Interaction Modeling with Artificial Life Agents

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Abstract. In this work, an interaction model between artificial life agents (creatures) is proposed, which allows studying emergent social behavior of agents. This model describes the environment of artificial life and autonomous creatures in terms of goal-states, rules of behavior based on agents' goals and actions, initial knowledge and the use of communication instructions. For the case of study, the technology and environment of Creatures Labs are used to implement artificial life agents based on the proposed model.

1 Introduction

The goal to construct autonomous agents has been explored within the artificial life (AL) community focusing mostly on such aspects of reactive, non-predictable and spontaneous behavior as action generation, adaptation and learning, than on knowledge and reasoning. An extensive discussion on autonomous agents and their typical AL architectures can be found in [9]. Within the AL paradigm, the agents are entities inhabiting the digital world of the computers and networks (i) with the purpose of simulating tasks like survival and exploration in the environments inaccessible or dangerous for the humans or (ii) developed for training purposes [3, 8]. Recently, more attention has been paid to interaction, considering such aspects as emotions modeling, intentions, social behavior and communication [1, 12].

This work has its origin in the interest to apply some of the fundamental aspects of the agent theory in combination with the AL technology called Cyberlife [5, 6], with which intelligent organisms (called creatures or agents) can be created. The idea is that creatures interact with others through the implementation of diverse interaction mechanisms for the cooperative problem solving, actions coordination or synchronization, conflicts resolution and, this way to handle the social, learning and adaptation issues. In order to obtain the emergent social behavior based on the individual behavior of the agents, their design is an integration of (i) the reactive architecture [2] based on situation-action rules for the basic behavior and (ii) a deliberative architecture based on individual and group goals [11] adding intelligent social functionality.

The infrastructure used for the accomplishment of this work is the Cyberlife Creature Labs platform [10], based on the biological metaphor of the artificial life. This work explores new capabilities to simulate interaction and social coexistence usually limited in traditional behaviorist models. In order to obtain this, the AL environment and autonomous creatures are modeled in terms of goal-states, rules of behavior based on agents' goals and actions, initial knowledge and use of more sophisticated communication instructions than those that the creatures have at the moment. The artificial life agent model is defined including these elements. As the case study, several scenarios of a planet exploration are implemented and discussed.

2 Model of Artificial Life Agent

The creatures developed using the Creature Labs technology have a set of mandatory elements like organs, cells, sanguineous flow, chemical reactions and can handle emotions, diseases and abilities to survive in an environment where they are able to simulate an emergent reactive behavior. The creatures use artificial neural networks as controls for the coordination of perceptions and actions and also the ideas of biological evolution in the form of genetic algorithms and genetic evolution. In both cases, the aspects of the agent design, like the values of certain parameters that govern his structure or operation, are codified like genetic material or genome of the agent.

Creatures simulate the senses of vision, smell, and tact. All are modeled using semi-symbolic techniques. The vision simulation, for example, does not involve a simulation of the retinal image processing, but if a certain object is within the vision scope, a neuron is activated representing its presence in the field of view.

The features of the creatures are specified in their genome. This is the genetic structure composed of two main parts. On the one hand, the brain is responsible for the sensorial - motor coordination and the selection of behavior, on the other, biochemical system models a simple power metabolism interacting with the brain. Taking the stimuli from the environment, the neurons of an input lobe are excited where each one represents a different object type and by means of an output lobe the signals are transformed to determine the attention focus. Three layers participate in the decision making: the perception layer, the concepts space and the decision layer itself establishing the relations between memories and decision making where each neuron represents an action like *to activate, to deactivate, to walk,* etc. Finally, reinforcement learning layer is implemented by changes in the decision layer in function of the existence of a chemical award or punishment. In the following sections, the elements composing the structures that we have added to agents in order to produce social behavior during their interaction are explained in more details.

2.1 Actions

The actions are the activities allowing interaction between the elements of the environment, and as well denoting a behavior class. Creatures make decision on an action to execute through their neural networks. From the actions, three levels of interaction can be defined. First, called agent-internal state, occurs when an agent executes some action and registers internal changes in his internal state and components that later can influence the other actions. Another type of interaction we called agent-environment, which takes place when an agent interacts with its elements, producing effects on the environment and enabling the interactions between its objects that further can be perceived and manipulated by the creatures. Finally, the third type allows creatures to interact with each other. This leads to the development of the awareness capacity both on his own actions and those of the others, since by means of this interaction, agreements, distribution of tasks, etc. can be achieved.

2.2 Goal-States

A goal is defined in the sense to represent a state that the agent can obtain if some preconditions in the environment, in the realized actions and in his internal state are fulfilled. Its purpose is to guide agent's behavior within the community. The goals found to be useful for this type of AL environments have been classified in two ways: first, called permanent goals, stimulate the agent guiding his existence during the life cycle; second, called temporal goals, stimulate him until they are fulfilled.

The permanent goals from the beginning of the creatures' life take care of the survival conditions, although an agent also can acquire permanent goals on run time. The temporal goals are adopted to obtain the permanent goals. These two types of goals can be used for individual or group effects. A group goal is such an objective that involves a group of agents because if being reached it brings common benefits. Normally, this type of goals is composed of a set of activities or responsibilities (roles) that the agents can acquire as their own goals. When creatures obtain a role to fulfill a group goal, they activate their neurons to fire the rules allowing them, by means of the temporal goals, to reach their group goal. Whenever a group goal is reached, the system sends a stimulus that the creatures interpret to finish their participation in an associated role.

2.3 Rules of social behavior

A rule of social behavior is defined in terms of the internal states that an agent has, indicating by means of this, the execution of the actions as a result of being in the situation defined by such states. With this class of rules, the execution of actions that guide the behavior of the creatures during their interaction with the environment and its objects is characterized. Each one of these rules is represented in the brain of the creatures and its activation is defined by the priority of their internal goals and the group goals at the moment. One of the main objectives of the rules of social behavior is to try to avoid the interference in the actions executed by different agents, and this way they can fulfill their goals.

2.4 Initial knowledge

Knowledge is the information considered useful to reach the goal that resides internally in the creatures' brain. An agent begins to operate with primary knowledge. Much like the humans do in their rationality, the creatures use instincts, activated by this initial knowledge. This way, creatures can identify objects (through creature's neurons that represent them), be aware of the actions (neurons that represent the actions, see section 3.1) and the rules of social behavior to execute.

2.5 Instructions of interaction

Interaction results in a series of actions by means of which agents communicate with each other. Perceived information is interpreted according to the receptor's goal-state and finally generates a change in his internal state, keeping or modifying some knowledge or changing the goal-state. Perception is implemented by different specialized senses as follows. By means of the vision sense, the agents can recognize objects and their states. With the ear sense, the messages like an order are received. Orders are represented like action-object (get-food) or action-object-direction (walk-room-right). Different composed forms can be obtained enabling to implement more complex behaviors. For example, when an agent requires to take an object and to walk to the right followed by another order like to stop and to eat, a composed instruction like ((get, object, right), (stop, eat)) can be used. The things that an agent can touch (like a chemical substance) are perceived by the tactile sense.

On the other hand, the communication scheme being used for the agents is based on two types of information: the first is called "help", when the agents emit information that indicates request or dangerous situations. The second type is called "call for agreement", representing the choice to participate in collaborative interactions in a multi-agent system. It needs the answer to enable the posterior course of actions. A predefined protocol of interaction does not exist to control the communication between agents. Rather, the interchanged objects of communication are codified like scripts that represent goals or actions coded within the agents' neurons. The receiving agent perceives the message, its type and intensity. The latter is determined by the level of authority of the emitting creature. If it is high and the goal or action has greater priority than the current one, then the agent commits to it.

2.6 Learning

The creatures are equipped with a source that emits information arriving to the receiver by means of its sensors. In the case of unknown source, this information is related to its source by means of neurons. The receiver has the capability to remember it. Also he can find some features that make the received information unique. This information represents an object allowing its recognition. For example, in the case of a place, if the creature does not have initial knowledge of the location of the other places, he begins moving from a starting point being the first that he relates, and then according to the movements (left, right, up, down, etc.) he makes the distinctions between the places along the trajectory. This way, a mental map is generated, that makes easier the future displacements in the environment.

The actions are based both on the initial knowledge and that acquired by means of the reinforcement learning that occurs by changes in the brain at the layer that perceives creature's action effects in response to the existence of a chemical award or punishment. These stimuli serve as exciters and inhibitors of the neurons representing actions. Learning enables a creature to show a certain level of autonomy, i.e. his behavior is not only based on some basic rules, usually called instincts, but as well he acquires knowledge from the environment's state and make decisions based priority rules to fulfill his goals. This way an adaptation to the environment occurs.

3 Case Study: Exploring a Distant Planet

In this section, an AL application is described that has served to implement the defined concepts. The environment represents an unknown planet being explored by the creatures. This environment has been designed considering the static objects [4] (plants, water, food), dynamic objects (objects that can move from one place to another), and classes of creatures. Creatures are designed and implemented with different types of behavior and capabilities of learning and coexistence, modeled over the basic genetic and reactive attributes [9]. All these elements can be configured through the application's GUI and be manipulated by the user during the execution.

It is a primitive society that is self-controlled by the agreements generated from the interaction between the agents. The design of the creatures involved the definition of a set of actions, goals and rules, focused to set the behavior to be acquired under the scheme of social interaction being studied.

3.1 Creatures

Two types of creatures exist in the environment: *native* and *explorer*. They try to adapt, survive and coexist taking into consideration the group goals being modified during the system execution. Both types of agents are governed by the behavior of a goal-based agent; in addition to being autonomous, they can realize individual and collective actions (Table 1). Initial knowledge elements that the creatures have are defined and represented for the case of the explorer agents in Table 2.

Table 1. Creatures actions, goal-states and behavior rules

Actions	Goal-States	Behavior rules
Pay attention	Hungry	If there are a lot of creatures ->escape
Communicate	Tired	If find elements ->inform
Express necessities	Collecting	If has pain->run
Learn	With many creatures	If it is hot ->explore
Turn	Angered	If communicate and find elements->collect food
Fight	Exploring	If locked up or lost->explore
Explore	Found food	If on the ship ->explore
Escape	Informing	If has elements and on the ship->leave

Table 2. Examples of explorer creatures' initial knowledge elements

Environment	Creature itself	Creature's goals
Elevators can contain creatures and what they are carrying	Can carry and transport elements	I must not die
Buttons are in machines, doors and elevators	Needs water	My goal is to collect food (Group goal)
Food can be found on the trees, it is ingestible, it is an element	Can die if the food, water and health levels are low	
There are food and fruits	I am a creature	

The explorer type of creatures begins exploration by interacting with different objects that he finds, like elevators, button, doors, food, etc. moving through the scenes in which his operation has been designed. The second type is the natives representing the wild creatures. The latter ones have aggressive behavior and increase their anger during coexistence and interaction with those who are not of their species.

3.2 The environment

There are a number of objects on the planet, with which the creatures can interact in several forms. Some objects are automated, like for example the elevators that can move up and down when the corresponding buttons (within the cabin and an outer one) are pressed by the creatures. The user can interact both with the objects by moving, gathering and dropping them in the environment, and with the creatures granting awards or assigning punishments to them.

3.3 Scenarios of interaction

In the first scene, an explorer agent finds “rucksack” objects that indicate him to play a collector role. This is done by activating the neuron that indicates that an agent has a rucksack, and a new goal is settled, which can be fulfilled by executing the actions “collect elements”. Since then, he begins to explore the other scenes with a new goal added to the initial one “survive” (always of highest priority). If another creature is found playing the same role, he communicates with him trying to collaborate in order to fulfill a group goal, dividing the work (collect-food) as shown in Fig 1.

Fig. 1. Explorer creatures playing a collecting role and trying to get the elements.

In the second scene, the creatures learn and communicate the places and locations of the food to the others. The location layer of their brain allows them to relate a scene to an object, creature or scene maintaining therefore a mental map with the visited places, activating the lobes of their memory to learn and to remember. When the explorer begins to collect elements, a stimulus is sent to the brain that allows finding the food. If he travels to another scene and finds another creature of his type and playing the same collector role, he communicates towards what direction he has to move to find more food (walk-towards-direction) (Fig 2).

Fig. 2. An explorer group collecting and storing elements

The third scene is the home of the native creatures where elements like food, water and toys are stored. Here the interaction between groups of two different classes of creatures can be explored. When creatures of different classes meet, they try to communicate with the creatures of their species. The natives show their aggressiveness, attacking if they are more (Fig.3), or flee away in the case of numerical inferiority. Being attacked, the explorer creatures can ask for help or inform the others not to approach this place.

Fig. 3. Explorer attacked by native creatures

3.4 Implementation details

For the environment generation the following tools were used: *Creatures Map Editor 1.08* for the world edition, *gimp* to develop *.bmp* images, and *sprite builder* to convert them into the frame format. Creatures or agents living in the virtual world are composed of images, scripts and genome. Since our goal was not to develop a new world for entertainment purposes but to study social interactions between agents, we have used already developed creature images obtained from *Creatures 3*. To develop creatures' behaviour, *scripts* were modified by adding new actions and behaviour rules described above. For implementation, CAOS (Creatures Agent Object Script) 1.002 and *Creatures Engine* 2.286, which enable the execution of our world in *Creature 3* and *Docking-Station* were used. The creatures' brains (neural network) and their biological structure defined by the *genome (.gen)* were generated using *Genetics kit for Creatures 3 1.16.4* enabling adding initial knowledge, states, goals and actions.

4 Conclusions

In this paper, a set of elements that we considered important for applications of artificial life through the Cyberlife technology integrated with autonomous agents are developed through a hybrid architecture consisting of the reactive and deliberative layers, each based on behavior rules and goals respectively.

The elements that appear in this work are focused on the three main aspects of interaction: (i) between agents of the environment, (ii) between agents and objects of the environment and (iii) of agents with their internal structure. Agents must have initial knowledge to represent objects of the environment. Goal-states serve to direct the individual and social behavior of agents within the environment. Behavior rules allow the agents to behave on the basis of their individual and goal states. Actions represent the means by which agents reach their group goals and interact with others by means of communication actions. Actions permit to obtain their group goals considering the priorities for each goal within the genome of the agent, which is possible to manipulate during the design and execution. The necessity to establish communication and learning that influence the interactive processes of agents and that represents the key to obtain more advanced forms of interaction in this class of artificial environments is argued.

The results obtained during the tests indicate that the Cyberlife technology is an excellent base to develop AL systems that in combination with the construction of autonomous agents based on the proposed elements allows obtaining interesting cooperative behaviors. With this type of environments, it is possible to develop collaborative agents based on their goals, agents that can adapt and learn on run time, agents that can compete for resources and agents who develop their capabilities to negotiate on the basis of their internal states and the group goals.

Different experimentation schemes to study interaction models in more details are under development. We are also analyzing now the possibility to use different aspects of this technology in the system of information security.

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