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Emotions, Implicit Information that Allows the Conscious Phenomenon

Ana Lilia LAUREANO-CRUCES, Eduardo MIRANDA-ROCHIN, Javier RAMÍREZ-RODRÍGUEZ, Martha MORA-TORRES, Lourdes SÁNCHEZ-GUERRERO

Departamento de Sistemas
Universidad Autónoma Metropolitana – Azcapotzalco,
San Pablo 180, 02200 México D.F., MÉXICO
clc, jararo,mmt,lsg,{@azc.uam.mx}, e.miranda.rochin@gmail.com

Abstract: the field of distributed artificial intelligence makes a distinction between cognition and reactive multi-agent systems. Cognitive agents have a symbolic and explicit representation of their environment in which they can reason and from which they can make predictions. Cognitive agents are directed by intentions, that is, by specific objectives established in their behaviors. The above allows them to choose between possible actions. Emotions represent an important element on the *decision-making process*, since they have an adaptive value. This paper proposes an *action-selection mechanism* for *multi-agent reactive architecture*, which takes emotions into account in order to enrich the information with this perspective. Including emotions on this process involves the ability to choose from a range of behaviors according to what is desired, and being able to make the best decision according to the state of the environment *which implies a level of awareness about relevant environmental events and its potential consequences.* In the case of the study, we want to highlight the behavior of the individual within a society by involving, within a whole, the external motivations (environment) and internal motivations (emotions, cognition and needs); besides involving some random variables of genetic type such as: being more irritable or having a bigger size for confrontations. In this case we leave implicit the behavior previously implied in an animat within a society; where these behaviors are replicated with the only difference of the genetic characteristics and the dynamic events of the environment. The cognitive structure of emotions is used as the base for its representation, developing a *cognitive-affective structure* designed to model a *well-being behavior inspired in the behavior observed in a troop of chimpanzees*. The *cognitive-affective structure* of the chimpanzees is adapted within a reactive agent, based on motivations (emotions) and objectives (goals). To make that happen, a cognitive model is developed taking into account the *cognitive-affective structure's* context*, and the knowledge representation for the implementation made by the inference engine called fuzzy cognitive map.* The study shows the simulation of a small society of animats made up of individuals with relatively complex behaviors in a multi-agent system.

***Keywords*:** reactive agents, affective computing, multi-agent architecture, cognitive-affective structure, artificial consciousness.

1. Introduction

Distributed artificial intelligence began in the 70's but was formalized with its first congress in 1980. The greatest change is achieved by exhibiting coherent collective behavior in the solution of a problem, where there is no global perspective. Coherence is a global or regional property of the system; measured through the efficiency, clarity and quality of the global solution as well as the ability to solve the problem [1].

Understanding the process of evolution of a population is important from the point of view of ethology, and sociology among others [2]. Previous simulation works have been developed in different domains. For example, the work developed with economic models aims to know the capacity and evolution of these communities by varying the parameters related to economics, other simulations are focused on communication and learning processes, others to video games and their ability to react to other players and pattern recognition [3,4,5,6,7,8], among others.

Simulation is as much a design tool as it is an analytical device, which is used to experiment on a model [1]. What we want in a simulation is to artificially reproduce a phenomenon that can be described according to Ferber and Drogoul [9] by the following quintuplet of elements:

<system, model, representation, tool, evaluation procedure>

Where:

1) **The system** represents the natural system under study; *in this case is the behavior of a set of animats in a society, implying consciousness through emotions.*
2) **The model** is the abstract definition of the system according to the theory; *in the case of the study, it is represented by a multi-agent-reactive architecture.*
3) **Representation** is a function that maps the individual properties of the behavior to the properties of the environment; *we have an inference engine developed from a cognitive-affective structure; able to map the events of the environment.*
4) **Tool,** is the computational device; *Unity is used.*
5) **The evaluation procedure;** it is a methodology that evaluates the results and compares them with the real system. *The five axioms are considered to show that the phenomenon of artificial consciousness proposed by Igor Aleksander can be modeled.*

In the case of study we have these five elements that will be described throughout the text. Our objective is to create an affective-cognitive model that allows us to reproduce the phenomenon of consciousness, taking into consideration emotions as part of motivation.

To achieve this we have designed *the behavior of well-being* of an animat, inspired by the behavior of chimpanzees. The animats are represented through the behavior encapsulated in an agent. The behavior of the latter is programmed from birth to death. This simulation is based on the construction of a microworld. *Modeling the behavior of well-being considers the emotions by their relationship with the motivation of a behavior.*

It was not until the late 1990s that a new branch of research related to emotions (in the text we refer to emotions, as a synonym of affects, the latter being a cognitive representation of emotions) and called affective computing (AC) [10, 11]. And that marked the time when emotions acquired importance as part of various aspects of behavior, among them the *decision-making process* [12,17].

Affective computing is divided into two main areas: a) affectivity in the interaction between humans and computers, b) simulation or synthesis of emotions in machines. In the first area researchers are primarily interested in identifying the user's emotional state in order to generate an adaptive system that can respond to the user in some way even emotionally. Systems belonging to this area have the ability to recognize and express emotions [13, 14]. The study of emotions in the second area focuses on the simulation of emotions in the machines themselves trying to find out more about the emotions of living creatures [15,16].

As emotions are a crucially important aspect of human behavior, - due to the implicit information that entails; the idea of including them, in addition to the physical stimuli received from the dynamic environment is represented in a *cognitive-affective structure* of emotions derived from an internal interpretation of the same environment. This will be represented by an abstraction, which will be the sum of events that will combine to become an emergent behavior [16, 18, 19, 20, 21, 22, 23, 25, 24, 30]; reactive agents will form this abstraction.

Two of the effects of emotions on living creatures are: reorganization of the hierarchy of goals and focusing on aspects of their environment according to these goals. When a living creature experiences an emotion, its hierarchy of goals is restored by placing the most urgent first; the importance of a goal depends on the context of the individual and their previous experiences. On the other hand, focuses its attention on the environmental variables that are relevant to the fulfillment of that goal, the other aspects are discriminated [25, 26].

In the case of animals, we cannot know what they feel about a certain event because awareness of their environment is different from the point of view of humans [27]. Last being one of the problems when trying to read emotions in animals. But *is a fact that they have an impact on their decision-making process*. The latter related to: the needs, intentions and what they want. *In this paper, an attempt is made to represent these emotions and bind them to a specific behavior taking into account the interpretation of events in the environment, in accordance with internal goals (needs, intentions and desires). This abstraction is implemented using a multi-agent architecture* [28].

Based on the above, emotions are one of the most important sources of motivation that human beings have; when it comes to behavior. Hence the enormous influence they have over the decision-making process [16, 23, 26]. The study of motivation is related to the processes that give energy and direction to behavior [29]. Behavior energy represents the relationship among: strength, intensity and persistence. As for the direction, refers to behaviors (actions) are aimed to achieve a particular goal or a specific state intermediate during the persecution of the goal state [30]. So, emotions are an important aspect of human behavior, especially in the decision-making process [25].

Late 80's, multi-agent architectures were introduced [1, 9]. The contribution of this kind of architectures to simulate process is the ability to create abstractions of different behaviors encapsulated on software entities called *reactive agents* [31, 32]. These behaviors are proactive in the sense that constantly reviews the environment in order to act upon the submission of the necessary stimulus to generate intelligent behavior. Hence the importance of these architectures for artificial intelligence; it is a technique that allows the representation of knowledge that underlies the ability to generate reactive behavior. Petta and Trappl [33, 34], stress about emotions and agents, indicating that it is unlikely that the intelligent autonomous behavior of a system can be achieved without emotions. *Even more, emotional interpretation may be an evolutionary incentive to the development of more sophisticated cognitive abilities*.

Reactive agents are also known as agents based on behavior. Their main features are: 1) a constant interaction with the environment, and 2) a control mechanism allowing them to work with limited resources and incomplete information. The main advantage of the use of reactive agents lies on the speed of adaptation to unforeseen situations This advantage has a high cost, since reactive design leaves a great deal of deliberative tasks to the designer [7, 35, 36, 37, 38].

In the case of reactive agents their actions are completely determined by their immediate situation. This is a very important point for *decision-making processes* (the focus of our work) because we try to get into an inner mechanism that takes into account: the stimulus from the environment, and the internal objectives of the agent that come from its emotional state. So it is necessary to take into account the behaviors; because the actions are the only thing we can see to know that the behavior is effective and efficient.

Now in the case of a troop of chimpanzees this sets up a multi-agent system where the process of communication is through what happens in the environment (one of the ways to do message passing [39]), and then we have autonomous agents [40].

The ability to express emotional behavior and interpret its meaning in congeners has therefore played an important role in the evolution of an interactive and moralistic social system that is regulated as much by conciliatory tendencies as it is by dominance and aggression [41]. *On the other hand, having such a high degree of emotion management also involves a high degree of consciousness*. The highest levels of consciousness are ruled by emotions according to researchers as Aleksander [42] and Minsky [43]. So from this perspective, although we cannot know what they feel, we know that emotions are an important part in regulating their behavior in society, *therefore we infer that they have a high level of awareness in its micro-world*. In the conclusions section it is proposed a level of consciousness according to the five axioms of Aleksander to make clear that emotions are important to animals and humans.

This study combines two theories: the first is affective computing that tries the different emotions like a motivation source; that gives the direction to the behavioral analysis, as a means of finding the reactive elements of the environment in order to trigger different action; the second one is an *artificial intelligence knowledge representation,* called multi-agent architecture, and fuzzy cognitive maps; which allows the simulation of a society conformed by different agents into a dynamical environment; our study is based on the *emotional cognitive model* described in the work developed by Laureano-Cruces et al. [44], for the welfare of chimpanzees that inhabit, a community; with a *cognitive-affective structure* based on the OCC theory of emotions [45]. It is implemented by a multi-agent architecture, with reactive agents [47].

Taking the previous research as a premise; one of the pillars of the phenomenon of artificial consciousness are emotions. Based on the development of the previous investigation [44], where an inference engine is developed inspired by the behavior of a chimpanzee; now we develop the simulation of a society of several chimpanzees using this one; the foregoing in order to verify the importance of emotions within the phenomenon of artificial consciousness in a community.

In this context, our work is ordered as follows: section *two* gives an explanation of the cognitive structure of emotions, summarized in the OCC theory called in this way by its authors (Ortony, Clore and Collins), in order to understand how to develop a *cognitive-affective structure*, and describes the behavior of the study case (well-being), emphasizing the characteristics of this within the context of a social life. This is synthesized in the *cognitive-affective structure* and the behaviors that are part of it. Section *three* explains the mechanism for *behavior selection*. Based on a *bottom-up* design, which uses reactive agents. Making a link with the *cognitive-affective structure* developed in section *two*. An explanation is given of how emotions affect the interaction cycle between the *animat* and the environment. Section *four* explains the implementation model, considering the different behaviors and skills necessary to achieve them. These behaviors are encapsulated into an *animat* as part of a cycle that allows according to environmental events and emotions of the *animat* that one of them be released. It also explains the platform on which the simulation was developed; explaining according to *object oriented programming the classes* that were developed in the implementation. Section *five*, describes the different behaviors taking into account: *conditions* (environment events), *motivations* (emotions internal state), and *the results in the environment* (refers to the perceptions that are added or deleted once the behavior is developed), according with the model developed in section *two* and *three*. Section *six*, shows and explains some examples of the simulation. Section *seven* outlines the conclusions of this work. The main objective is to propose an interaction mechanism that allows a *decision-making process* which are included the emotions and physical stimuli from the environment. Include emotions as part of the information to decide between ranges of behaviors implies a greater awareness of the environment. From this perspective has been taken as the axis the *five axioms* of Igor Aleksander [42] to infer the simulation model evaluation.

2. Affective-cognitive structure and The OCC Model

In this section we discuss the first and third element of a simulation model. Our research was conducted using the OCC theory; which establishes a computer model for its treatment and application of a cognitive influence in emotion. A cognitive influence can be considered when involve: appraisal, comparison, categorization, inference, attribution, or judgment.

The OCC theory [45] proposes a *general model*, which postulates the existence of three main classes of emotions, resulting from a focus on each of the three fundamental facets of the world:

i. Events and their consequences
ii. Agents and their actions
iii. Pure and simple objects

For this purpose, it establishes as evaluation criteria:

i. Goals to evaluate events.
ii. Norms to evaluate the action of agents.
iii. Attitudes to evaluate objects.

The three main classes of emotions postulated are:

i. Emotions based on events: goals related to events are specified.
ii. Emotions of attribution: responsibility is attributed to agents for their actions as a function of norms.
iii. Emotions of attraction: based on attitudes in relation to objects.

The intensity of emotions can be affected by what are known as local variables (desirability, plausibility, and the ability to attract) and global variables (proximity, sense of reality, arousal, and unexpectedness). Thus, the cognitive interpretation of emotions is also modified.

Through these variables, we get the emotions linked to these classes of emotions, in a specific context. OCC theory proposes a hierarchical structure *(cognitive-affective structure)* composed of a higher goal (general) and sub-goals called instrumental goals (more specific). These goals are related to each other with links defined as: necessary, sufficient, facilitators, or inhibitors. The goals are of different kinds: a) active persecution (AG), one wants to get done; b) interest (IG), one wants to happen, and c) filler (FG) that are cyclical, reason why even when they are done, they are not abandoned.

The case study considers 1) events, that take into account the goals and their consequences; and 2) the emotions based on attribution, that take into account the plausibility of the action from an agent. The OCC theory gives a local variable to measure each kind of emotion, in the first case the desirability and in the second the plausibility [39].

Cognitive affective structure (CAS), born from the OCC theory [45], shows the relation among agents, objects and environment taken into account emotions; each *animat* feels emotions, as a consequence of its interaction with the environment and its goals. All the goals are associated to a variable, which can be either: *proximity or desirability*. Achieving the lowest-level goals (walk, move, perceive) allows the animat to grow on its society and achieve higher-ranked goals (feed, explore, fight), until it reaches the maximum goal: welfare [48,49].

According to Igor Alexander [42], a consciousness is the ability of human beings of perceiving the world and gives it a meaning through representations of it, in his inner world. For everything that exists in the external world exists an internal representation and the individual throughout their life creates these representations, and they involve accumulating experience from birth. In order to achieve it, must be able to place yourself in the outside world by: 1) the imagination, 2) paying attention to important events, 3) planning ahead, 4) feeling emotions about what can happen.

We are unable to know what animals feel; it is a fact that they have emotions (gorillas and chimpanzees). In the case of primates these are similar to those of humans [50]. The experience and education of human beings involve different ways of feeling and therefore to associate different emotions. If we apply this principle to primates, then their feelings will be different from ours. Over the five axioms proposed by Aleksander [42] could be inferred the level of consciousness and this would imply different experiences.

The emotions have and adaptive value, for example: what is the point of being able to react to the presence of a predator with a body state of fear (deep breath, high blood pressure, blood flowing to: muscles, heart and brain, a surveillance state). In this case there is a body preparing for struggle or flight. So the beauty of the emotional response system, over and an instinctual one, is that it is not strictly predetermined [24]. There are neurological and psychological changes that can be very fast and look like reflexes. But the behavior chosen from a repertoire varies according to the situation and experience. In other words, *is elected an intelligent response appropriate to the situation*. So, the variability in response is important in relation to the question about the usefulness of the concept of emotion in behavioral analysis [12, 23, 26].

Emotional contagion is able to put in tune the behavior of individuals within a society, to an alarm call, in order to hide or flee. Emotional contagion in a primate society involves the emotion of empathy that is essential part for consistent behavior in groups. Empathy lets you know what they are feeling the other members of society and based on this feeling able to take some action. More complex forms of empathy imply the ability to approach the matter from another point of view (the agent concerned). This kind of empathy can provide comfort and support, depending on the event.

In the case of mood contagion serves to coordinate activities, which is crucial for any traveling species (as most primates are). If my companions are feeding, I'd better do the same, because once they move off, my chance to forage will be gone. The individual who doesn't stay in tune with what everyone else is doing will lose out like the traveler who doesn't go to the restroom when the bus has stopped [51,52].

Considering the importance of the characteristics described above relating to the emotions, and being these triggers of behavior in society, is developed a *cognitive-affective structure* of a community of animates, being the limited context the *welfare of a chimpanzee*.

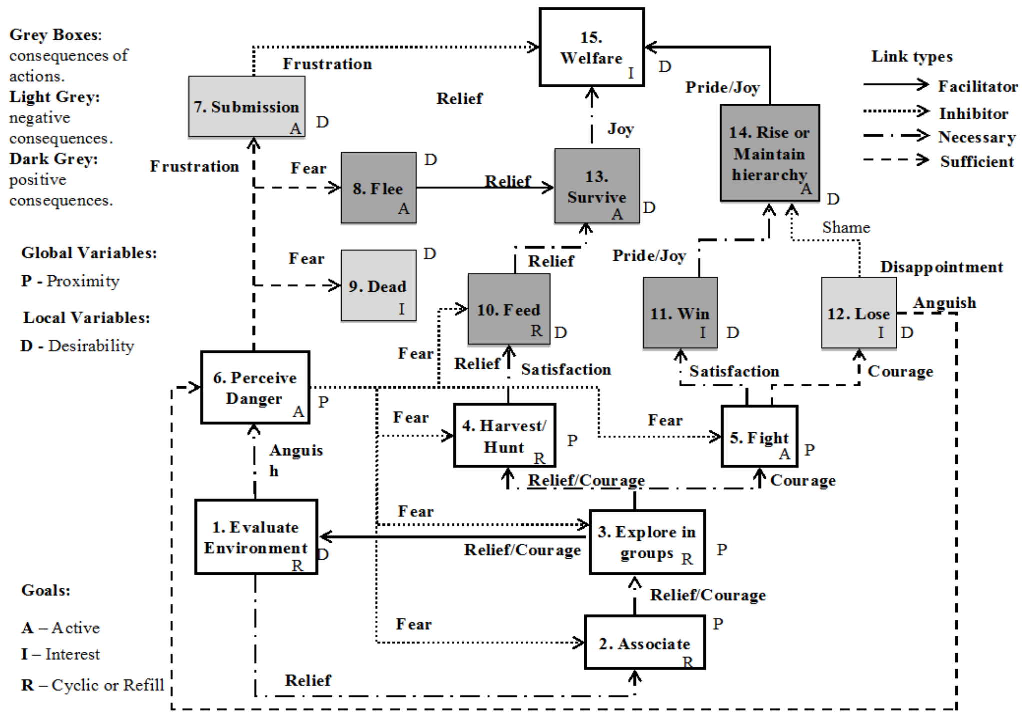

Figure 1. Chimpanzee cognitive-affective structure of the welfare [44]

The *cognitive-affective structure* is developed taken as basis the OCC theory. An agent represents each chimpanzee, that is, each agent will be represented by encapsulating behavior and according to our context refers to the behavior of *welfare*. A society is made up of several elements; in the specific case of this simulation twenty *chimpanzee-agents* form the troop. Agents act by pursuing goals in accordance with a *cognitive-affective structure* where specific goals are identified. In turn, sub-behaviors are created to accomplish those goals [23]. On the other hand is considered to achieve any goal or not, it will generate some kind of emotion. On achieving a goal other motivations may be formed that imply other goals, giving rise to the generation of emergent behaviors [6, 54].

Chimpanzees live in hierarchical societies, which are not static, so any chimpanzee is able to move between hierarchies, by challenging the dominant male. This challenge can result in a forward or backwards. Chimpanzees find attractive to climb in the hierarchy, because a better position ensures a *higher being* (better food, more subordinate females). The chimpanzee behavior is of course much more complex, but climbing hierarchy is one of his greatest motivations, so it was considered a general behavior model based on this motivation (*well-being*). In correlation with the goals, are dimensioned emotions that are related to the achievement of each of the sub-goals to be undertaken to ensure their promotion.

In order to design the *cognitive-affective structure*, were developed a set of *mental models* involved in the principal behavior *welfare* [44]. Our simulation is based on the *cognitive-affective structure* evaluation obtained in Laureano-Cruces et al. [44]; used the methodology developed in Laureano-Cruces et al. [53] and whose finally representation is showed in Figure 1.

The structure possesses *fifteen mental models* that constituted the characteristics of the global behavior, in this case the *mental models* proposed associated to its emotions and the variable proposes according to *OCC theory* are showing in Table 1.

Table 1. Behavior and affects/motivations

Behavior	Affects/Motivations	Local/ Global-Variable
1. Assess environment	Relief-anguish	Proximity
2. Associate	Courage-fear, Relief-anguish	Proximity
3. Explore in Groups	Courage-fear, Relief-anguish	Proximity
4. Gather / Hunt	Satisfaction-frustration, Courage-fear, Relief-anguish	Proximity
5. Fight	Satisfaction-frustration, Courage-fear	Proximity
6. Perceive Danger	Satisfaction-frustration, Courage-fear	Desirability
7.Submit	Satisfaction-frustration	Desirability
8. Flee	Courage-fear	Desirability
9. Die	-	Desirability
10.Feed	Satisfaction-frustration, Relief-anguish	Desirability
11. Win	Joy-anger, Satisfaction-frustration, Pride-shame, Relief-anguish	Desirability
12. Lose	Joy-anger, Satisfaction-frustration, Pride-shame, Relief-anguish	Desirability
13.Survive	Joy-anger, Relief-anguish	Desirability
14. Raise or Maintain Hierarchy	Joy-anger, Pride-shame	Desirability
15. Welfare	Joy-anger	Desirability

The goals are related to emotions through a cognitive–affective structure (Figure 1). In order to satisfy these emotions that are the principal motivation of the behavior and accomplish the proposed goal, the following *skills* are needed: *walk alone and with the troop, see, hear, grasp objects, eat, throw objects and capacity to associate*. With these skills we can define more complex *behaviors* like: *hunt, gather, flee, fight, feed and evaluate the environment*.

Emotions can be classified basically into three types: 1) *primary and fast emotions*, refer to the emotions experienced before they arrive at the cortex and that feel before have awareness of what is happening. Sometimes we behave according to an emotion before you know you have it. Animals have these instinctive reactions, especially to events that can be dangerous. These reactions are not always successful; tend to err in favor of survival, 2) *cognitively generated emotions*, deal with the emotions generated by reasoning cortex, they may emerge slowly as a result of our thoughts, 3) *perceived emotions*, is the recognition of one's emotional state, they are intimately related to consciousness since being able to detect a sense of consciously implies a greater capacity to act and thus creates an extreme flexibility in future decisions and behaviors.

According to Tagliasco [55], one of the principles of consciousness is, in order to achieve this, *experience is needed* and this in turn requires *the ability to pay attention*, which in turn requires *a stimulus*. In this way the human being builds up experience with respect to different processes, which make learn.

Awareness is important because it implies the ability to deal with the world in the broadest sense (with all that is in it), hence this process is related to the capacities of: 1) move in the world, 2) act in the world, 3) remember what I can do for me, 4) the best I can control events, 5) get what I want. And this is transformed into experience and learning.

Experience is one of the qualities of living creatures most appreciated; provides living creatures of consciousness in different contexts. This allows them to avoid unwanted future states taking into account important elements in dangerous activities or decision-making processes due to the number of variables to be considered. For example, a robot-driver could be more aware and careful as a human in the same activity, because it could give the feeling of fear and the ability to recognize their own emotional state [16]. But the best and be the main objective is: *be capable of dissect consciousness gives us the opportunity to understand and not forget that this is one of the major goals of artificial intelligence* [56].

Cognitive-affective structure (Figure 1) allows us to generate the emotions on a limited context. This structure reflects the *cognitive emotions*, considering learning within the context of *well-being* for a *chimpanzee*. In our simulation these are represented as *perceived emotions*. That is, when the *chimpanzee* has to deal with its *micro-world*, need to know: what will happen and what can be done. *This implies that we allow being aware of their emotions*.

3. Mechanism for behavior selection

In this section we discuss the third element of the simulation model. With this in mind, we turn our interest to the study conducted by Laureano-Cruces et al. [44]. Using this mechanism we get a spectrum of possible scenarios within the environment; once we have a possible outcome, it is necessary to do a review of the dynamic events on the environment that will match any actions of the *chimpanzee-agent*; this way, the former will provoke the trigger of an action. On the other hand, the distributed artificial intelligence (DAI) decentralizes the control process; which brings us to the autonomous agents [1, 9]. These agents are specialists that cooperate between each other, opposed to the general control systems. Summarizing, these architectures aim to achieve an implicit mechanism selection, i.e. that the action became an emergent property of a dynamic process. In this kind of architectures, the system control schemes will emerge on a distributed way, based on local interactions between a set of simple modules [3, 6, 36]. In Laureano-Cruces [44], mental models to achieve the cognitive affective structure were developed (Figure 1) to help the construction of the causal matrix; represented in a cognitive fuzzy map. Last is the inference engine that gives multiple possible scenarios, which makes it necessary to check the environment events that could drive to a specific action. With the purpose of finding the ultimate action, a *set of rules that allow the interaction of the troop itself and the environment were developed*. Further details will be given next. *From now and on we call animat to the chimpanzee-agent.*

3.1. Animat

chimpanzee-agent

a) *Animats* are aged somewhere between 1 and 60 years at the beginning of the simulation.
b) *Animats'* personality can be rebellious or submissive.
c) *Animats* have hunger and energy levels. They will look for food when their hunger level surpasses a stablished threshold; when its energy level drops below a stablished threshold, it will stop moving and start resting.
d) Each *animat* is born with strength, which will help it impose over other *animats* during a fight.
e) Each *animat* is born with speed, which will help it move faster or slower than other *animats.*
f) No *animat* will be part of a herd or food-searching group by the beginning of the simulation.
g) Each *animat* will have a hierarchy: Alpha, Beta and Gamma.
h) *Animats* can climb and, in some cases, lower hierarchy (when losing a fight or submitting).
i) An *animat* is considered to be mature at age 30.

3.2. Troop

a) All troops have an alpha leader; there cannot be more than one alpha on a troop.
b) A troop is formed when two *animats* associate. This can happen on two scenarios:
    a. One *animat* is *alpha* and the other is from a lower hierarchy. In this case, the *alpha* becomes the troop leader.
    b. None of the *animats* are *alpha*. If both are on the same hierarchy, they fight and the winner becomes the troop leader, climbing to *alpha* hierarchy.
    c. Note: If both *animats* are *alpha* the troop cannot be formed.
c) Each troop has a random number of beta slots. The number of slots ranges between 2 and 5.
d) *Animats* within a troop can fight each other in order to climb hierarchy, one at a time.
e) *Alpha animats* cannot join a troop, they must form one.
f) *Beta animats* can join a troop if there is a slot available.
g) *Gamma animats* can always join a troop.
h) Troop members will always follow the leader except for certain circumstances described later.
i) Troop leader will move independently.

j) If a *Gamma animat* fights a *beta animat* and wins, a new *beta* slot will be created for it to occupy. If the *beta animat* wins there will not be changes.
k) If a *beta animat* fights an *alpha animat* and wins, the winning *beta* will become the troop leader and the *alpha* will submit if submissive, or die if rebellious.
l) When an *animat* dies of a predator doing: if it was *beta* hierarchy, a *beta* slot will open at the troop; if it was the troop leader, the strongest highest hierarchy *animat* will become the leader.

3.3. Group

a) The groups' objective is to look for food.
b) Groups are formed by members of the same troop.
c) Every group has a leader; it can be from any hierarchy but it must be the highest hierarchy member. If there are two *animats* of the same hierarchy, the leader will be the strongest one.
d) A group is formed when two or more *animats* want to eat, and they have to look for food.
e) Every member of the troop can join the group.
f) If a higher hierarchy or stronger *animat* joins the group, it will become the leader.
g) Group members will follow the group leader.
h) The group leader moves independently.
i) If the leader dies, the next higher ranked or stronger *animat* will become leader.
j) If a group member spots food, the group will follow it.
k) If a group member finds food, every member of the group will be benefited.
l) When an *animat* stops being hungry or flees, it leaves the group.

3.4. Food

Food spawns randomly in time and space within the environment. The energy from food depends of its size.

3.5. Predators

a) Predators spawn at determined locations within the environment.
b) Predators die when stepping outside the environment boundaries.
c) Predators will always chase the last *animat* entering their field of view.
d) If a predator touches an animat, it will die.

The development of cognitive-affective structure of Figure 1, was developed taking into account two aspects of OCC theory: a) *emotions based on events:* goals related to events are specified, and b) *attribution of emotions:* responsibility is attributed to their agents (in this case *animat*) for actions as a function of norms. In *the first case*, this structure has emotions associated *with the objectives*. This implies that the *animat* will feel an emotion according to events that occur in the environment. The *cognitive-affective structure* is formed in such way that allows knowing the secondary objectives necessary to meet the objectives of the highest level, in this way getting the main objective, which in the *study case is the well-being*. In this case the *local variable is the desirability*.

In the *second case* the same Figure 1, has the behaviors necessary to achieve a limited and proper behavior within a troop of chimpanzees. In this case the *local variable is the emotion caused by an attribution*. This refers to the emotion that causes responsibility for an action that is attributed to an *animat*; the *animat* may be the same self.

According with the cognitive-affective structure of Figure 1, predecessor behaviors are at below level from the behavior in progress as long your links are facilitators and not inhibitors; these behaviors are represented by the instrumental goals. Last are necessary to achieve the higher goal (Theory OCC, Section 2). As an example, if the goal eats is active; based on *hunger* motivation. The instrumental goals are: *hunt or gather* (Figure 1).

In the case of successor behaviors, they are represented by the behaviors that are consequence of the behavior in progress and they are active goals. As an example, and given a continuity to the last example (about the predecessor behaviors). If the active goal is *hunt or gather*, the successor behavior is *feed* (Figure 1).

In the case of behavior that conflicts with another, it referees to behaviors where are involves inhibitors links. As an example, in the case of the goal *ascend hierarchy*, an inhibitor link corresponds to the *lose consequence* (Figure 1).

The meant in link cases are: 1) *necessary link:* would be one that comes from the *win* goal up to the *ascend of hierarchy* goal, 2) *facilitator link:* would be one that comes from the *associate* goal up to the *gather, hunt or fight* goal, 3) *sufficient link:* would be one that comes from the *perceive danger* goal up to the *flee* goal, 4) *inhibitors link:* would be one that comes from the *submission* goal up to the *wellbeing*.

3.6 Mechanism for behavior selection in the emotional cognitive model for representation of hierarchical ascension in chimpanzees

A *mapping* is proposed between the emotional cognitive model and the behavior selection mechanism; which is represented in causal matrix product of the affective-cognitive structure [44]. This mapping seems natural as the selection mechanism uses goals and behaviors, which have already been defined taking into account the OCC Theory [25, 57].

As the guiding mechanism, we use the proposal postulated by Acevedo-Moreno [18, 19, 46]. It consists in a cycle of interaction, shown in Figure 2, which can be summarized as follows:

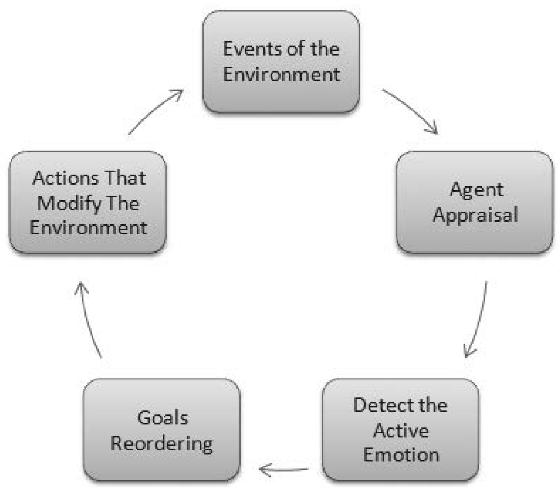

Figure 2. Cycle of Emotive Architecture

a) Events produced at the environment are interpreted, by the reactive agents (*animat*). The last ones make an evaluation based on desirability or social hierarchy, which produces increases in the intensity of the emotion. If this occurs, it causes a reorganization of the hierarchy of goals (Figure 2), and consequently a *review of the current behavior*. Behavior translates into actions that affect the environment producing changes that will eventually produce an event.
b) Each *animat* has a set of goals; to a greater or lesser extent, those goals are equivalent to behaviors in the emotional cognitive model: *hunt, gather, flee, fight, feed, evaluate the environment* and *ability to associate*.
c) Each behavior is made up of a set of simple *skills* like: *walk alone and with the troop, see, hear, grasp objects, eat and throw objects.*
d) In addition *to motivations, which are equivalent to emotions*, there is a set of cognitive goals.
e) There are individual characteristics inherent to each *animat*. The following model considers only *strength, intelligence and mood*; those conditions determine the chance of success in actions of hunting and fighting. We raise the possibility that the degree of increase or intensity in emotions also depends on this kind of factors; the relationship between these subjects is a subject for future investigations.

4. Implementation of the model

In this section we discuss the third and fourth elements of the simulation model We propose the following behaviors; based on the behaviors proposed by Laureano-Cruces [44]: *hunt, gather, flee, fight, associate, and evaluate the environment* and, the following activities are proposed as means of achieving them: *walk, see, hear, grasp objects and eat*.

Each behavior will execute a set of activities and is represented in the network of autonomous *agents* by an *animat* that *constantly perceives the environment*, in order to define its possible execution (Figure 1).

Table 2. Causal matrix of the autonomous behavior of the *animat*; represented by a fuzzy cognitive map where the number 1 implies positive relations and -1 negative relations

	Welfare	Submit	Flee	Survive	Raise Hierarchy	Perceive Danger	Feed	Win	Fight	Joy	Satisfaction	Courage	Pride	Relief
Welfare	0	-1	-1	1	1	-1	1	1	0	1	1	0	1	0
Submit	-1	0	-1	0	-1	0	-1	-1	1	-1	-1	0	-1	0
Flee	-1	-1	0	1	0	1	-1	0	-1	-1	-1	0	0	0
Survive	0	-1	1	0	0	1	1	0	0	0	0	0	0	0
Raise Hierarchy	1	-1	0	0	0	0	0	1	1	1	1	1	1	0
Perceive Danger	-1	0	1	1	0	0	-1	0	-1	-1	0	1	0	0
Feed	0	0	-1	1	0	-1	0	0	0	0	1	0	0	1
Win	1	-1	0	0	1	0	0	0	1	1	1	0	1	1
Fight	0	0.5	0	0	0.5	0	0	0.5	0	0	0	1	0	0
Joy	1	-1	-1	0	1	-1	0	1	0	0	1	1	1	0
Satisfaction	1	-1	-1	0	1	-1	1	1	0	0	0	1	1	1
Courage	1	-1	0	0	0	0	0	1	1	0	1	0	1	0
Pride	1	-1	0	0	1	0	0	1	1	1	1	0	0	0
Relief	1	-1	-1	0	1	-1	1	1	0	0	1	0	0	0

The *animat*s in the simulation are autonomous agents, each of which has the following *emotions*, which in the mapping are represented *by the motivations*: *happiness–anger, satisfaction–frustration, courage–fear, pride–shame, relief–disappointment and anguish–joy*.

Table 2, shows the *causal matrix that represents the autonomous behavior of each animat*. That causal matrix is made up by a series of behaviors related by links that determine an action at a given time (Figure 2). The causal matrix will be feed by the environmental conditions and internal motivations in this case are emotions of the *animat*; in other words the causal relation to each behavior (Figure 2) will be a function of the environment (physical stimuli) and motivations; these relations could be negative or positive [44].

Remarking, -if we consider that emotions are the guardian of actions; using this type of inference engine (fuzzy cognitive maps) that is able to process the information in a parallel and distributed way at a given time, we imply which is the possible state of the world at the next moment and in this way, the action that impact less negatively on the being-well of the agent-chimpanzee is chosen. For more details consult [44].

The simulation was developed using *Unity* 5, a modern game engine with support for multi-agent systems. Unity provides a *context*, that is, a data structure that contains the agents and their environment; so global variables are stored in a given context and state variables in the agent. At the same time, each agent consists of a group of behaviors to interact with the environment; an agent could also include a context of other agents, which allows a great degree of flexibility and control [58].

In this case the environment consists of a field where the agents move and associate (Figure 3). The field contains food resources which are treated as objects. These resource agents appear on random locations and disappear when consumed by the *animat*. The quantity of these agents and its spawn rate depends on the simulation configuration.

The *animat* represents a member of the troop; this agent has internal variables corresponding to the simulation parameters and a list of motivations.

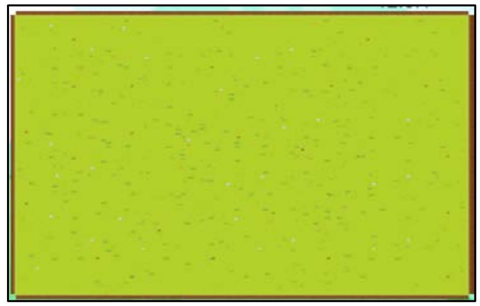

Figure 3. A field where the agents move and associate

The behaviors are interdependent *animats* working in conjunction inference engine. Each *animat* possesses internal representation of the possible actions. When a behavior reaches the point of activation, it's action list is executed by the *animat*, in this way the *animat* interacts with the environment and feeds the behavior vector with its environment information through methods and implementation of interfaces, a common technique in object oriented programming.

From the programming point of view, each *animat* agent was programmed using the Model-View-Controller (MVC) architecture pattern, splitting its implementation on a view: the *animat* interface with the environment, resources, predators, and other *animats*; model: a representation of the animat with its properties (age, personality, hierarchy, energy, among others), and; controller: where the mental models and the behavior selecting mechanism is implemented. The controller goes between the animat view and the animat model, acting as the brain of the *animat*. This architecture is presented on Figure 4.

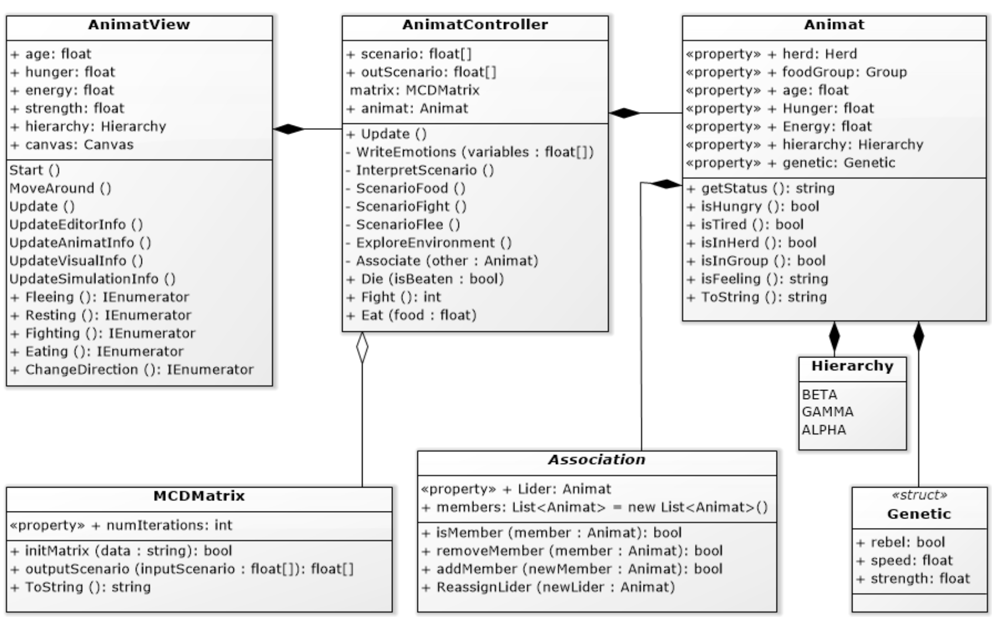

Figure 4. Animat agent anatomy

In addition of the property of "hierarchy" within the *animat* model class, each *animat* has a different color depending of its hierarchy. *Alpha animats* are gray, while *Betas* are red and *Gammas* brown.

5. Behaviors implemented

This section describes the different *behaviors* taking into account: *conditions*, *motivations*, and the behavior *results*. Last is the form of communication between agents/modules [39].

5.1. Evaluate Environment:

This *animat* behavior includes the following *skills*: *see, hear and walk alone and in-group* in order to evaluate the environment.

Conditions: without environmental conditions, activation appears only in response to *animat* motivations.

Motivations: *Well-Being*, the *animat* seeks top goal of *well-being*, for which it needs to find other *animats* with whom to *associate to: gather, hunt or fight.*

Results in the environment:
Add the following perceptions:

a) Animat_Close: it refers to answer the question, if it detects an *animat* in the field of vision.
b) Food_Close: it refers to answer the question, if it detects food in the field of vision.

5.2. Associate:

In this behavior the *animat* requests an alliance to: *gather, hunt or fight*. Last one, if it encounters an *animat* of equal or higher hierarchy.

Conditions:

a) Animat_Close: it refers to answer the question if it detects an *animat* in the field of vision.
b) Not_Part_Of_Group, if the *animat* is not presently associated with another *animat*.

Motivations: *Well-Being*: pursuit of well-being, relief, courage

Results:

Add the following perceptions:

a) Part_Of_Group: it refers to answer the question if it detects an *animat* in the field of vision and if it encounters an *animat*, it can send an alliance request.

Eliminate the following perceptions:

a) Not_Part_Of_Group: if the *animat* is not presently associated with another animat.

5.3. Explore In Group:

Once associated, the *animat* looks for an *animat* with whom to fight or hunt/gather food. If it is not the group leader, it will follow the leader. This behavior is necessary so that the other activities can be given.

Conditions:

a) Part_Of_Group: it refers to answer the question if the *animat* is currently in a group

Motivations:

a) Relief

b) Satisfaction

Results:

a) *Add* the following perceptions:
b) Animat_Close: it refers to answer the question if it detects an *animat* in the field of vision.
c) Food_Close: it refers to answer the question if it detects food in the field of vision.
d) Animat_Of_Higher_Hierarchy: it refers to answer the question if it detects an animat of higher hierarchy in the field of vision.
e) Predator_Close: it refers to answer the question if a predator is within the field of vision.

5.4. Gather/Hunter

Gathering is a group activity that previously required the ability to associate. In this case the ultimate goal is find food.

Conditions:

a) Part_Of_Group: it refers to answer the question if it detects an *animat* in the field of vision.
b) Food_Close: it refers to answer the question if it detects food in the field of vision.

Motivations:

a) Relief.
b) Satisfaction.
c) Courage.

Results:

Add the following perceptions:

a) Part_Of_Group: it refers to answer the question if it detects an animat in the field of vision.
b) Get_Food: it refers to ansewer the question if it can get the food.

Eliminate the following perceptions:

a) Food_Close: it refers to answer the question if it detects food in the field of vision.

5.5. Fight

Fight is a group activity that previously required the ability to associate. In this case the goal is to try to climb the level of hierarchy.

Conditions:

a) Part_Of_Group: it refers to answer the question if it detects an animat in the field of vision.
b) Animat_Of_Higher_Hierarchy: it refers to answer the question if it detects an animat of higher hierarchy in the field of vision.

Motivations:

a) Fearlessness.
b) Courage

Results:

Add the following perceptions:

a) Fight: the animat fights another higher-hierarchy *animat*, if it wins the animat ascends in hierarchy

Eliminate the following perceptions:

a) Animat_Of_Higher_Hierarchy: it refers to answer the question if it detects an *animat* of higher hierarchy in the field of vision.
b) Part_Of_Group: it refers to answer the question if it detects an *animat* in the field of vision

5.6. Perceive Danger

The *animat*: 1) if it fights an *animat* and loses, 2) if it encounters a predator.

Conditions:

a) *Animat*_Of_Higher_Hierarchy: it refers to answer the question if it detects an *animat* of higher hierarchy in the field of vision.
b) Predator_Close: it refers to answer the question if a predator is within the field of vision.
c) Lose

Motivations:

a) Fear
b) Frustration

Results:

Eliminate the following perceptions:

a) Submit.
b) Flee.
c) Die.

6. Examples of the simulation

The simulations considered populations of thirty-five *animats*, trying to simulate real troops. We spread the initial population randomly and placed some food sources also randomly. Figure 5, shows the initial environment of the simulation.

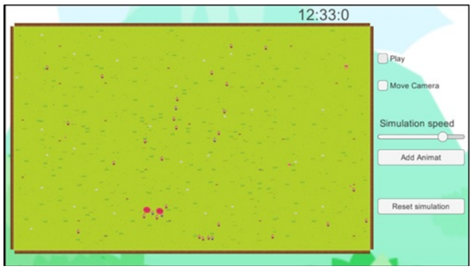

Figure 5. The initial environment of the simulation

Figure 6. New troop creation

Figure 7. Creation of a food gathering group

The *animats* groups search for food, following their leaders. In Figure 6, a group food is following an *Alpha*, which were both, the herd and the food-searching leader. In other parts of the environment are other herds, groups, and *animats* moving alone (Figure 7). Whenever a member of a group found food, all the group was benefited (Figure 8, Figure 9).

Figure 10. *Animat* group searching for food

Figure 11. *Animat* group eating

Fights were normal between group members (Figure 12); *animats* in a mature age try to climb hierarchy in order to achieve welfare. Higher hierarchy *animats* are more likely to win, since they are normally stronger (Figure11).

Figure 12. Alfa and Beta animats fighting

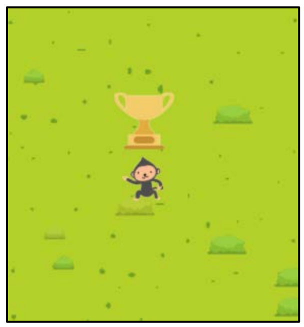

Figure 13. Alfa animat after winning a fight

One of the most important benefits of the troop is that members protect each other warning themselves about predators on the environment. If a member of the herd spots a predator, it warns the others, and they flee; this action increases their survival chances (Figure 13).

Figure 13. Group of animats running away from a predator

7. Evaluation of the model

In this section we discuss the fifth element of the simulation model. Simulation is a powerful tool that allows us to obtain results fairly close to reality, without the inconveniences from practical experimentation; e.g. flight simulations are cheaper and much safer for practice if compared to real flight time.

It is designed a reactive behavior taking into account two information sources: 1) the affective that is intrinsic; and come from an internal vision of the world and, 2) the physical environment. And considering them implies contemplating a different perspective on *decision-making process* [59].

This work makes a contribution to the implementation of perceived emotions in order to be considered in *decision-making process*, emphasizing the phase that allows creating awareness through *perceived emotions* and last in a limited context, within the behavioral *well-being*.

Igor Aleksander [42] proposed five axioms to determine the degree of consciousness of a living creature. Based on the recreation of the behavior of agent-chimpanzees and doing an analysis of these axioms, we infer the following results:

Axiom 1. I feel that I am part of, but separate from an ‘out there’ world.

In the case of an *agent-chimpanzee*, its experience is that lives and moves in a micro-world. This world has static and dynamic properties, and this is reflected in the experience of walking. As a living creature must understand that is part of that world and its rules. When walking, moving about the world, and its action or inaction has an impact on the world: the branches lying on the forest floor can break and generate sounds depending on the choice of walking on them or not. Since it is a separate part of the world can voluntarily choose if it walks on the branches and broken or simply take another route to avoid them.

The focus of this axiom is the ability to internalize the external world. It is a pivot from which everything else depends. In this study case the *agent-chimpanzee* behavior includes the following *skills*: *see, hear, and walk* in order to *evaluate the environment* (Figure 3).

Axiom 2. My experience of the world out there.

Apparently the researchers who study animal behavior are clear that they have memories and emotions attached. Then transcribing a segment of Waal [51].

The mother of a dead baby baboon can spend days, even weeks, in behavior patterns resembling grief. The mother’s appetite wanes, and she searches familiar haunts for her baby. Eventual, however, her life returns to normal. She socializes, has more babies, and behaves like any other healthy, female baboon.

This type of situation records that they have memories that keep them as experiences in the world. And even closing her eyes the memory continues.

In this context we can identify different experiences by several goals and the preference according to the emotional level (Figure 1).

Axiom 3. Out to get experience

In the case of *agent-chimpanzee*, they learn by imitating and paying attention to the gestures of adults. Learning focuses on social closeness, the connections through body language and the desire to behave like the others. There is widespread evidence that apes learn more from to see another monkey developing certain action, and do not have the same effect hundreds of demonstrations of the same action dispossessed of body [52].

In this context it is identified that they are able to focus and get specific experiences. For now the experience is expressed within the designed behavior in *cognitive-affective structure* and the precive emotions (Figure 1).

Axiom 4. Thinking ahead

Constantly is thinking forward considering alternatives and deciding which will be chosen. The goal is to ensure that exist specific brain areas that are capable of learning descriptive sequences as part of the construction of experience. And these in turn become descriptive sequences of states. This means being able to think forward from a given state and let them run some descriptive sequences.

In the case of *agent-chimpanzee*, there is evidence of learning, they are able to have a repertoire of skills that leads them to develop more sophisticated behaviors. In the study case, sophisticated behaviors are represented in the *cognitive-affective* structure (Figure 1).

Now what happens in the case where there are several alternatives, what makes you want to run a particular plan. This leads to the following axiom.

Axiom 5. Emotions-the guardians of thought

Is unlikely to achieve a simulation of consciousness without emotion. Here we talked about the three types of emotions, being that we learn through experience that allow us to feel and somehow makes us aware to what we want at any given time.

In the case of chimpanceez has made it clear that they have learned behaviors and they make them feel certain emotions (Figure 1). In this context the chimpanzee have emotions that allow them to select what they want and get away from that which gives pain.

For the time being the *agent-chimpanzee* considers only the environment and motivations in the simulation. The structure of goals is dynamic [18, 19, 20, 21, 46] and, as mentioned in *section two*, we have different types of goals. This structure is hierarchical and dynamic, and allows planning and implementation of goals of higher hierarchy through other goals of lower hierarchy.

We created a simulation to include emotions in the *action-selection process* and therefore we have provided the *animat* of the sense of being in an environment. According to the evidence of these five axioms we believe that animats are aware, in their micro-worlds and have a range of emotions that make them aware of this environment.

We are convinced that emotions are very important and in this virtual laboratory can test many theories of *living creatures* and gradually creating theory of *consciousness and emotions*. In such a way that allows them to be considered during the decision-making process. The simulation on this investigation presents an effort to contribute to the artificial consciousness, ethology and cognitive psychology fields of studies [60].

The ability to visualize animal behavior on a controlled and dynamic environment becomes greatly useful to predict their behavior. The results obtained through this kind of simulations are precise and reliable, as they take into consideration all of the internal motivations (personality and emotions), as well as others physiological factors (strength and size, among others).

This type of tools could have an immediate application: working with endangered species, for example, would allow us to analyze their behaviors, ways of social interactions and their relationship with their surroundings, which, along with cognitive ethology would help us establish the most suitable protection measures and wildlife reinsertion plans.

8. Conclusions

We understand that the mechanism proposed in this work is not the same mechanism that produces a physical mechanism in the body. Within cognitive science, we are trying to understand how the mind works, in fact, cognitive science has been developing a lot of empirical methods that synchronize observation (ethology) and use studies of: human studies, animals and cases of patients with brain damage. The cognitive sciences are interested in using modeling to advance knowledge of cognition and obtain greater precision in computer implementations.

We do not know when an action comes from a behavior designed within the emotions, in fact, just by looking, the action will not know, but it is expected that having more information; that action could be more precise, in other words, with a more rational (more emphatic) level. The last one leads to a great anthropoform.

However, we propose a means to quantify emotions, associated with a *cognitive-affective structure in conjunction with a multi-agent architecture* (which is our proposed model). The model presented describes variables and procedures that are useful for synthesizing emotions. For the moment, we have created an architecture that allows us to consider emotions in reactive behavior. And perhaps the most important thing is transposition.

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