ATTENTION, MOTIVATION AND EMOTION IN COGNITIVE SOFTWARE AGENTS

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Abstract: The observations that the emotional phenomenon is an essencial component to the living beings cognition has influenced the conception of artificial intelligent mechanisms. This influence has lead to the discussion whether it is possible to elaborate an inteligent system without including into it the emotions's role. The proposed model implements an affective mechanism inside an architecture to build cognitive software agents, called ARTIFICE. Its conception was inspired in a biological bottom-up approach for classifying affections considering ideas and neuroscientific concepts about emotions and their influence on learning. Also it is considered that the attention, motivation and emotion are interdependent aspects that need to be considered together by an affective mechanism. The main objective of this work is to reproduce the adaptive functions of survival value in software. Moreover this study also aims to presents how the autonomy in artificial organisms can be acquired inserting appropriate synthetic emotions. The experiments suggest that the model is appropriate to allow agents to adapt themselves in generic environments, according to their incorporated affective structures. Their learning was accomplished solely from live interaction experiences with environment and other existing entities. No previous information about the artificial world were built-in into these agents.

1 INTRODUCTION

There were many frustrated attempts by engineers to apply artificial intelligence (AI) following that traditional and non biological approachs (Terra et al., 2004). According to (Varela et al., 2003), the field of cognitive sciences has finally yielded to openings in alternative approaches to cognition. AI mechanisms have been built without including environmental representations (Clancey, 1997). Some agree that emotions perform an essential role to the living systems, so emotions need to be abstracted to constitute a bio-inspired model (Edelman, 1987).

The affective mechanism proposed here is part of an architecture of building cognitive situated software agents (CSSA), named ARTIFICE (Santos, 2003). CSSA are agents biologically inspired, built without representations of the external environment, with sensory-motor capacities to interact and adapt to the unpredictability involved in their ontogeny. The ARTIFICE model is based in a view of "intelligence" under the perspective of situated cognition (Maturana and Varela, 2002; Varela et al., 2003; Edelman, 1987; Bateson, 1972).

The affective mechanism model was conceived to integrate the nervous system (NS) of a CSSA. It seeks to reproduce in the agents some basic adaptive capacities assigned to emotions. The model considers that emotion, motivation and attention are all intrinsic aspects of the affective process. It is due to this interdependent perspectives the nomitation "emotional-motivational-attentional" (AME) mechanism.

Some concepts, ideas and theories that based the AME mechanism conception are cited in the following section. The AME model is explained in section 3, section 4 describes the environment and the CSSA instantiated for the computational experiments and the conclusions follows.

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2 BIOLOGICAL INSPIRATION

This study tried to recontextualize some concepts and ideas from a biological affects typology (Buck, 1999) and from other theories and researches in neuroscience (Edelman, 1987; LeDoux, 2003; Varela et al., 2003) for a software model.

2.1 The Motivational-emotional System

The (Buck, 1999) typology of biological affects defines motivation as a potential to the behavior due the dynamic induced by the cerebral neurochemical systems. Emotion is seen as the expression of this motivational potential when the individual faces a challenging stimulus. Motivation and emotion are like two sides of the coin, aspects of a motivational-emotional phenomenon. This is a bottom-up approach where emotions are seen as based in biological systems, structured by evolution. (Buck, 1999) named primary motivational-emotional system (primes) the affective systems wich signal to the organism the perception of its internal environment for auto-regulation.

The primes can be hierarchically classified according to an increasing degree of interaction with the general proposed systems. This hierarchy classifies: a)*reflexes* which involve completely inflexible reactions (e.g., the patellar reflex); b)*instincts* like fixed patterns of innate behavior (e.g., the migratory behavior of birds); c)*drives* of primary needs that require specific consumatory learning: hunger, thirst, pain, etc.; d)*primary affects* that motivate the auto-regulation of fear, rage, etc. The higher the hierarchy of primes more influenced by learning.

2.2 Learning, Forgetting and Attention

Another essential concept of the (Buck, 1999) typology is the expectancy system. The operation of this non-specific affective system is connected to the operation of some primes such as drivers, among others. The expectancy system associates to reward (activation) and punishment (inhibition) behaviors. It is a flexible mechanism of instrumental learning through which the behavior is directed towards environmental stimulus and against existing threats.

It may be said that attention is an implicit concept of motivational-emotional phenomenon. For (Damasio, 2003), attention is a mechanism that allows the maintenance of a mental image in the conscience with relative exclusion of others. The influence of emotional states in attention is recognized. For (Edelman, 1987), attention seems to comprehend multiple mechanisms operating in many levels which involve large brain portions, including emotional areas.

The cognitive process also includes a phenomenon that can seem as an embarrassment to learning: the forgetfulness. Using the (Edelman, 1987) TNGS terms, forgetting implies the decay population process subjacent to maintenance of neural group selection due the absence of neural activity.

2.3 From Biology to Modeling of Intelligent Systems

These ideas and concepts substantiate the modeling of AME mechanism. The primes as specialized and innate systems suggest the creation of specialized affective circuits. So, artificial primes need to be integrated to the NS of the CSSA. These primes are specialized according to the complexity of their operation. The reflections/instincts, drives and primary affects must be incorporated to support the automatic reactions, the survival basic needs and other important affective needs, respectively. A CSSA will only have the primes needed to a given application. In other words, a phylogeny or a lineage of agents will have similar primes.

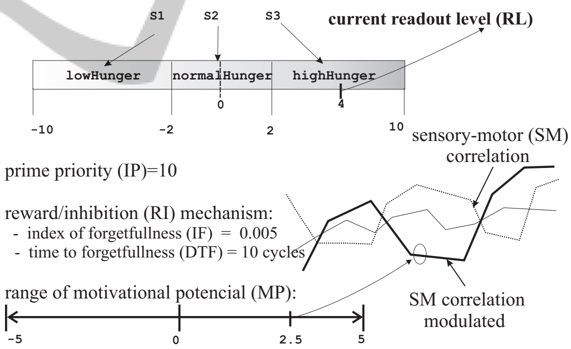

Figure 1: The primes structure.

The permanent operation of artificial primes influences all the behaviors of the CSSA. The perception-action (PA) dynamic of agents must express a motivation of primes' auto-regulation. This auto-regulation tends to establish a primes' redout level (RL) found in the limits of what is considered a great equilibrium. Attention should focus in the direction of satisfaction of the unregulated affective necessities at a certain instant.

The agents' learning occurs according to what is suggested by the expectative system. There must be a mechanism responsible to reinforce and inhibit behavior conducive or not conducive to regulation of embedded primes. According to the suggestion made by (Buck, 1999), the developmental primes dimension needs a kind of attenuation to the acquired conditionings, over time. For such, a selection of the most executable behaviors must at same time reproduce the acquired learning extinction effect associated with learning of behavioral repulsion or reward.

3 THE AME MECHANISM

The AME model consists of the artificial primes, of an aggregating component of these primes called AME container, of a mechanism of behavioral reward/inhibition (RI) and of the attentional mechanism (Terra et al., 2006). The primes are divided into three categories: *innate contextual reaction* for the reflexes and instincts; *primary needs* for the drives and *compelling state* for the primary affection.

All primes are aggregated by the AME container its operation defines a global emotional state (AME state) that will influence the CSSA PA at every instant. Based on the AME state, the RI and attentional mechanisms operate to select an environmental stimuli and a viable behavior, considering the innate tendencies and the experiences acquired by the agent throughout its ontogeny. The internal dynamic of the primes occur via alterations of its activation level (RL) within the pre-established maximum and minimum limits. The specification of the activation states for the CSSA hunger drive used in the experiments performed is illustrated in Figure 1. The dynamic of the AME container consists of considering all active primes and defining the AME state.

Based on the dynamic of each NS structure, the PA cycle should select a sensory-motor (SM) correlation for the agent representing its emergent global state. The SM correlations are the elements to be considered by the RI mechanism for application of the coefficients of learning and forgetting. Learning occurs when a performed SM correlation corresponds to a behavior that promotes the re-establishment of the equilibrium or increases the disequilibrium of any primes. When this occurs, a learning coefficient proportional to the degree of affective regulation/non-regulation is calculated. This coefficient will be applied to update the motivational potential (MP) of the respective primes in the SM correlations involved (see Figure 1). Thus, the MP refers to the influence that a specific primes possesses for the establishment of a certain SM correlation in the CSSA.

The selected action reflects the influence of not only one but potentially all the affective necessities of the agent. This is one of the aspects of the proposed attentional mechanism. The other is that the AME state also modulates the selection of the environmen-

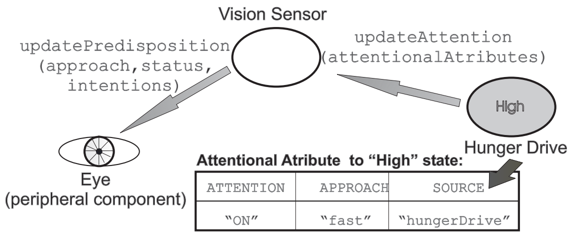

Figure 2: Attencinal mechanism: peripheral atributes.

tal stimuli percieved by the peripheric sensory-motor components of the CSSA. An example of an attentional attribute sent to a visual sensor by the agent's hunger drive is illustrated in Figure 2.

The operation of the AME mechanism assures a CSSA auto-regulation (an homeostasis maintanence) based on its AME state. It should be emphasized that this emotional permanent influence is essential for the incorporation of the experiences in accordance to the situated cognition approach.

4 COMPUTATIONAL EXPERIMENTS

The experiments for the validation of the AME mechanism were made in a two dimension artificial life environment. In it is possible to insert different types of nutrients (green, blue and red apples) and a non-edible object (brick). The walls that limit the "artificial world" were also inserted during the initialization. All these are software components (non-cognitive beings) that the CSSA will interact through the exchange of stimuli by the sensory-motor components of its peripheral system (Figure 3).

The CSSA instanciated included the following NS structures: a) Vision Sensor; b) Mouth Touch Sensor; c) ME Primary Temporal Need Hunger; d) Hit And Turn Reflex; e) Mouth Moviment Effector; f) Translation Effector; g) Rotation Effector. The are two primes: (i) a "Hit and Turn" reflex to make a right turn after CSSA hit a wall and (ii)a drive for "hunger" as a temporal primary need whose RL evolves from a unit at each time.

It should be considered that among the possible SM correlations some should be defined as innate tendencies. It is so to motivate the CSSA behavior of approximation and ingestion of the entities detected in its visual field. These are seen by the agent as a nutrient if a positive nutritional coefficient (NC) is perceived by it. For example, imagine a CSSA with hunger drive in a high state. After the ingestion of a blue apple (NC = 4 kcal) the hunger drive signals satisfaction and generates a positive (proportional) affec-

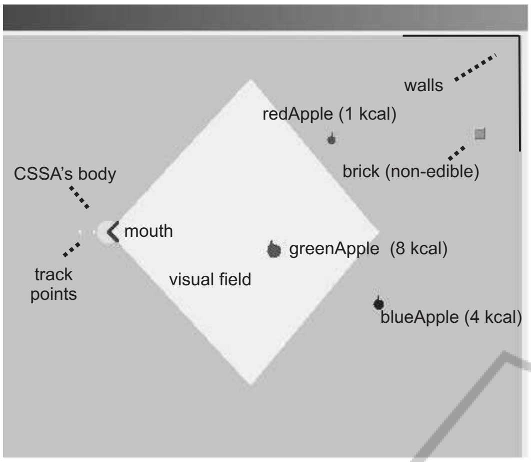

Figure 3: Non-cognitive components of the CSSA' artificial world.

tive regulation index that should be applied to reinforce the MP of all SM correlations associated with that behavior. The MP scale ranges from -5 to 5, the same is true for all CSSAs primes (Figure 1).

With respect to the learning extinction, as the SM correlations aren't being selected their MP is adjusted gradually in direction of a neutral MP (0). This neutral MP is the one at the beginning of CSSA ontogeny for all primes except innate contextual reaction.

5 FINAL CONSIDERATIONS

The proposed model presents some advantages in relation to other affective mechanism proposals (see (Terra, 2007) for details). It is possible to make important configurations to the AME mechanism specifying: (i) the internal specific dynamic of each primes; (ii) the attentional attributes to the peripherical system; (iii) a strategy to generate the AME state. Second, behavior can be influenced by more than one emotion. The resolution of the affective need will be limited only by the sensori-motor skills.

Third, it is considered that the outcomes that were obtained are satisfactory. The model is coherent to the non-representationalist view and with the cognitive-emotional process as stated. The AME mechanism is appropriate to tally with autonomy (auto-regulation) of a CSSA. One aspect to be explored is the insertion of high order emotions in the AME model. Finally, it is necessary to clarify what are the applications of the model proposed. If the behavior of the software system must be determined by the received external stimulus, the proposed model is not applied. Intelligent systems that have these characteristics are not applications of cognitive and situated agents.

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