Proposal for a Multiagent Architecture for Self-Organizing Systems (MA-SOS)

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Abstract. This work investigates the trade-off between individual and collective behavior, to dynamically satisfy the requirements of the system through self-organization of its activities and individual (agent) adaptability. For this purpose, it is considered that each agent varies its behavioral laws (behavior-switching) dynamically, guided by its emotional state in a certain time instant.

Keywords: Emergent, SelfOrganizing Systems, Swarm Intelligence.

1 Introduction

Nowadays, to level multiagent systems (MAS) it is advisable to have a general agent architecture able to emulate human behavior, capable of modelling self-organizing systems which can adapt dynamically to their environment. For this purpose, we propose a hybrid generic architecture, where agents are able to have reactive or cognitive responses, depending on the received stimulus, and to collectively generate emerging behavior, with the goal of improving individual and social performance. Besides, considering cognition as a social phenomenon, an agent would develop individual behavior based on the collective behavior of its neighbors. Moreover, the architecture adds the characterization of the emotional state of the agents.

2 Theoretical Aspects

A cognitive architecture is a generic computational model for studying behavior and cognition at the individual level. It provides an agent with decision-making mechanisms. Among the cognitive architectures we have: **SOAR** [4]; **CLARION** [5, 8] and **ACT-R** [7, 8]. SOAR is the most complete one. It includes *working and long-term memory,* and learning mechanisms (*chunking, reinforced knowledge, etc.*). For emotional computing considering agent dynamic behavior-switching see [1, 3, and 10].

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3 Generalities about the Proposed Architecture

Fig. 1 shows how the learning process and acquisition of knowledge takes place in the architecture. An agent increases its knowledge through an individual learning process. It interacts (socializes) through its environment and directly with other agents using local information. A "Bottom-Up" mechanism allows emerging of collective explicit knowledge. Additionally, a feedback "Top-Down" process promotes individual learning of this collective knowledge.

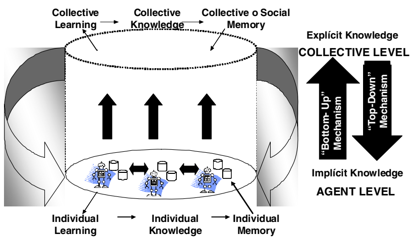

Fig. 1. Types of Knowledge and Learning in MA-SOS

It consists of the following phases involved in a circular cause-effect process of general knowledge management that reflects the process of creation, conversion, integration and diffusion of knowledge according to [6]: a) **Socialization;** consists of sharing experiences through local interactions, and requires **turning implicit knowledge into explicit transferable concepts**. b) **Aggregation;** the agent **creates trustworthy explicit knowledge** through exchange of points of view, meetings, etc. c) **Appropriation;** consists of **translating explicit knowledge into the implicit kind**.

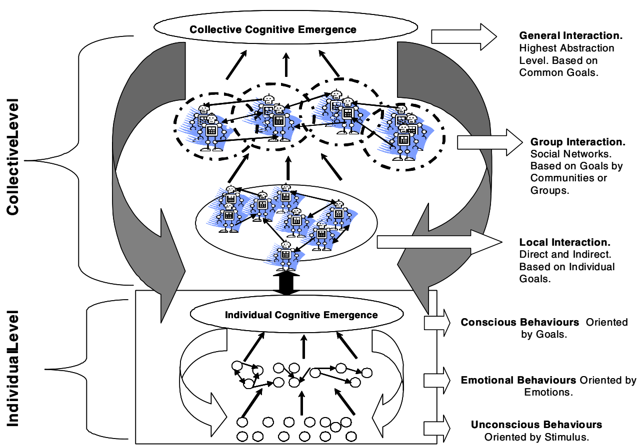

Fig. 2. Multiagent Architecture for Self-Organizing Systems

3.1 Multiagent Architecture for Self-Organizing Systems

The proposed architecture allows emerging coordination among hybrid agents. It is divided into two levels: *individual and collective* levels (see Fig. 2). C**ollective cognitive emergence** arises from three interaction levels: **Local Interaction Level,** which might be direct or indirect (via the environment); **Group Interaction Level,** involving social networks or structured groups; and, **General Interaction Level,** which includes the whole set of agents.

On the other hand, **individual cognitive emergence** consists in generating cognitive emergence imitating the way in which neurons act, when generating a range of behavior from unconscious to conscious [9]. Inspired by this, agent's behavior is modeled at three levels, each activated or inhibited depending on the agent's objective: **Unconscious or reactive Behavior**; **Emotional Behavior;** and **Conscious Behavior**.

3.1.1 Components of the Architecture at the Collective or Social Level

At this level the architecture consists of (see Fig. 3): a) **Hybrid Agent:** This agent reacts and reasons depending on perception, emotions and the state of the environment. b) **Feedback Mechanisms ("Bottom-Up" and "Top-Down" Approach):** Interaction among components could be [2]: Positive (to promote the creation of structures and changes in the system) or Negative (to offset positive feedback and help stabilize the collective pattern) Feedback. c) **Mean Field:** It represents the area circumscribed and delimited by agents within the **environment** for coordinating behavior.

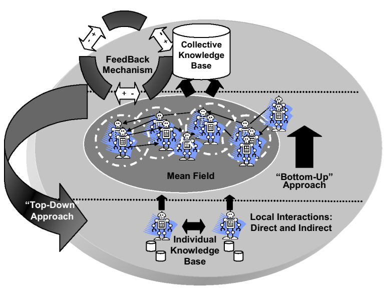

Fig. 3. Components of MA-SOS at Collective Level

3.1.2. Architecture Components at the Individual Level

The architecture at an individual level is made up of 4 components (see Fig. 4): **Reactive, Cognitive, Behavior** and **Social**. In order to exploit diversity and to favor the development of collective cognitive emergence, each agent can have hybrid behavior: reactive, emotional-reactive, and cognitive-reactive, among others.

a) Reactive Component: It produces the agent's reactive behavior. **Reactions Selector:** selects among different behavioral routines (reactive behavior) to be executed according to the agent's emotional state.
b) Behavior Component: It favors the agent's adaptation to its environment, creating an internal model of the outside world. Each agent's decision will be based on its

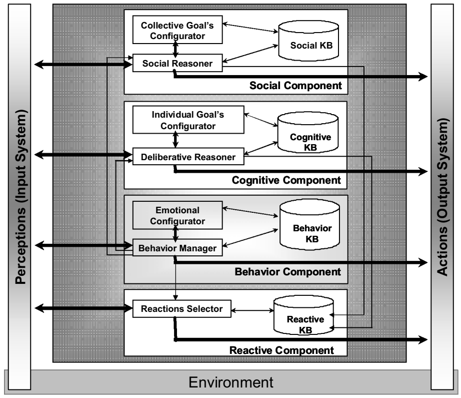

Fig. 4. Components of MA-SOS at Individual Level

individual and collective objectives, its emotional state and acquired individual and collective knowledge. The types of behavior to handle are: to imitate, to react and to reason, linked to an emotional state (positive or negative) (see Fig. 5). **Emotional Configurator:** It is the component manipulating agents' emotions. Emotions are considered as signals and evaluations that inform, modify and receive feedback from a variety of sources including reactive, cognitive processes and other agents (social processes). **Behavior Manager:** It is the component managing the behavior-switching mechanisms. Its objective is to suggest a type of behavior based on its emotional state, its goals and the situation of its neighbors (social situation) and environment in general. Knowledge associated with the agent's emotion management is stored in the **Behavior KB.**

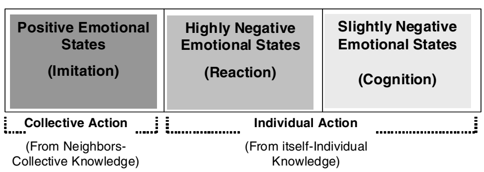

Fig. 5. Positive and Negative Emotional States with its Associated Behavior

The role of emotions in this work is for the behavior selection (e.g., which behavior is convenient according to the current emotional state) based on the classification of agent's emotions. For this classification, each agent could have emotions in three different areas [10]: goal-based emotions [e.g., *Joy, distress; Hope, Fear*], other agent's actions [*e.g., Anger, Gratitude; Gratification, Remorse; Pride, Shame; Admiration, Reproach*] and tastes/attitudes towards objects or places [*e.g., Love, Hate; Like, Dislike*]; the idea is that each agent can have an emotional memory which allows it to put "tags" to its emotions in each one of these categorizations. Moreover, each agent will have a positive, negative or neutral attitude which will affect the intensity of the emotion.

However, determining if the emotional state is positive or negative and selecting the type of behavior are both based on the following: *"Negative affection can bias problem solving strategies in humans towards local, bottom-up processing; whereas, positive affection can lead to global, top-down approaches"* [10]. Thus,

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Rule 1: If <Emotional State> is Positive then    <Prior-
ity_Social_Behavior>

Rule 2: ElseIf <Emotional State> is Slightly Negative then
              <Priority_Cognitive_Behavior>

Rule 3: ElseIf <Emotional State> is Highly Negative then
              <Priority_Reactive_Behavior>
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c) Cognitive Component: It is in charge of producing the agent's cognitive behavior. **Individual Goal's Configurator:** makes the configuration of the agent's individual objectives and priorities. **Deliberator:** It's responsible for cognitive mechanisms (learning, reasoning) and intentional or deliberate decision-making, among others; the knowledge generated is stored in the **Cognitive KB.**
d) Social Component: It promotes conscience in the agents about the work and experience of other agents. Specifically, it takes advantage of experiences of others (Social Learning), i.e., to avoid a long process of individual learning of things which have been learnt by its neighbors. This component connects the collaborative collective learning and the individual learning. **Collective Goal's Configurator:** makes the configuration of the agent's collective objectives and priorities. **Social Reasoner:** selects which action to imitate and from which agent based on the collective goals; the knowledge about decisions taken by its neighbors is stored in the **Social KB.**
e) Other General Elements. Input System: It provides agents with information about the world they live in. This system passes perceptions (inputs) in a parallel manner to the reactive, behavior, cognitive and social components. All components interact with that input but it is the behavior component which must establish which component has higher priority for answering. **Actions:** They are rules of condition-action (if…then) or generated from a deliberative process. **Output System:** It must choose the action of the component indicated by the Behavior Manager in case there are several answers.

4 Conclusions

Our proposed architecture is split into two levels: *an individual level and a collective one*, trying to model systems which produce or have self-organizing behavior from local interactions of agents, generating collective knowledge from those interactions. We have developed a collective architecture based on 3 phases for knowledge management. Additionally, our architecture provides each agent with an emotional state. This allows us to have a multiagent architecture whose agent's behavior might better represent a wide range of human situations, since each agent could have multiple behaviors depending on its knowledge, emotions and social situation. Therefore, it offers an alternative model to represent and better understand self-organization and emergent processes in human environments. Further work in progress includes modeling systems like *Wikipedia, free software development and collective behavior of pedestrians.* These works aim at validating our architecture from a design point of view.

Additionally, further work also involves implementing a simulation prototype, for a specific problem, in order to instantiate each mechanism and component, validating the architecture from an implementation point of view.

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