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

An Enactive Perspective of Language in Artificial Agents

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***Abstract*—We propose here a meta-model based on the enactive and autopoietic theory for the description of social and language processes by 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. We propose a social cycle in which the architecture of agents evolves according to their practices, uses and social groups, the basis on which language evolves. Our meta-model was developed 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. 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 point of the enactive criticism that we carried out here was the concepts of interiority and individuality present in Wilber's theory.**

***Index Terms*—Cognition; Socio-cognitive processes; Enaction; Meta-model; Language; Multi-agent model**

I. Introduction

Meta-models are of great help in building models that involve very complex frameworks, typical in the study of socio-cognitive relations among agents and the environment, serving as scaffolding for the development of simulation architectures. The purpose of this article is to introduce a meta-model for the description of Multiagent Systems (MAS) and the emergence of language in artificial agents.

The proposed meta-model is derived from two other meta-models: a) that of the enactive and autopoietic theory of cognition, which describes language as a social phenomenon and the linguistic domain as coordination of behavior and consensual coordination of behavior [12]; [13]; [14]; 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]. The meta-model described by Maturana [12] and the meta-model describing an integral view on MAS, proposed by Ferber [6] both emphasize the description of language and other social processes as an emerging social practice in complex social organizations. However, the differences between the enactive and autopoietic view compared to Wilber's integral view [18] cannot be made compatible, as we will argue. 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. The concepts of interiority and exteriority have been reduced and replaced by the concepts of organizational and functional closure and; the concepts of individual and collective were analyzed, as is traditionally done in the enactive and autopoietic perspective, from the concept of structural coupling orders – levels – (first, second and third order structural couplings).

The paper is organized as follows: Section II presents the enactive and autopoietic theory of social and language phenomena. Following, section III presents the quadrangle map that describes the four aspects of a MAS, derived from a decomposition: Individual / Collective and Interior / Exterior. Section IV then presents our proposal for a meta-model to describe cognitive processes, such as language as a social phenomenon, using a four-quadrant map.

II. Enactive and autopoietic theory of social and language phenomena

Enaction is bring forth a world, an experiential world. In Enactive Cognitive Science, we argue that the realization of the experience occurs within the organizational and functional closure of structurally coupled living machines [12]; [13]. The figure 1 illustrates the history of recurring interactions of living beings, A and B, in the medium C. Maturana considers these recurring interactions as recursions, and not as simple repetitions in a sequence [12]. He gives an example of such recursive function: $\sqrt{a} = a'; \sqrt{a'} = a''; \sqrt{a''} = a'''$.

Then we say that A and B are organizationally and functionally closed. In biological systems, the organization of A is represented in the Maturana meta-model above and refers to the process of self-organization of the physiological domain. It is also said that A is functionally closed to medium C,

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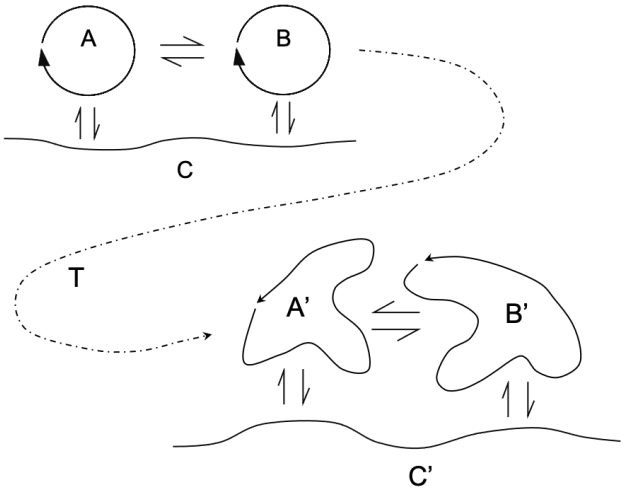

Fig. 1. History of interactions in a medium. A, B and C named as different systems by an observer change depending on their interactions while remaining congruent with themselves in the forms A', B' e C'. (Adapted from [12], p. 82)

altering the medium by its conducts and suffering medium disturbances. This is the domain of the behavior of system A. In the position of A, systems B and C are part of the medium. For B, the medium consists of A and C. Systems that self-produce structurally coupled to the medium, such as A and B, are said ontogenic phenotypes [12]. Notice that A, B and C change along the course of interactions, undergoing a set of transitions, collectively denoted T. The functional closures of A with B, A with C and B with C, result under T, respectively in the functional closures A' with B', A' with C' and B' with C'. According to Maturana [12], the observer notes this organizational change of A in A', B in B' and C in C'. Recurring interactions that occur in the contingencies of structural changes in the environment, undergo also structural changes due to their coupling to their respective local media. While dealing with living beings, the observer reckons a history of transformations (T) in the conducts, which constitute recurrent interactions. In a history of transformations, it is possible that there will be an expansion of dominance in the contingencies of changes. Consensual coordinations of conducts inaugurate the linguistic domain [12]; [13]. An example of language coordination is the situation that occurs when a couple starts their living with a first baby, and some friend visiting the house notices, as an external observer: "Wow, the dynamics of this house have completely changed!" The parents and the baby initiate a history of recurring interactions where the coordination of conduct between family members and the baby undergoes changes in their environment as a result of that history. A domain of consensual behavior is then established, as it was easily noticed by an observer.

Maturana emphasizes that language appears in this type of "co-drift story", "as an inevitable condition of the history of recurring interactions". The language emerges as "coordination of behavior and consensual coordination of behavior" ([12], p. 85), as a set of normative social practices [2]; [9]. An example of behavior in the linguistic domain is the friend's speech when visiting the newborn. It is classically highlighted in enactive and autopoietic theory that the emergence of language does not demand anything special, such as internal mental content or intentional representation, these concepts are reduced and eliminated by the concepts of functional closure [2]; [9]. Chalmers, also, highlights this point in his functional theory of language [4].

In the following section, we will go on to describe an integral view of MAS using a quadrants-based meta-model. In the section IV we will present the meta-model from an enactive perspective for describing MAS and the realization of social processes, like the emergence of language in MultiAgent Based Simulation (MABS).

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

In order to describe different aspects of Multiagent systems, Ferber [6] leaned on Wilber's theory [18], who describes in four quadrants an integral view for psychology based on the concepts of subjectivity, objectivity, interobjectivity and intersubjectivity. The subjectivity quadrant is obtained by the Individual / Interior composition (I-I). The objectivity quadrant is obtained by the Individual / Exterior composition (I-E). The interobjectivity quadrant is obtained by the Collective / Exterior composition (C-E) and the intersubjectivity quadrant is obtained by the Collective / Interior composition (C-I).

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 ([6], p. 15).

A series of psychological and social aspects are described in the meta-model, serving as a basis for understanding the investigated phenomena for the design of agent and MAS architectures. In Wilber's integral view, mental states, emotions, beliefs, desires, intentions and even cognition are described as subjective phenomena or as inherent to the interiority of individuals [18]. In this quadrant everything that concerns to the "I" (the "self") would be comprised. Behaviors of agents, of objects, observable processes and the bodies of agents are described as objectives or external things. In an emblematic way, this quadrant is described as being in the order of "It" or "This". In the integral view, facts and social structures are subject to reification. Organizations, forms of interaction and the environment as a space for interaction are

described as interobjective phenomena or as of the order of the “Sociosphere”. In this quadrant everything that is of the order of ”Them” or ”All This” would be comprised. Shared knowledge and collective knowledge, ontologies, social norms and conventions, language and semantics are described as intersubjective or of the order of the “Noosphere”, which is all about ”We” or ”us”.

In our view, quadrants are an interesting tool for the schematic understanding of popular descriptions of psychological and social phenomena. Mapping these descriptions is useful to transpose notions expressed about a psychosocial theme in models and simulations based on agents. Nevertheless, Wilber’s view is not compatible with the enactive and autopoietic theory of psychosocial phenomena [18]. In both meta-models, from Maturana [12] and Ferber [6], we find a description of language as social norms and practices. However, fundamental differences do occur, which we will be explored in the next section.

IV. 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 [6] 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 is traditionally done in the enactive perspective from the concepts of structural coupling of second and third orders.

Traditionally, agents are described as autonomous units of information processing, notion that derive 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, their initial organization and thus, an initial mode of functioning in the environment.

In the proposed meta-model it is intended to situate very common concepts in the domain of MAS. The agent and its architecture, which may or may not have a semiotic structure [10]; [11]; [16]; [17], is described as an organizationally closed unit, which when concretely implemented (as it is commonly said), will be structurally coupled by a human designer in a physical (material) level of the natural organization. In this sense, robots like Sophia from Hanson Robotics, are designed with such a body structure that enables it to be inserted in a certain way in the social dynamics of human relationships.

Starting with the upper-left quadrant of figure 3, from the composition “Structural coupling level n / Organizational closure” (SCn-OC), we describe the concepts of agent, agent architecture and semiotic structure of agent architecture. Following to the upper-right quadrant, 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.

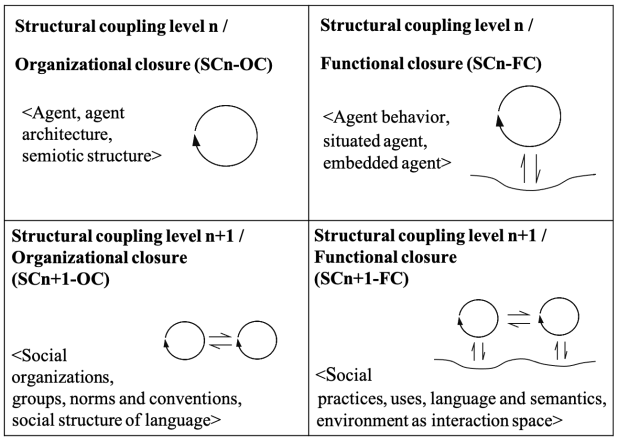

Fig. 3. Analysis of MAS according to an enactive vision. The figure illustrates language in artificial agents occurring from a semiotic structure, situated behaviors, social practices and a social structure of language, that is; as “coordination of behaviors and consensual coordinations of behaviors”. Social practices occur as behavior coordinations, but consensual coordinations depend on the formation of social organizations; social norms and conventions and, then, the emergence of a social structure of language.

The following two quadrants at the bottom of figure 3, describe fundamental characteristics in the so-called Organization Centered Multiagent Systems (OCMAS) approach. In this case, the concept of emergent organization takes the focus of the design and implementation of the MAS [6]. From the composition “Structural coupling n+1 / Functional closure” (SCn+1-FC), there is a series of emerging phenomena. Classically, it is understood that micro-behaviors (at level n) can lead to macro-behaviors (at level n+1). We then describe 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. In the last quadrant, at bottom right, we zoom in again on the internal dynamics of the system, highlighting 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. It is emphasized that these phenomena cannot be reduced to the processes described in the architectures of the agents. The social processes in their organizations provide normative patterns of disturbances on the structure of the agent, which may lead to the evolution of their architecture. The following meta-model in the figure 4 presents the evolution of these ontologies described above.

With the modification of the agent’s architecture due to the

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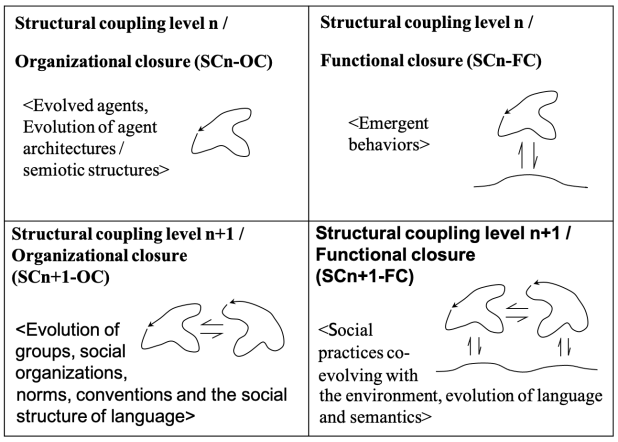

Fig. 4. Evolution of MAS according to an enactive vision.

emergence of normative social practices embodied in social organizations, a new cycle begins in the MAS. Thus, the new architecture will provide for the emergence of behaviors in the system, social practices will evolve together with the environment, leading to the evolution of language and semantics (emergent uses in MAS). Finally, the social organization itself also evolves as a result of these collective practices, with the possibility of forming new social groups, norms and conventions, and thus also of the social structure of language. We understand that language variation occurs fundamentally with the formation of different social groups, it occurs as variations in the norms of social practices.

We understand to capture here the essentials of Maturana and Varela views about language as "history of co-drift", "as an inevitable condition of the history of recurring interactions". The language emerges as "coordination of behavior and consensual coordination of behavior" [12]; [13]; [14], as a set of normative social practices. The realization of language in artificial agents is the result of several recurring functions in MAS defining the agent architecture, as well as the MAS architecture. The organizational and functional closure embodied in certain structural coupling level leads to coordinations of behaviors (collective practices), and consensual coordinations of behaviors (normative social practices), occurring from an agent architecture (that can have a semiotic structure), situated behaviors, social practices and a social structure of language. Social practices appear from coordinations of behavior, however, consensual coordinations require the formation of social organizations, with social norms and conventions and, then, with the realization of the social structure of language. 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 system, not directly implemented by the programmer.

V. Final considerations

The objective of this article was to describe social processes and among them language in particular, based on: a) the enactive and autopoietic theory of cognition, which describes language as a social phenomenon and the linguistic domain as processes of communication over communications [12]; [13]; [14]; b) the Ferber's meta-model [6], which describes MAS from a view based on Wilber's [18], where each quadrant of the meta-model describes psychosocial processes from the subjectivity and objectivity dichotomy. Fundamental aspects of MAS, such as the architecture of agents, the formation of artificial organizations and the emergence of language were presented from this meta-model [1]; [6]; [7]; [15].

However, even though the enactive theory and the integral view describe language as a social process, occurring in social organizations, based on social structures and processes, there are incompatible differences between the enactive view and the Wilber's integral view. Fundamental ontological differences were pointed out, which led us to propose a meta-model to describe MAS and the realization of language in artificial agents in a strictly enactive perspective, using a four-quadrant map. The central point of our conceptual analysis highlighted that the concepts of interiority and individuality present in Ferber's meta-model [6] are liable to be reduced and replaced by the concepts of organizational and functional closure and that, the concepts of individual and collective were analyzed as it is traditionally done in the enactive perspective from the concepts of structural coupling of second and third orders.

We conclude with the understanding that our meta-model of 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" (p. 85). We emphasize that language emerges as "coordination of behavior and consensual coordinations of behavior" ([12], p. 85), 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 because it is necessary that the semiotic structure of the agents architecture can be self-developed by the Multiagent system and not directly implemented by the designer, which is a target for a future work.

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