A Survey on Zamin Artificial Ecosystem

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Abstract: - Zamin that has been introduced as a high level Artificial Life environment has a variety of good features that make it a general purpose ALife test bed in which different aspects of real life may be modeled and studied. In this paper we will first describe the general structures of Zamin and living mechanisms of its creatures and then we will discuss about some of our successful studies in Zamin test bed to show the ways in which this simulated life environment can be used for cognitive researches.

Key-Words: - Fuzzy Modeling, Artificial Life, Simulation, Genetic Algorithms

1 Introduction

Computer and mathematical simulations of real life can help us in two important matters: First, to evaluate our assumptions about real life by implementing them with a strict language and second, to explore the interactions between different contributing factors influencing the behavior of the creatures [1]. The first artificial life model was introduced in 1966 by Von-Neumann [2] as the idea of creating cyber-organism, capable of showing characteristics of living creatures such as reproduction, self-healing, growth, etc. Von Neumann's first artificial life environment was a simple cellular automaton which evolved patterns that could influence on their surrounding cells and change them so that they would resemble the same pattern. Artificial life continued in several different forms and with several different targets in the next years such as studying the evolution of complex behaviors [3], [4] and [5], emergence of social behaviors [6], simulation of natural creatures [7], emergence of computer programs [8], etc.

There are different categories of artificial life models, simulating different levels of real life objects and creatures. The main difference between these categories is in their level of abstraction and creatures' capabilities, which directly results in differences in possible studies that can be done on any of these models. One of the most recent works in this area is Zamin which is a test bed suitable for studying many aspects of cognition and social behavior. It has been compared with a number of similar testbeds and shown to be a very flexible simulation instrument specially for studying cognitive and behavioral attributes of living creatures[12].

In this paper we will provide a survey on some of our recent studies on Zamin. The next chapters are organized as follows: Next to this part, there is a section on Zamin model describing its world model, time and life cycle, etc and then, we will describe some of our experiments on Zamin environment to show the way in which this test bed can be used as a general test bed for cognitive research.

2 Zamin General Structures and Organisms

Zamin environment consists of a simple lattice and three types of inhabitants: the *Aryos*, the mobile, learner organisms that are the main subject of study; the *Sentinels*, another mobile organisms whose behavior is hard-coded and they are just aimed to kill the Aryos; and the *plants* which are the green energy resource of the Aryos.

2.1 Zamin Overview

Zamin environment is a simple spherical lattice (if an organism keeps moving in one direction, it will reach its initial position again). Each cell of this environment can at most include one living object.

2.1.1 Aryos

The main creatures of this environment are the Aryos. Each Aryo has an internal energy state that must be kept above a certain limit to prevent death. Energy level increases when the organism eats a plant or the flesh of a dead creature, and decreased as other creatures attack it. Each Aryo can reproduce (asexually) once its energy level exceeds a specific threshold. After the reproduction, a certain amount of parent's energy is given to the child.

Besides position, Aryos' also have an orientation (also called direction). They receive inputs from that direction.

Many of the Aryos' properties are not constant and are specified by a data-structure that is called the *Genetic Code* or *Genome.* When an Aryo is born, the parent Genome is mutated by a predefined factor and passed to the infant. Following the Mendel theory [11], an Aryo's genome remains unchanged during the lifetime of the organism and is mutated only during its pass to the infant. As Aryos' reproduction is asexual, no combination operator is used.

At each time step, each Aryo can choose an action. This action can be a choice of stepping ahead, turning to left and right, asexual reproduction, attacking to other creatures, eating plants or the flesh of dead creatures, and resting.

As we mentioned before, Aryos' have sensory inputs, that can be categorized in to internal and external state sensors. Internal sensors are composed of its energy level, its last change of energy level, its age. The external sensory inputs specify the type and some properties of the most near object in its visible field. For a plant, only distance, relative angle and plant energy is given as sensory input, but for another Aryo or Sentinel, its energy level, carnivorousness, age, tiredness, etc. are also given.

To guide Aryo's unsupervised learning system, each Aryo has an internal pleasure system that specifies how favorable its current state is. If the pleasure level is positive, it means that organism is pleased with its current state while a negative pleasure level means it is in pain. The absolute value of pleasure value states the severity of organism's pleasure or pain.

As can be seen in Figure 1, each pleasure rule in *Zamin* is an *(S,P)* pair and tells "if current sensory input is *S*, then organism pleasure is *P*". The *State* part of each rule provides a fuzzy membership set for each of the brain inputs. These sets, express the membership measure for the entire range of values for their corresponding input. For example, in the left-most item of Figure 1, the entire range of values for brain input 1 is expressed by the horizontal line and the membership values are shown by the trapezoid over that line. The membership set of this input expresses that if the input has a value from its minimum till its middle, the value totally belongs to this case and as the value increases past the middle point, it belongingness decreases till it reaches zero at the last point.

On the other side of Figure 1, the *Pleasure* part of this rule is specified. This example states that if the brain inputs totally belong to the *State* part of the rule, the *Pleasure* value would be around +0.8.

Pleasure rules remain unchanged during the lifetime of an Aryo and are initiated by the genome it receives. Thus, they only change by evolution.

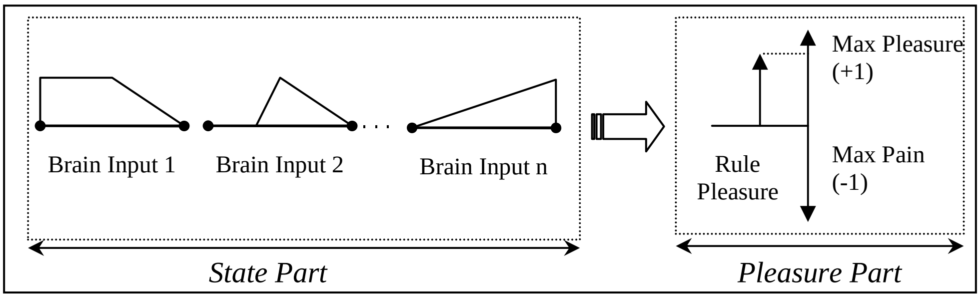

Fig.1 - Pleasure rules' schema in Fuzzy Zamin

Pleasure computation is performed as in traditional fuzzy rule sets: As in Figure 2, first, the brain inputs are put onto the x-axis of their fuzzy membership sets. The value of the membership set on y-axis is regarded as the activation value of that set. Then, the minimum value of all activation values for all sets is chosen as the rule activation value. At last, the rule's current pleasure is computed by multiplying the *Rule Activation Value* by the *Pleasure* part of the rule.

This procedure is performed for all pleasure rules and their current pleasures are computed. Next, the current pleasure of rules whose *Rule Activation Value* is above a specific limit are combined. We have implemented several methods for this combination. Each method has a gene

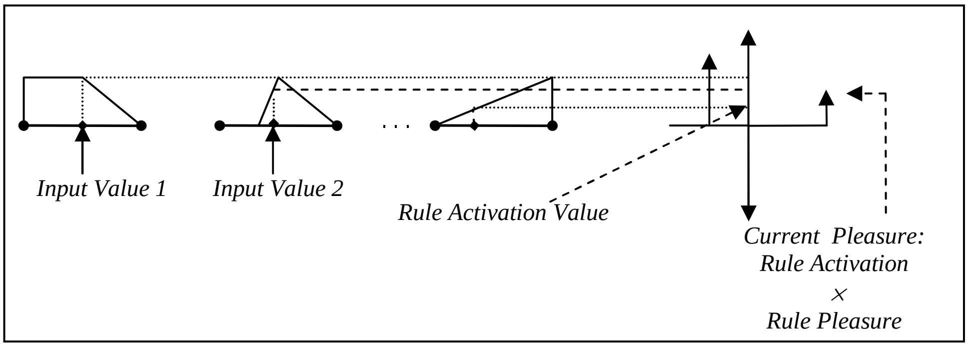

Fig. 2 - Pleasure Computation for a single fuzzy pleasure rule

specifying the likelihood of its usage as the combination method.

Another set of cases build Aryos' decision-making system. Each case (also called a "decision rule" or "decision experiment") is in *(S, A, P)* or *(state, action, pleasure)* triple format and states that "in an experience where the sensory inputs have been *S*, action *A* was chosen and it has resulted in pleasure level *P*".

At each action choice, sensory inputs are compared with the *S* parts of all action rules. Then the case whose expected pleasure (its similarity multiplied by its *P* part) is the biggest is selected and its *A* part is chosen as the action to be performed.

Here again, a minimum limit for rule activation and several combination methods are used. Similar to pleasure rules, each method has a gene that specifies its usage likelihood.

Once an action is selected and applied, organism's pleasure is computed and the action selection rules are adjusted to increase or decrease the probability or re-selection of this action, based on the pleasure value.

2.1.2 Sentinels

Sentinels are the second living creatures of Zamin and are quite similar to the Aryos with two major differences: Their behavior is hard-coded and they are just aimed to search for the Aryos and to kill them; and they gain energy by attacking to Aryos and do not eat at all.

3 Some Recent Experiments in Zamin

In following sections we will describe some of our studies on Zamin environment. In all of these studies we have tried to model new features of real world and real creatures while using Zamin as our general test bed.

3.1 Evolution of Communication

In order to study the effect of communication on the species' success, one way is to add a means of direct transfer of knowledge from one mind to another[5]. To implement this method, we enabled Aryos offer some energy to others and in return learn some of their experiments, directly and without any translation.

To test the usability of this new capability, we modified the Zamin environment and created another environment called the *OtherLand* and called its creatures the *aliens*. The differences between Zamin and *OtherLand* are set so that a creature that is evolved in one cannot use its experiments in the other and even cannot learn the other world's rules easily because of its evolved pleasure system. Then some creatures from *OtherLand* were transferred to *Zamin* to see their reactions in three different experiments: In the first experiment, the *aliens* are alone in *Zamin* to learn its rules by themselves. In the second, they live together with some normal residents of *Zamin*, where they can guide them on how to live but they also compete for resources. And in the third experiment, the *aliens* live together with *Zamin* residents, but they do not compete with them for the resources and are extinct after a short time.

The results showed that the rules of the *OtherLand* were so different from *Zamin* that the transfer of *aliens* to *Zamin* and leaving them without guide results in 90% extinction of *aliens*. This extinction percentage increases to 100% when there is a competence between the *aliens* and the expert residents of *Zamin*. But in cases that *Zamin* residents do not compete and just share knowledge, the success probability increases to 70%. Hence, the creatures have been able to use their communication capability.

3.2 Evolution of Generalization

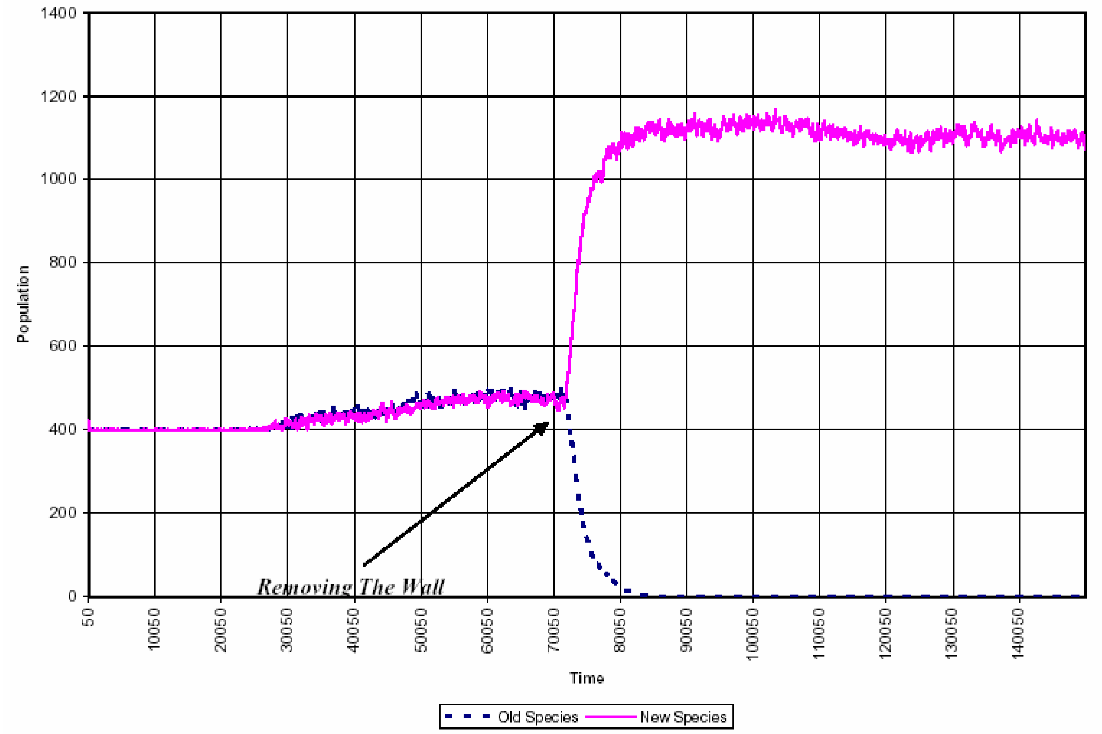

Fig.3-Population of new and old *Aryos* before and after of removing the wall.

As we described before, in fuzzy version of Zamin in both behavior and pleasure rules brain inputs are defined using fuzzy member ship functions. This structure was shown to be more powerful than initial crisp state definition structure, but it was not compatible with real pleasure or behavior rules in which there many of brain inputs are not relevant for a single decision making or pleasure computing task. In addition there are several facts in real world that can be defined in a binary form.

In this experiment, we extended the structure of rules such that they can cover these binary and don't care values. In other words, in this revised version, each brain input value in rules structure, can be of one of two types: *Fuzzy* or *Binary*. In addition each brain input in each rule has a *Don't Care* flag that can disable that input value.

In this new version of Zamin we also defined a combination mechanism for similar rules in learning mechanism. In this mechanism we find those behavioral rules that are similar enough to be combined in to a single rule. The measure of similarity between two rules is computed as function of similarities between state parts of these rules. Table 1 shows the way in which we compute measure of similarity between brain inputs and Table 2 contains the result of combination for different types of brain inputs. We delayed the combination and abstraction processes until the mind's capacity becomes full. At that time, combination process starts and combines similar rules in mind. This process continues until no more similar rules remain in mind.

We let the new extended version of Aryos, to compete with the old version and for this goal we let both species to evolve for a while in two sides of a wall that divided Zamin to two distinct areas. Then we removed the wall and the match started. Figure 3 shows the population of each species before and after removing the wall. As it can be seen in this figure revisions in this experiment made Aryos more powerful than old ones.

State Types	Similarity Measure
Don't Care (at least one of two state values)	1
Binary	1 if equal 0 otherwise
Fuzzy	Reverse of Difference between COG values

Table 1: Computing the Similarity Measures

Two Initial States' Values	Resulting State Value
At Least One of Two States is Don't Care	Don’t Care
Equal Binary Values	The Same Binary Value
Different Binary Values	Don't Care
Fuzzy Values	Fuzzy Union of Two Fuzzy Values

Table 2: Computing the Combination of Two Initial States' Values

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3.3 Evolution of Pleasure System

In the previous version of Zamin, the authors had coded an external pleasure system, which could guide Aryos' decision making at the first stages of evolution and before the evolution of their own pleasure system and all trials of Zamin without this guidance system has resulted in failure. This external guidance gradually became more and more noisy and enforced Aryos to use their own internal pleasure system. But, this external guide had a major effect on the evolutionary trend and the way the internal system could evolve, as it had to comply with the external one. Thus, we decided to remove this external guide and evolve a self-dependent pleasure system.

As we described before, Aryos could define arbitrary trapezoidal fuzzy values to construct their pleasure and decision rules. Although the method used here for set definition could give them the complete freedom to define any sort of rule, it had the following two negative side effects: First, they could construct narrow fuzzy sets, or approximation of real numbers, and this could have negative effect on the nature of fuzzy approximate thinking. And second, the genetic state space had become very large, because each set required at least four genes to code its four points. And this second flaw could be the main reason for failures in evolution of pleasure system.

To overcome these two weaknesses, we changed the fuzzy set definition method and bounded their selection to a choice of one of seven predefined fuzzy sets. This way, each fuzzy set is defined by just one gene and drastically decreases the genetic space also the creatures are limited to use approximate thinking.

Also, previous Aryos had to act totally rational, in other words, at each action selection phase they had to use all their previous recorded experiments to choose the most beneficial action. But this could ban them from experiencing new cases and limited them to follow their very first actions, resulting in non-efficient behaviors. To overcome this problem, we followed an idea taken from animals' world. Many animals, at least at their childhood, do not act exactly based on their former experiences and sometimes to tend to do new things and know more about themselves. Thus, we gave Aryos the right to random action selection. This way, at each cycle, they can choose either to make a decision totally neglecting the former experiences and not caring about the result, or like before based on previous results. The results of all experiments, whether rational or random, are recorded and used for further action selections.

After applying the above changes, we had several experiences with Zamin, and in all experiences, the pleasure system was evolved in an acceptable time. More over, the results of different runs usually converged and almost the same interesting pleasure rules “*if energy level has recently changed positively, it is a pleasing case*” and “*stepping toward a plant and moving away from another walking creature is pleasing*”. The new Aryos could find much more efficient behavioral rules than what previous ones could. These rules are completely consistent with pleasure rules, so that we can interpret them as the behavioral interpretation of pleasure rules.

3.4 Evolution of Emotional States

Although Aryo's decision making system seems to be sufficient for them to survive in complex and hard-to-live environments, it is a very simple model, in compare with a real animal (or human). One of the most important aspects of human decision making is the role of emotions in its behavior and reactions. Humans choose their actions and make their decisions due to several internal variables called emotions, while the agents of Zamin model have just one internal state. Thus, we tried to add emotions as a new factor in decision making mechanism. At the first step, we defined a structure that lets the Aryos to fall in one of two internal states. At each of these states, there is a separate pleasure computing system. Also, Aryos maintain separate sets of behavior rules, one set for each internal state. Figure 4. shows the schema of this structure.

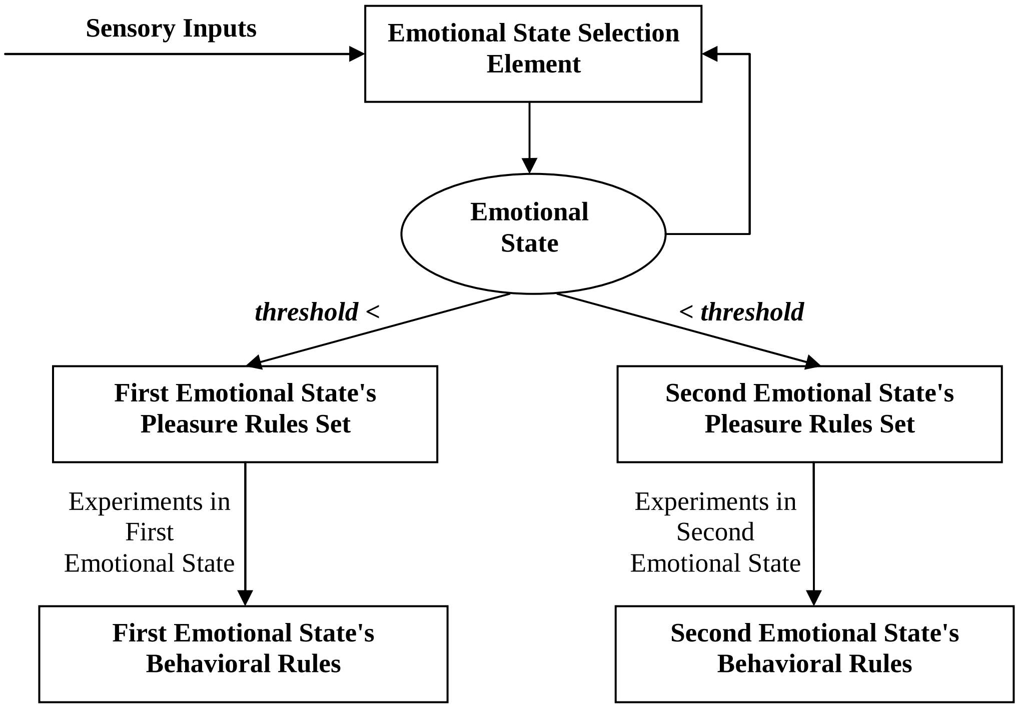

Fig4. The Three Layered Model of Emotional Decision Making System

As it can be seen in this figure, the first step in decision making cycle, is defining the current emotional state in which the Aryo falls. This decision is made by checking the sensory input values and current emotional state.

The internal state computation mechanism, acts much like the pleasure computation procedure: Each agent can keep a set of emotion rules in its genome. An emotion rule consists of current internal state as well as sensory input values as its condition part and a positive or negative value as its result part. This result value determines the measure of change in the current value of internal state variable.

This strategy lets Aryo's internal state change gradually, from first emotional state to another. This phenomenon seems to be compatible with the real world in which many animals and also humans' emotions have inertia and do not switch suddenly.

As we mentioned before, in different emotional states, Aryos use different pleasure rules. In other words, in state 0, an Aryo may be pleased of occurrence of some event while in state 1 the same event may be interpreted as unpleasant or even painful.

As it seems necessary, at different states, the same experiments may result in different amounts of pleasure. This means that at each of these internal states, Aryos should construct a separate behavioral rule sets, and may have different behaviors: a simple model of reality. It's important to remember that it is up to Agents to assign specific meanings to each of these emotional states. We have just prepared an infrastructure that lets Aryos to use advantages of thinking and acting in two different internal states, the decision about weather to use this structure or not, and the way in which the agent interprets his internal states will be taken by the evolution.

The results of our tests show that Aryos have used this mechanism successfully. They assigned the concept of "*fear*" and "*relax*' to their emotional states, and using these internal states and in the presence of sentinels, they could live much longer.

3.5 Evolution of a Voice Recognizer

In this experiment we tried to use Zamin environment to evolve an agent to recognize human speech. The main change we made in Zamin, was our interpretation of the concepts of food and eat. In this altered model, each plant consisted of a sample of voice signal. If a creature could identify the phoneme to which this sample belonged, it could eat the plant and absorb its energy. But if it could not, it didn't get anything. In other words, Aryos needed to learn to relate voice samples to phonemes through learning and evolution. The results show that in our limited domain, Aryos could identify the phonemes of a single speaker with accuracy above 70%.

4 Conclusion

In this article we tried to provide a brief survey on our recent studies using Zamin artificial world. We have evolved some new features of real life such as communication, pleasure computing, emotion system, and the ability of abstraction in Zamin simulation environment. In addition we have used Zamin test bed for constructing a voice recognition system. We believe that Zamin could be considered as a general test bed for such researches in which the main subject of study is the evolution of species with high levels of mental and behavioral capabilities. In addition it seems to be such a rich environment that can provide suitable conditions for modeling many aspects of real live creatures. As we described here, these aspects may vary from mental capabilities such as learning to complex social behaviors such as communication.

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