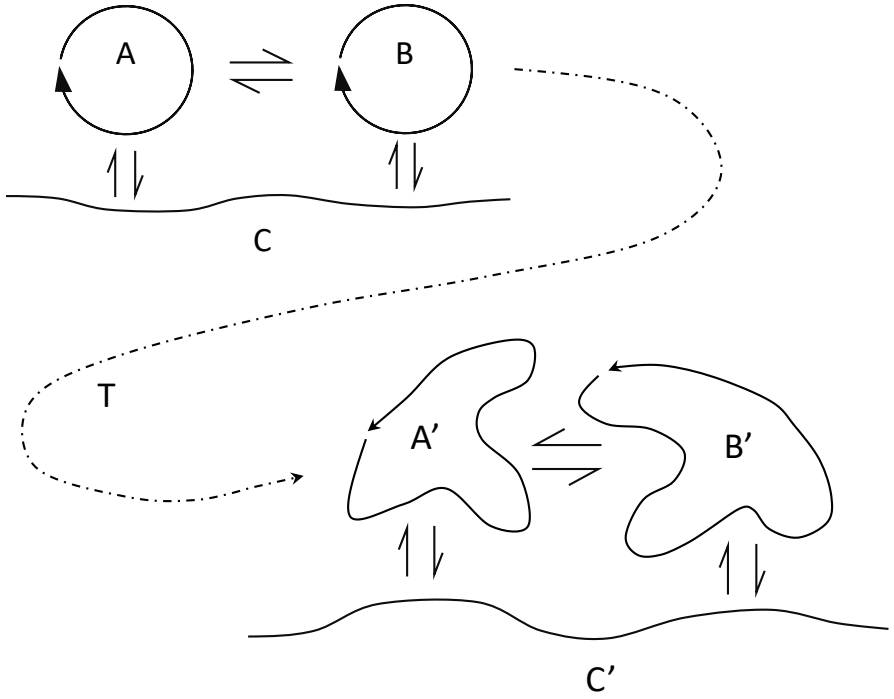


Fig. 1. History of interactions in the medium (adapted from Maturana, 2014)

- A, B and C change along the course of interactions, undergoing a set of transitions, collectively denoted by T.
- The functional closures, of A with B, of A with C, and of B with C, result under T, respectively in the functional closures A' with B', A' with C' and B' with C'.
- This mechanism give rise to the origin and evolution of living systems by means of natural drift.

ENACTIVE AND AUTOPOIETIC THEORY OF SOCIAL AND LANGUAGE PHENOMENA

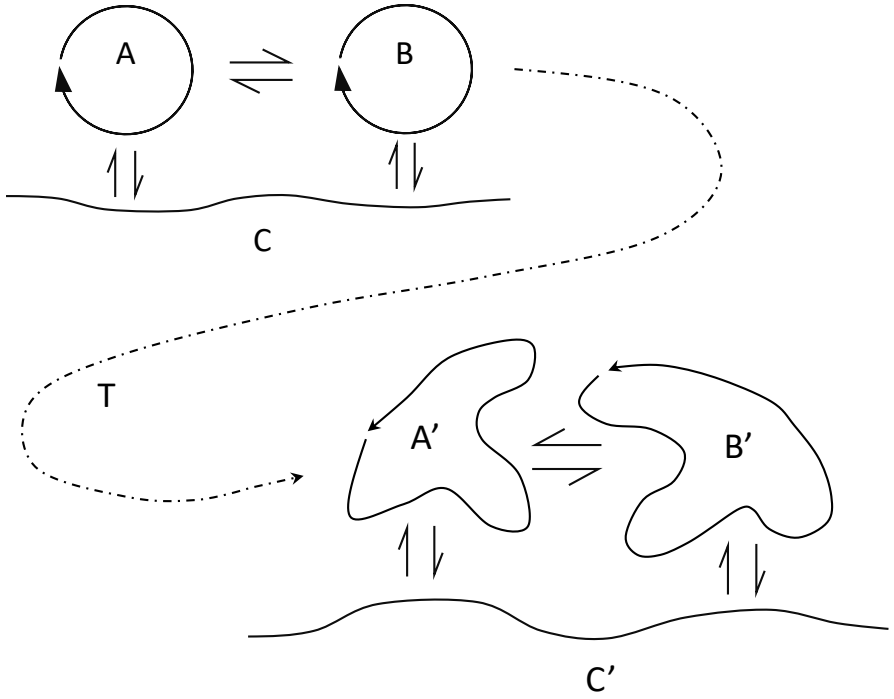


Fig. 1. History of interactions in the medium (adapted from Maturana, 2014)

- Consensual coordination of conducts inaugurate the linguistic domain [12] [13].
- Maturana emphasizes that language appears in this type of “co-drift story”, “as an inevitable condition of the history of recurring interactions” [12].
- The language emerges as “coordination of behavior and consensual coordination of behavior [12]), as a set of normative social practices [2] [9].
- An example of behavior in the linguistic domain is a friend’s speech when visiting a newborn, describing changes in the family dynamics.

MULTIAGENT SYSTEMS IN AN INTEGRAL VIEW: LANGUAGE AS NORMATIVE SOCIAL PRACTICES

Individual/Interior (I-I)	**Individual/Exterior (I-E)**
I *Subjectivity* <mental states, emotions, beliefs, desires, intentions, cognition> "*Interiority*"	**It, This** *Objectivity* <agent behavior, object, process, agent body> "*Observables, exteriority*"
Collective/Interior (C-I)	**Collective/Exterior (C-E)**
We *Intersubjectivity* <shared / collective knowledge, ontologies, norms and conventions, language and semantics> "*Noosphere*"	**Them, All This** *Interobjectivity* <reified social facts and structures, Organizations, forms of interaction, environment as interaction space> "*Sociosphere*"

Fig. 2. Analysis of MAS according to an integral view (Adapted from [6]).

- In order to describe different aspects of Multiagent systems, based on Wilber's theory [18], Ferber [6] describes in four quadrants an integral view on MAS based on the concepts of subjectivity, objectivity, intersubjectivity and interobjectivity.
- A series of psychological and social aspects are described in the meta-model, serving as a basis for understanding certain phenomena for the design of agent and MAS architectures.

MULTIAGENT SYSTEMS IN AN INTEGRAL VIEW: LANGUAGE AS NORMATIVE SOCIAL PRACTICES

Individual/Interior (I-I) **I** *Subjectivity* <mental states, emotions, beliefs, desires, intentions, cognition> "*Interiority*"	**Individual/Exterior (I-E)** **It, This** *Objectivity* <agent behavior, object, process, agent body> "*Observables, exteriority*"
Collective/Interior (C-I) **We** *Intersubjectivity* <shared / collective knowledge, ontologies, norms and conventions, language and semantics> "*Noosphere*"	**Collective/Exterior (C-E)** **Them, All This** *Interobjectivity* <reified social facts and structures, Organizations, forms of interaction, environment as interaction space> "*Sociosphere*"

Fig. 2. Analysis of MAS according to an integral view (Adapted from [6]).

- In our view, quadrants are an interesting tool for the schematic understanding of popular descriptions of psychological and social phenomena. To map these descriptions is useful to transpose notions expressed about a psychosocial theme in models and simulations based on agents.
- In both meta-models [6] [12], this one of Maturana and the other of Ferber, we find a description of language as social norms and practices.
- Nevertheless, Wilber's view is not compatible with the enactive and autopoietic theory of psychosocial phenomena [18].

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

- The central point of our conceptual analysis rests on the concepts of interiority and individuality present in Ferber's meta-model (2007) that demanded a conceptual review from an enactive perspective, which resulted in the proposal of our meta-model below for describing MAS.
- From an enactive perspective, the concepts of interiority and exteriority are reduced and eliminated by the concepts of organizational and functional closure, and the concepts of individual and collective were analyzed as traditionally done in the enactive perspective from the concepts of structural coupling of second and third orders.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

- Traditionally, agents are described as autonomous units of information processing, a notion derived from a cognitivist perspective [3].
- According to Ferber, however, the agent is a computational entity, a process, located in a virtual or real environment [6].
- Starting from the theoretical framework of the enactive and autopoietic theory, we defend that an artificial agent is defined, first of all, by its organization and then by its functioning in the environment. Thus, **the agent is an organizationally and functionally closed unit**, and artificial agents have, as designed by the human being, an initial organization and thus an initial mode of functioning in the environment.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

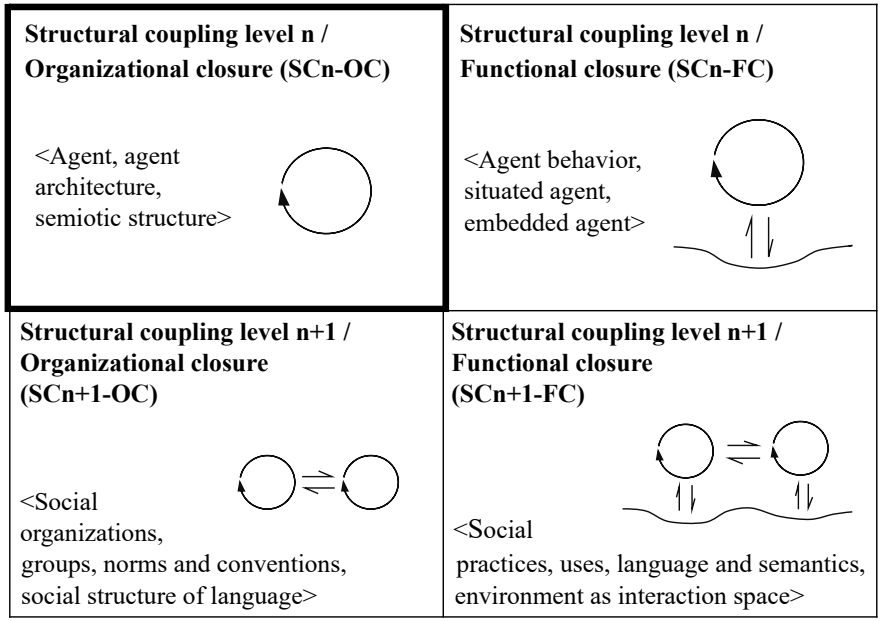


Fig. 3. Analysis of MAS according to an enactive vision.

- From the composition “Structural Coupling level n / Organizational Clousure” (SCn-OC), we describe the concepts of agent, agent architecture and semiotic structure of agent architecture.
- When concretely implemented, the agent will be structurally coupled at certain physical (material) level of organization [10] [11] [16] [17].

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

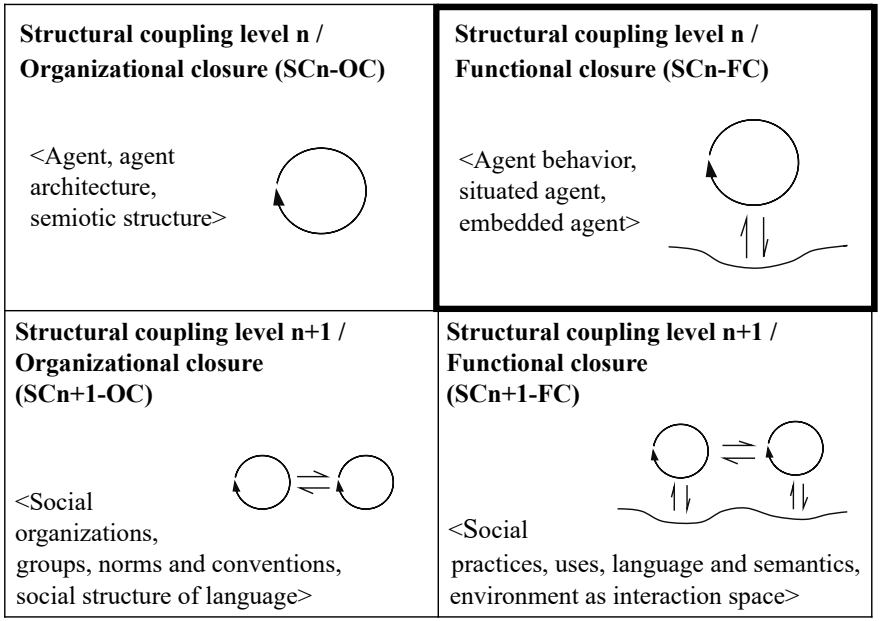


Fig. 3. Analysis of MAS according to an enactive vision.

- From the composition "Structural coupling level n / Functional closure" (SCn-FC), we describe the behaviors of agents in the environment, the concepts of situated agent and embedded agent.
- These first two quadrants are central to the so-called Agent Centered Multiagent Systems (ACMAS) approach.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

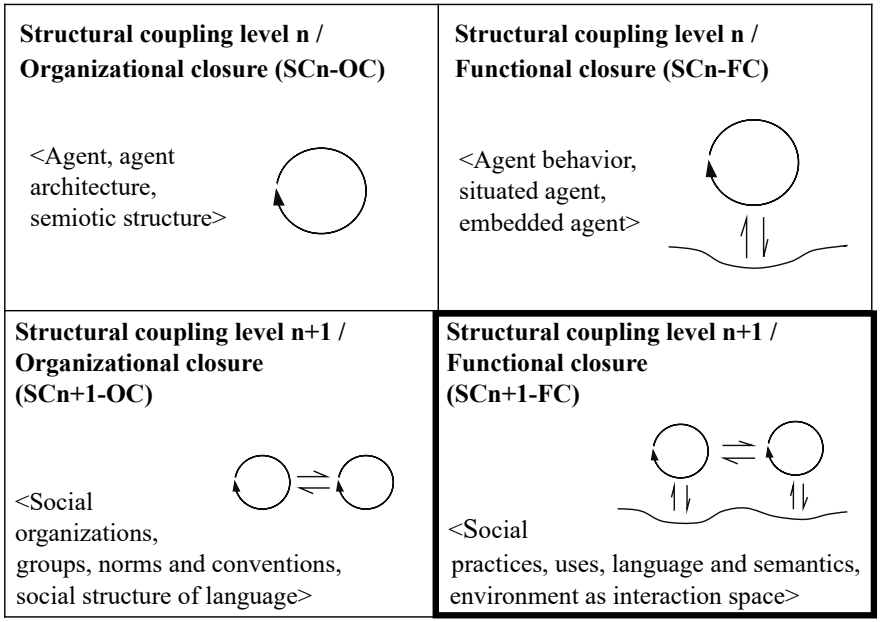


Fig. 3. Analysis of MAS according to an enactive vision.

- The following two quadrants at the bottom of Figure 3, describe fundamental characteristics in the so-called Organization Centered Multiagent Systems (OCMAS) approach.
- From the composition SCn+1-FC (Structural coupling n+1 / Functional closure), there is a series of emerging phenomena.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

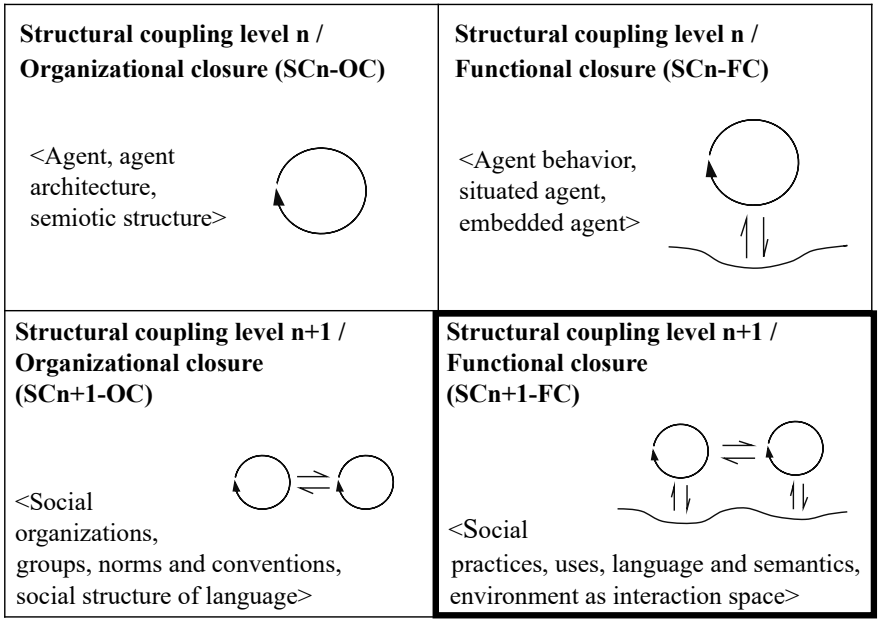


Fig. 3. Analysis of MAS according to an enactive vision.

- Classically, it is understood that micro-behaviors (at level n) can lead to macro-behaviors (at level n+1).
- We describes in the bottom left quadrant; social practices, uses, the semantics as uses, the language as coordination of the practices of agents in their environments and the environment, as a space modifiable by interactions.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

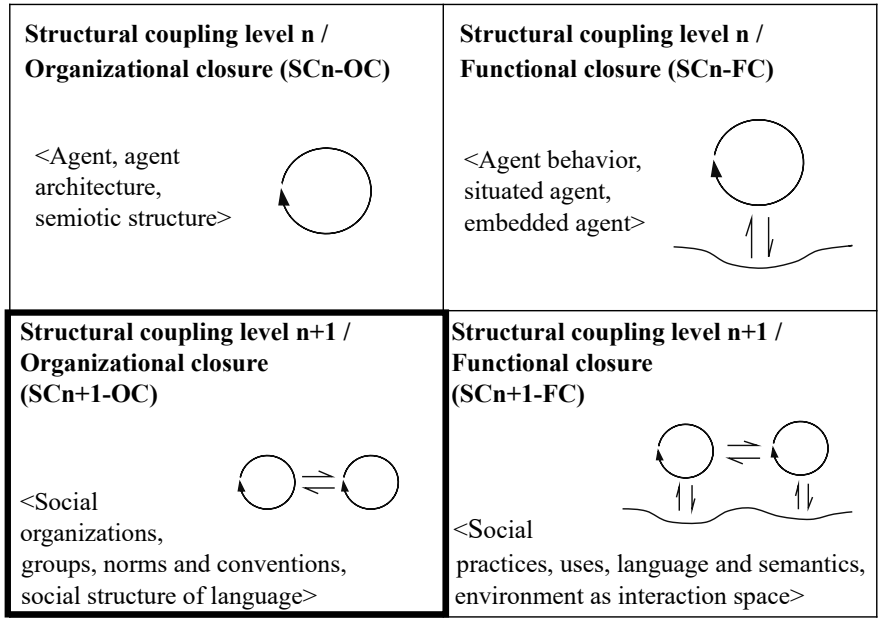


Fig. 3. Analysis of MAS according to an enactive vision.

- In the last quadrant, we highlight the formation of social groups, with a social organization being a group of at least one social group [6].
- At this level of the organization of the system we describe social organizations, social norms and conventions and, also the structure of language.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

- The emergence of language in artificial agents is illustrated in Figure 3 as resulting from the development of combinations of the structural coupling level and the organizational and functional closures.
- Language is produced by coordination of behaviors, and consensual coordination of behaviors, occurring from distinct levels of structural couplings evolving a semiotic structure, situated behaviors, social practices and a social structure of language.
- Social practices appear from coordination of behaviors. However, consensual coordination require the formation of social organizations, with social norms and conventions and, finally, the emergence of a social structure of language.

A MULTIAGENT META-MODEL FOR THE DESCRIPTION OF SOCIO-COGNITIVE PROCESSES

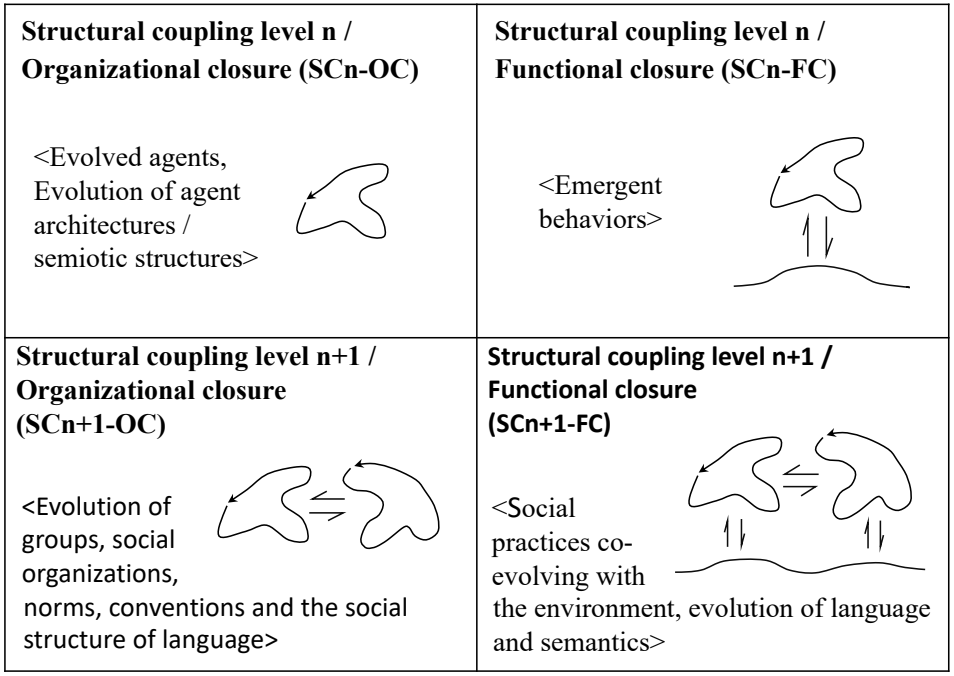


Fig. 4. Evolution of MAS according to an enactive vision.

- With the modification of the agent's architecture due to the emergence of normative social practices and social organizations, a new cycle begins in the MAS.
- Evolved agents will lead to emergent behaviors, social practices will evolve together with the environment, leading to the evolution of language and semantics.

Final considerations

- We conclude with the understanding that the proposed meta-model for description of MAS under an enactive vision captures the essentials of Maturana and Varela about language as a *history of co-drift* [12], [13], [14], as an inevitable condition in the history of recurring interactions.
- We emphasize that language emerges as “coordination of behavior and consensual coordinations of behavior” [12]), as a set of social practices in different forms of social organizations.
- However, a challenge is imposed in the design of semiotic architectures of agents from an enactive perspective. As a requirement, it is necessary that the semiotic structure of the agents can be self-developed by the Multiagent system, not directly implemented by the programmer, which is a target for a future work.

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