CALANGOS Level 4: The Environmental Influence on the Players' Strategy in a Simulation of the Ecological and Evolutionary Level of the Game

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Abstract

Calangos is an educational videogame about ecology and evolution for high school students. The game is based on the fauna and flora of a desert-like field of the sand dunes in the middle São Francisco River, located inside the Caatinga biome. One of the player's goals is to manage the behavior of species of lizards that inhabit this biome, with consequences to their ecology and evolution. In this paper, we report functional aspects of the game, the features that have been developed until the present time and, mainly, the initial results concerning the game level (Level 4) in which the players will deal with the evolution of the lizards simulated in Calangos. More specifically, a simulator for Level 4 was developed and a genetic algorithm was used in order to understand what types of strategies a player may use in environments with different levels of difficulties. It was observed that favorable environments (with sufficient food and slow predators) may easily lead to an explosion in the number of lizards within the environment; hostile environments (with little food and very fast predators) lead to an extinction of lizards, no matter what strategy a player may adopt; and a balanced environment (with sufficient food and fast predators) lead to suitable survival strategies. These results are very important, from an educational point of view, because they show that there are situations in which the students will be challenged to devise survival strategies (based on an ecological and evolutionary basis) and succeed, but there will also be cases in which students will fail, no matter how good their strategy is. This failure due to hostile environments will be understood by the students if they succeeded in grasping the key concepts of ecology and evolution embodied in Calangos.

Keywords: educational games, videogames, evolutionary computing, ecology, evolution.

1. Introduction

Games are important tools for science teaching. The playing activity is, after all, the cradle of intellectual activities required of a child; it is directly connected to the children's mental development [Piaget 1976, Vygotsky 2000]. Games are effective institutional tools, providing fun and motivation and, at the same time, facilitating learning and increasing the capacity for retention of what was taught, exercising the mental and intellectual functions of the player, and requiring both the recognition and understanding of rules, and the proper identification of contexts [Tarouco et al. 2004]

By playing, young people take great intellectual effort and have a high level of learning of the rules and strategies involved. It seems promising, therefore, to explore such tools for the mediation of students' learning experiences. They seem to carry great potential for the cognitive engagement and learning of specific contents. From this perspective, games and, in particular, videogames can be appropriate complementary curricular materials [Battaiola et al. 2001].

The Calangos project involves researchers and developers from several universities (MACKENZIE, UEFS and UFBA). It is based on the modeling of a real ecological case about lizards that inhabit a desert-like field of sand dunes in the middle São Francisco River, located in the Caatinga biome (at the state of Bahia, Brazil). The project's overall objective is to develop and test in classroom situations an electronic game that aids in the teaching and learning of core concepts of biology related to ecology and evolution. More specifically, the game should work as a tool to support the teaching and learning of ecology and evolution at the high school level, not by direct exposure of contents to be learned by the player, but by learning from the experience of trying to solve problems within the game. Both ecology and evolution are central subject matters in biology, as we can see by considering the relationship between ecology and key environmental issues in our times, as well by entertaining the role of evolutionary thinking both in the structure of biology and in citizenship education, given its bearing on important socioscientific issues [Sadler, 2005].

By the end of its development, the videogame Calangos is going to have four distinct levels.

- **Level 1**: the player will act as a single lizard, choosing one of out of the three species available; the main objectives are survival, development and reproduction.
- **Level 2**: the player must “build” a lizard from an interactive editor, choosing characteristics of morphology, physiology and behavior which will determine success or failure in its survival. More is to be potentially learnt, in this manner, about the relationship between the traits of the animal and its likelihood of success in survival and reproduction.
- **Level 3**: there will be the passage from the individual organism level to the level of populations, putting the player in the condition of managing an entire population of lizards. Population ecology will then come to the fore as a subject to be learnt.
- **Level 4**: involves a passage from ecological to evolutionary time, being given to the player not only the challenge of maintaining a population of lizards, but also of dealing with its evolution over the generations. The main objective of this paper is to present the initial results of this level’s development. Here, we intend to expand further on the potentialities of the game for the learning of evolution.

This paper presents a simulator for Calangos, emphasizing its Level 4, introduces the use of a genetic algorithm [Holland 1975, Holland 1992, Goldberg 1989] to automatically investigate how the environment influences the survival strategy of the lizards. The goal is to show that different environments require different strategies that involve an understanding of the biological concepts of ecology and evolution. It will be shown that favorable environments lead to an easy survival of the lizards due to a sufficient amount of food and slow predators, whilst a balanced environment will require a more refined strategy, and a hostile environment will inevitably lead to the lizard population extinction. In all cases, an appropriate understanding of ecology and evolution will have to be grasped by the students (players) so that they can devise suitable strategies for playing Calangos.

2. Related Works

As examples of educational videogames involving biology and ecology that are similar to Calangos, we can mention Web of Earth Online[tm] [Web Earth Online 2007] and SimForest[tm] [SimForest 2002].

Web of Earth is an online multiplayer strategy game in which each player plays with various animals such as mammals, reptiles or birds. There are many possibilities of interactions with predators, prey and other elements of the ecosystem such as plants and rivers. Making right choices about the interactions between the animals and the environment is the game’s greatest challenge.

SimForest is a development of a forest simulator. Like Calangos, SimForest focuses on modeling different aspects of an ecosystem, such as humidity, rainfall, temperature and soil conditions. This is not really a game, but a simulator for educational purposes.

Commercial videogames launched from 1990 to 2000 on the theme of ecology, such as SimAnt[tm], SimEarth[tm] and SimPark[tm], all produced by Electronic Arts Inc., are simulation games rich in details with regard to the relations between the elements and the possibilities of intervention by the player. Some of these games, as SimEarth[tm], have a clear educational purpose, while others do not.

None of these educational electronic games performs the modeling of the ecological relationships between individual organisms and the environment, with connections also with the evolutionary process, as it is done in Calangos. The game also represents a significant advance within the context of educational games, since, unlike the mentioned games, it is based on consolidated biological (see Section 3.1) and pedagogical concepts from David Ausubel’s Meaningful Learning Theory [Ausubel et al. 1983; Ausubel 2003].

3. The Videogame Calangos

The Calangos project started in 2007. In the early stages of the project, we developed the first level game, and started the development of the second and third levels, which include the three-dimensional modeling of the characters and scenery, climate and environmental modeling and the development of the game’s graphical interface [Loula et al. 2009; Oliveira et al. 2009; Oliveira et al. 2010].

This section will describe some general aspects of the first three levels of the game, which are the basis for developing the fourth and final level, the main focus of this paper.

3.1 Real Case Inspiration: the Dunes of the Middle San Francisco River

Calangos is inspired by a Brazilian real biological case, in order to valorize Brazilian wildlife and the knowledge produced by the national academic community. In addition, the inspiration source reflects one of the most important regions for biological conservation in the Caatinga.

The dunes of the São Francisco River form one of the most outstanding landscapes in the Brazilian Caatinga. Located in the state of Bahia in Brazil, these dunes show the highest level of endemism in the Caatinga, with several species of lizards, snakes, birds, small mammals and plants that can be found only there.

Among the animals found in the dunes, lizards and snakes show the highest diversity. Moreover, we find lizard and snake species living on opposite sides of the Sao Francisco River and eventually into its islands which are distinct but are also the closest relatives in their clades, corresponding to an interesting case of reproductive isolation and, thus, speciation derived from the separation of geographical areas that were connected in the past [Rocha et al. 2005].

3.2 Level 1: Playing as an Individual Lizard

At the first level, the player controls a single lizard of one of three species available (*Tropidurus psammonastes, Cnemidophorus sp. nov.* and *Eurolophosaurus divaricatus*), being able to play from the first or third person views, or through an aerial view. The player must analyze various types of data and graphics (Figure 1) to better understand aspects of the character, such as temperature regulation and hydration control. The goal of this level is to introduce players to aspects of the everyday life of a lizard, such as feeding, regulating its temperature, finding mates, fleeing from predators and reproducing. If the player is well succeeded, the lizard will survive long enough to develop and reproduce.

To develop the first level, it was necessary to implement the NPCs (non-playable characters) based on existing animals from the Caatinga. The behavior of these animals was also modeled (in a simplified way), for example, termites and ants grouping, hunting strategies of predators (owls hunting at night, snakes being guided by smell, etc.). The lizards' predators modeled for the game are: tegu (carnivorous reptile), wildcat, fox, owl, seriema (bird), jararaca and colubridae (snakes). Figure 1 shows the three-dimensional models based on these predators which were made for the game.

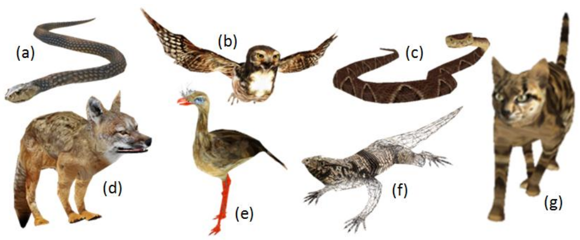

Figure 1: Three-dimensional models of the predators: (a) Colubridae. (b) Owl. (c) Jararaca. (d) Fox. (e) Seriema. (f) Tegu (g) Wildcat.

Lizard's preys were also implemented, including: maggots, grasshoppers, termites, beetles, ants and spiders (see Figure 2). There are also frogs in the game, which can be eaten by large enough lizards.

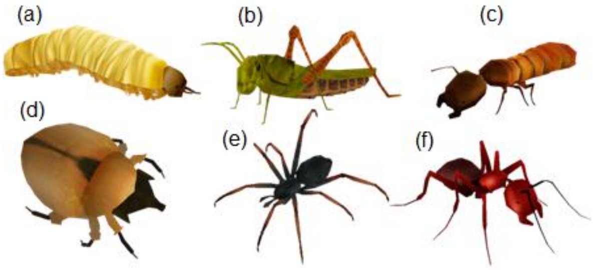

Figure 2: Three-dimensional models of the preys: (a) Maggot. (b) Grasshopper. (c) Termite. (d) Beetle. (e) Spider. (f) Ant.

Some insects, such as ants and termites, tend to cluster together or form trails, simulating, in a simple way, their natural behavior, as seen in Figure 3.

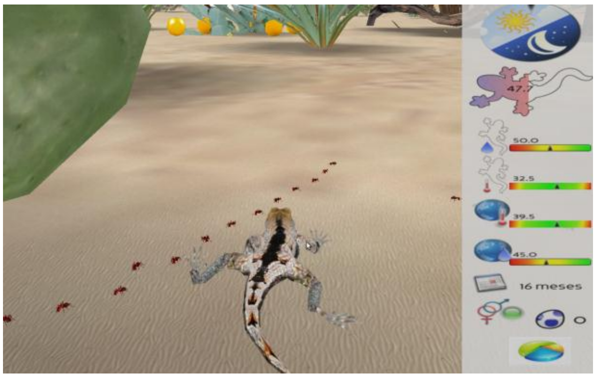

Figure 3: Screenshot of the game. The main character next to a trail of ants. On the right the graphic information (temperature, energy, hydration, time of day, etc.) about the character and the environment.

In addition to the insects and arachnids, lizards may also feed on a wide variety of fruits and flowers found in the environment. Each type of food provides a different amount of energy and hydration.

A beta version of the Level 1 of the game is available for download from the following web address (calangos.sourceforge.net/download.html, accessed 20/07/2011).

3.3 Level 2: Defining Morphology, Physiology and Behavior of the Lizards

In Level 2 the player students must create their own species of lizard using a character editor. This editor's development started in an earlier phase of the project [Oliveira, 2010]. Morphology, physiology and behavior may be assigned to the characters by the player. Among the morphological features it is possible to modify:

- **Body size:** The larger the body of the lizard, the greater its speed and ability to inhibit the attack of predators, but the greater the difficulty in regulating its body temperature and the greater its demand for food and water, and, also, the requirement of time to reach maturity;

- **Head width:** Lizards with heads of different widths have different restrictions on the types of food they can consume. Larger heads have larger mouths that can catch larger objects, but they make it difficult to catch small ones;
- **Color pattern:** Lizards can have different color patterns, ranging from visible patterns to more stealthy ones. A stealthy pattern makes it less likely that opposite-sex conspecifics may see each other, but their chances of being spotted by predators decrease. The color pattern also influences the regulation of the body's temperature: lighter colors reflect more heat, while darker colors absorb more heat.

Among the physiological and behavioral features that can be selected in Level 2, there are:

- **Temperature:** Lizards' ability to better adapt to the cold or heat;
- **Diet:** There may be lizards experts in eating fruits (they get more nutrition from this type of food), there may be experts on ant-like food (get more nutrition from ants and termites), as well generalists that get an average nutrition of several types of food;
- **Circadian cycle activity:** Susceptibility of lizards to perform daytime or nighttime activities. Some preys and predators manifest themselves only during certain periods of the day or night, so the choice of the period of activity of the lizard must be planned carefully;
- **Ability to sink under the ground:** The sinking ability allows a lizard to evade predators by hiding itself under the ground. However, lizards with this skill have greater thermal inertia, in other words, it is harder to control its body temperature when it is not buried;
- **Maximum velocity:** The higher the speed of a lizard, the greater its ability to escape predators, but their basal energy and hydration expenditure (energy spent at rest) is higher (due to its rapid metabolism). Lizards moving quickly also may call the attention of predators;
- **Initial density of the species:** Refers to the size of the lizard population that will exist at the beginning of the game (in Level 3). The greater the number of individuals, the more likely is the probability of a lizard to find a partner for reproduction; however, the consumption of resources available in the ecosystem will be higher;
- **Aggregation of the lizards:** Lizards who live next to each other are more likely to find partners for reproduction and have less individual chance of being preyed. However the aggregation of lizards causes a greater competition for food in small regions;
- **Minimum energy and hydration thresholds:** They define thresholds that represent the percentage of energy and hydration of lizards in which they begin their search for food. For example, being the minimum hydration threshold of a lizard *L* (*hT)* equal to 25% and its energy threshold (*eT*) equals to 30%, *L* will start searching for food if its hydration level is below 25% or if its energy level is below 30%.

3.4 Level 3: Managing a Population of Lizards

The options selected by the player in the second level will also take effect in the third, where a population of lizards (based on the selected attributes) will be generated. The player must then manage his/her new population seeking success and avoiding extinction.

This level is still in its modeling stage. The proposal is that the gameplay of this level will be similar to the gameplay of a real-time strategy game (e.g. Age of Empires[tm]), where several characters can be controlled simultaneously and commands such as "move to a particular area" and "look for resources" can be performed by the player.

4. Development of Level 4

The fourth level of the game gives the player not only the challenge of maintaining a population of lizards as in Level 3, but also of dealing with their evolution over several generations. This section presents the evolutionary algorithms and techniques used in developing the project, which are the main focus of this paper.

To simulate the natural evolution in Calangos, we used genetic algorithms [Holland 1975; Holland 1992; Goldberg 1989].

4.1 Genetic Algorithms

Genetic algorithms (GAs) are computational methods inspired by the neo-Darwinian theory of evolution. They are population search and adaptation techniques based on the evolutionary principle that beings that are better suited to obtain resources in an environment have increased probability of survival and, therefore, are more likely to reproduce successfully (i.e., show higher fitness) [Holland 1975, Holland 1992, Goldberg 1989].

A classical GA begins with a set of data structures representing a population. Each of these structures contains data that represent the genetic information (genes of a chromosome) of an individual of the population. The initial population is usually generated randomly. The level of the ability of each individual to obtain resources is evaluated, being given a grade corresponding to its fitness. That is, these are the individuals with higher reproductive success. The selection process is a probabilistic method based on natural selection, where a certain number of individuals is eliminated according to their fitness (least fit individuals are more likely to be eliminated) [Floreano et al. 2000, Goldberg 1989].

After the selection process, the reproduction of individuals is made observing their fitness values, by means of a crossing between pairs of individuals, given a certain crossing probability. When two individuals are crossed they generate two new individuals from the combination of their genes, so that the offspring will be mixtures of both parents, as illustrated in Figure 4.

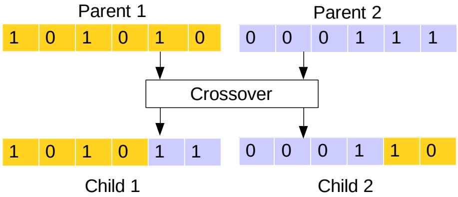

Figure 4: Crossover process in a GA.

Mutation is another important process in a genetic algorithm because it allows for genetic variability. In other words, mutation introduces in the population further genetic variations that did not exist before. Mutation takes place with a given probability, usually small, where an individual newly generated by crossing may undergo a change in a random order of their genes.

The selection, crossing and mutation are repeated in the new generations for a number of times or until the expected result is obtained. Figure 5 shows a flowchart of the basic steps of a classical genetic algorithm.

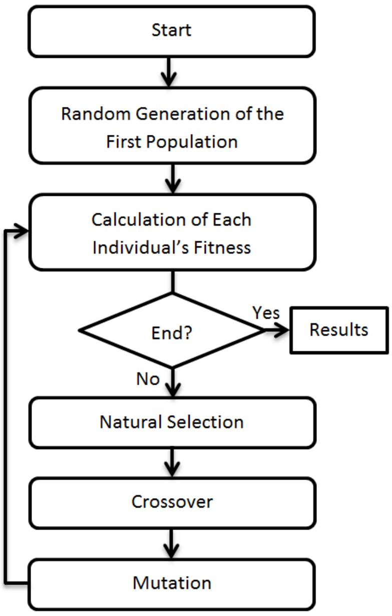

Figure 5: Flowchart of the steps of a classical genetic algorithm. [Floreano et al. 2000; Goldberg 1989].

4.2 Evolution in Calangos

Our work is focused now on modeling natural selection, among the several evolutionary mechanisms, within Calangos. The genetic algorithm used in the game is an adaptation of the classic genetic algorithm. The initial population is generated according to the player's choices, with each individual having small random variations in their genes (to be sure that they are similar but not identical). There are no direct calculation of the fitness of the individuals; rather, natural selection is made by the digital environment, i.e. those lizards that are most suited to obtain resources in the environment will have better chances to survive and reproduce, spreading their genetic material to a greater extent than those less well succeeded. The inherited genetic traits so far defined for Calangos lizards and their possible values are listed in Table 1.

The crossing process of the lizards occurs between males and females of the same species, when both are close to one another and able to reproduce. One reproduction event may generate from one to four offspring. There is also competition between males for mating with a female and, usually, the strongest male will overcome the weaker. Thus, there is a higher probability that the fittest lizard's genes pass onto the next generations.

In a GA, mutation occurs right after crossing, in the newly generated individuals, where one or more of their genes are subjected to random changes, given a certain probability (usually small). In Calangos the probability of mutation in the genes of the new individuals will be defined by the player (with allowed values ranging between 0.1% and 3.0%).

Table 1: Model of the genetic characteristics of the lizards in Calangos and their ranges of possible values. Data based on Rocha & Rodrigues (2005) and on assumptions made by a researcher of the Calangos team with large experience in the field of herpetology, who conducted extensive research on the lizards of the dunes of the San Francisco River [Rocha et al. 2005].

Feature	Range of values
Gender	*sx* ={female, male}
Body size	*bs* = [10.0cm, 30.0cm]
Head width	*hs* = [bs/5 – bs/10, bs/5 + bs/10]
Color patter	*pc* = {stealthy, visible}
Maximum velocity	*vm* = {slow, average, fast}
Tendency to live aggregated with conspecifics	*ag* = {yes, no}
Preferential diet	*dp* = {expert in fruits, expert in ants, generalist}
Circadian cycle of activity	*cc* = {daytime, nighttime}
Ability to sink under the ground	*sa* = {yes, no}
Ideal climate	*tmp* ={cold weather, hot weather, warm weather}
Minimum hydration threshold	*th* = [20%, 50%]
Minimum energy threshold	*te* = [20%, 50%]

The crossing and mutation processes modeled for Calangos are illustrated in Figure 6, where each offspring receives part of the male parent's genes and part of the female parent's genes. In the case of Figure 6, the mutation occurred in a gene of the L4 offspring, generating a feature that previously did not exist.

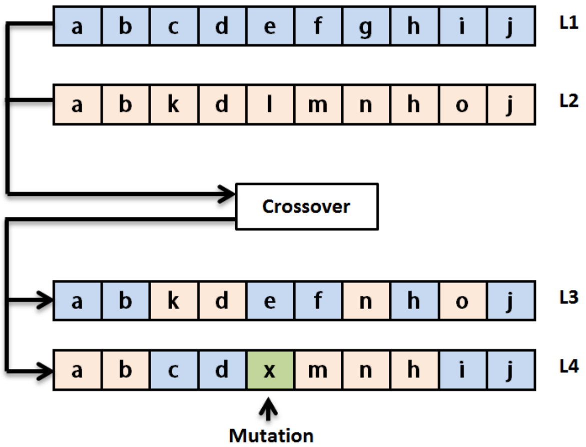

Figure 6: Crossing and mutation of the genetic characteristics of lizards L1 and L2, generating two new descendants L3 and L4.

Mutation occurs differently for each kind of gene, when genes represented by number ranges mutate it is replaced by a number within that range (e.g. the body size gene can mutate to any value between 10.0 and 30.0). Genes which have a predetermined set of possible values can mutate to one of these values (e.g. ability to sink under the ground can be set as “yes” or “no”).

4.3 Evolution’s Simulation

This subsection describes aspects of a non-playable simulation tool for Calangos, not the game itself.

In the development of Level 3, most of the control interface that will allow the management of a population of lizards and the autonomy of most characters will be built. This interface is also used in Level 4, with the additional controls for the investigation of evolution. Since Level 3 is still under development, a prototype of Level 4 is being built in Java.

The prototype contains only the most relevant features of Calangos to simulate the evolutionary process. It allows crossing, mutation and natural selection to be developed and tested before the final implementation of Level 4 within the Calangos game engine and also in parallel with the construction of Level 3. The prototype also allows changes to be made and tested quickly without having to worry about complex graphics.

The prototype has a simple interface that renders the position of the characters and objects on a two-dimensional grid (Figure 7). The characters of the prototype include an initial population of lizards (which can be set manually or randomly) and a population of simple predators (moving with constant speed) to represent the various types of predators. Food resources that provide nutrition and hydration to the lizards are also included.

Figure 7: The prototype’s visual interface.

The lizards have four distinct states:

1. **Searching for food**: When the energy and/or hydration levels reach a certain threshold;
2. **Searching for reproduction partners**: When energy levels and hydration are favorable and there is willingness for reproduction;
3. **Resting**: When the levels of energy and hydration are favorable and there is no willingness for reproduction or predators coming;
4. **Fleeing**: When threatened by predators.

Predators have only two states:

1. **Walking randomly**: When there is no prey nearby.
2. **Hunting**: When a prey comes into their range of vision.

The state transition diagrams for the lizards and predators are illustrated in Figure 8.

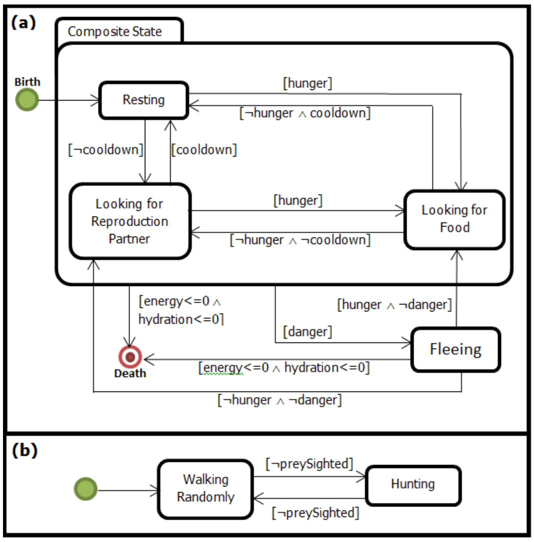

Figure 8: State transition diagrams of lizards (a) and predators (b).

The lizards and predators move around the grid vertically, horizontally and diagonally according to their states and their respective speeds. In the state of searching for partners, male lizards move towards the fertile females. When they meet, mating (crossing) occurs based on a pre-defined probability and genetic material is exchanged between then, creating from one to four new individuals, and, in accordance with a small probability, mutation may occur as well. The inherited genetic features which are already part of the prototype are shown in Table 2.

In the prototype the size of the bodies of lizards can vary from 10cm to 30cm. The body size influences the width of the head and the speed of the lizards, as shown in Table 2. Also there are two types of food preferences in the prototype: vegetables or insects. The amount of energy and hydration provided by each type of food are shown in Table 3.

Table 2: Genetic features of the lizards in the prototype.

Feature	Range of values
Gender	*sx* = {female, male}
Body size	*bs* = {10.0cm, 30.0cm}
Head width	*hs* = [*bs*/5 – *bs*/10, *bs*/5 + *bs*/10]
Velocity	*vm* = (*bs*/10) + [1.0, 5.0]
Preference for vegetables	*pf* = [3.0, 7.0]
Preference for insects	*pi* = 10 – *pf*
Minimum hydration threshold	*th* = [20%, 50%]
Minimum energy threshold	*te* = [20%, 50%]

Table 3: Amount of energy and hydration provided by the various types of food. Data based on assumptions made by a researcher of the Calangos team with large experience in the field of herpetology, who conducted extensive research on the lizards of the dunes of the San Francisco River [Rocha et al. 2005].

Type	Item	Energy	Hydration
Vegetables	**Flowers**	2,0	6,5
	Fruits	5,0	8,0
Insects	**Spiders**	3,0	3,5
	Beetles	4,0	4,5
	Termites	5,0	2,5
	Ants	2,0	2,5
	Grasshoppers	3,0	4,0
	Maggots	7,0	5,5

The prototype parameters are:

1. The amount of food in the environment;
2. A fixed number of predators;
3. The speed of the predators;
4. The probability of mutation during reproduction;
5. The size of the initial population of lizards;
6. The number of execution cycles;

Aspects of climate, temperature, humidity, and circadian cycles (day and night) are being developed for the simulator. The genetic features of the lizards which depend on these aspects (such as color pattern and ideal temperature) will be added soon.

5. Results

A preliminary sensitivity analysis of the prototype was carried out, aiming at evaluating the evolution of lizards over time. In this paper three simulations are discussed, in order to show the evolution of the lizards according to different, but biologically plausible environmental situations:

1. **Favorable environment**: A favorable environment for the lizards is the one in which predators move slowly and the amount of food available in the environment is sufficient to feed the whole population of lizards, no matter how large it is;
2. **Hostile environment**: A simulation with fast predators and a reduced amount of food mimics is a hostile environmental situation for the lizards;
3. **Balanced environment**: When the predators are fast, but there is a large amount of food available in the environment for the lizards, the environment shows itself slightly more balanced than in the previous case (hostile environment).

All simulations of the prototype in this paper run 18,000 cycles, with an initial set of 16 lizards with different features randomly generated, 10 predators (land predators with the same constant speed and based on the seriema model), a mutation rate of 1.5% and a 30% crossover rate (i.e., when a male spots a female he has 30% probability of mating her).

Figure 9 shows the progress of the evolution of lizards in a simulation, which was conducted with predators with speeds of two positions per cycle, and a random distribution of 50 fruit-like/flower-like objects and 50 different types of insects.

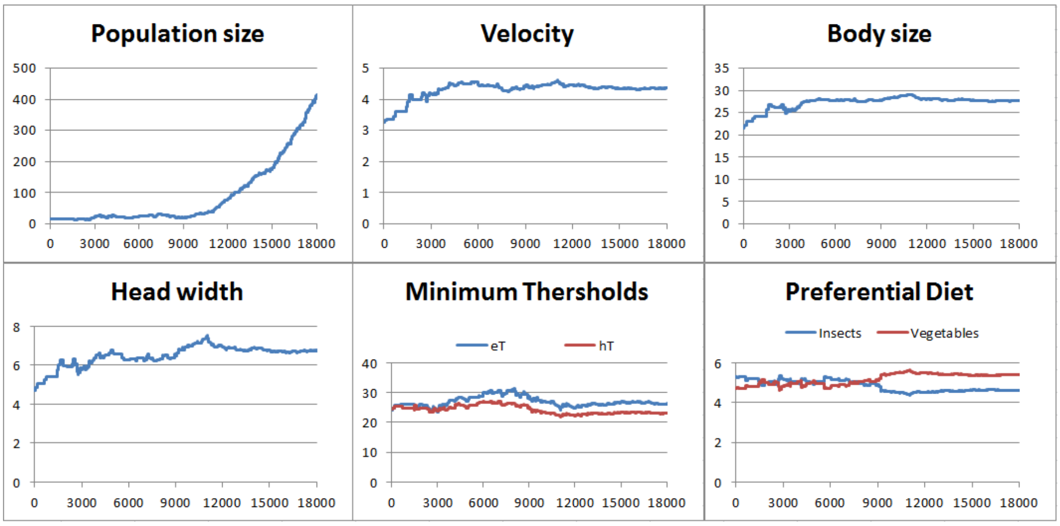

Figure 9: Simulation Results 1: 50 units of each type of food, predators with a speed of two positions per cycle. Data based on the arithmetic average of the attributes of the individuals of the population at each cycle.

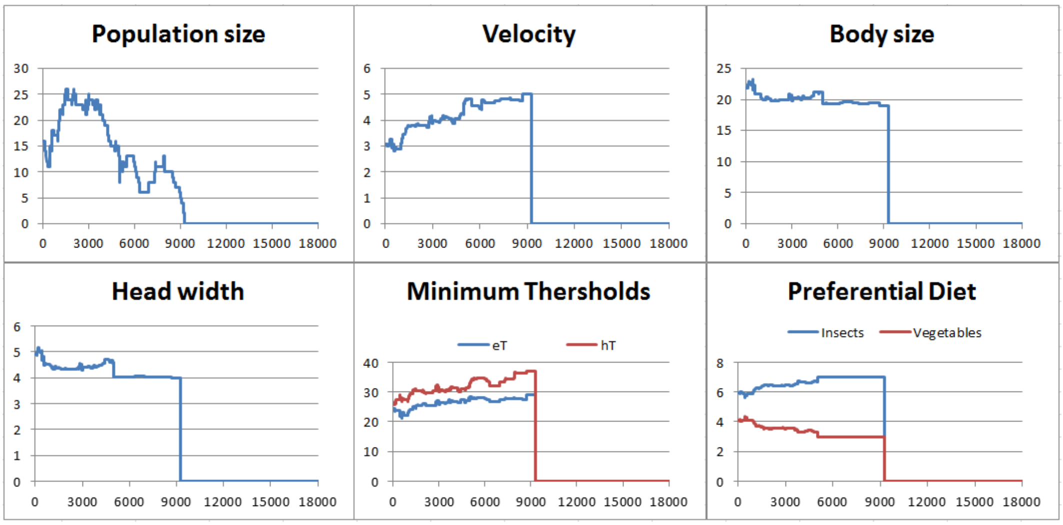

Figure 10: Simulation Results 2: 30 of each type of food, predators speed at seven positions per cycle. Data based on the arithmetic average of the attributes of individuals in the population at each cycle.

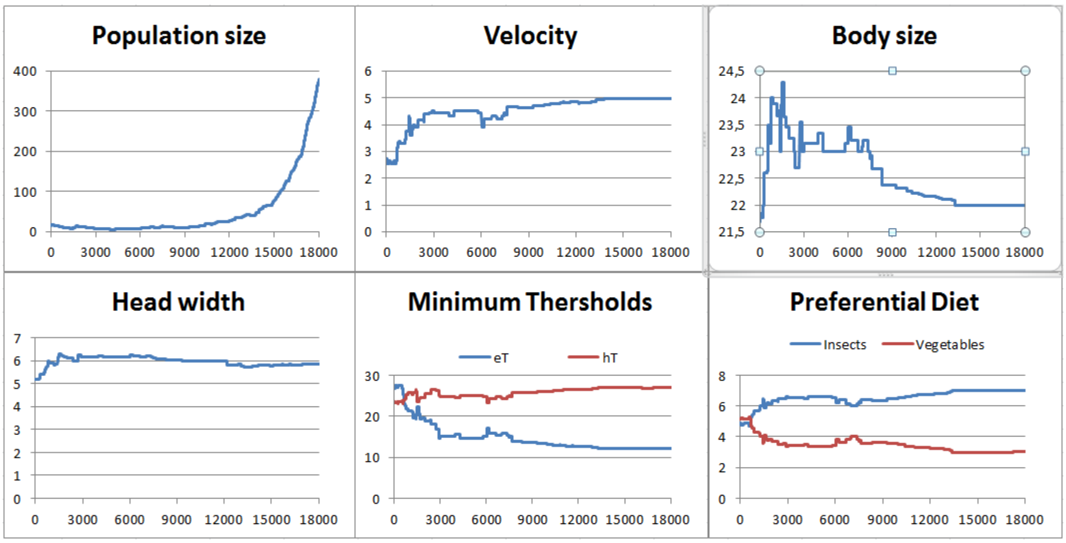

Figure 11: Simulation Results 3: 75 of each type of food, predators with speed of five positions per cycle. Data based on the arithmetic average of the attributes of individuals in the population at each cycle.

In the favorable environment, the amount of food remains the same throughout the simulation, meaning that when an object is consumed, another of the same type is added at a random position within the grid. This is an ideal situation in which lizards will never die of starvation. The goal is to observe how well they deal with their predators. In this simulation the lizards have become faster than the predators, probably due to the large amount of food, leading to an exponential population growth around the cycle number 11,000. The average body size (which may vary between 10cm and 30cm) was 27cm. The body size has a positive influence on the speed of the lizard, but also increases its energy needs. As expected, the abundant amount of food and the fast growth rate of the lizards' body size gave them a good survival advantage, thus promoting an explosion in their population size. It was also possible to observe that the lizards developed a preference for foods providing more energy.

Simulation 2 (hostile environment) was performed with 30 units of each type of food and predators with speed of seven steps per cycle (3.5 times the speed of the predators in the favorable environment of Simulation 1). In this simulation, as we can see in Figure 10, it is observed a fast decay of the population of lizards due to the lack of food and the existence of highly efficient (fast) predators, causing the extinction of the population in 9,274 cycles. The speed of the lizards converged to the maximum possible, showing that selection favored the individuals with greater capacity of fleeing from the predators, among the available features. Also, the average body size was around 20cm, thus balancing speed and energy consumption. The lizards in this simulation acquired preference for insects, possibly due to the higher energy they provide. However, the amount of resources available was not sufficient to maintain a population in which individuals needed a lot of energy to be in constant high speed fleeing. This simulation illustrates how a Calangos player may fail in level 4.

Simulation 3 (balanced environment) had 75 units of each type of food, and predators at the speed of five blocks per cycle (2.5 times the speed of the predators in Simulation 1). In this simulation, depicted in Figure 11, there was a growth in the number of lizards in the population, since the lizards had enough speed to avoid predators. It might be noted that there was a greater search for food high in energy, possibly due to the energy needs of the consequential increase in speed.

6. Conclusions

This paper introduced a simulator for Calangos, emphasizing its Level 4, with the goal of investigating how the environment influences the lizards' survival abilities. In order to do so, we designed three scenarios with various difficulty degrees and implemented a genetic algorithm in order to simulate the evolution of the lizards and their strategies for survival.

The following results were found. When the environment is favorable (great amount of food and slow predators), there is an exponential growth in the number of lizards, they grow large bodies and big heads, develop high (but not maximal) speeds, have a preference for insects, which provide them with more energy, and keep a low balanced energy and hydration levels. In hostile environments (little food and very fast predators), extinction is inevitable even though the lizards prefer insects, which increase their energy for fleeing, and become very fast. In balanced environments (sufficient food and fast predators), there is also an exponential growth in the population of lizards, who evolve large bodies and heads, maximal fleeing speeds, a preference for insects.

With these results in hand it is possible to conclude that a proper understanding of ecology and evolution is necessary for the students to become able to devise suitable strategies for successfully playing with Calangos. The students will have to realize that each environmental challenge faced by him/her will require a different playing strategy, and these are highly affected by the students' capability of understanding the ecological and evolutionary ideas that are relevant in the context simulated in Calangos.

Future works include the addition of other features of Calangos' Level 4 to the prototype, in the course of time, such as weather, circadian cycle, camouflage, maturation of the lizards, a more realistic distribution and "respawning" of the food resources (in order to improve the population control based on competition for food), and also the application of the results in the game.

The development of the game Calangos shows a great promise and challenge, since at each stage of development it reveals its complexity and its variety of contents. Large scientific and educational contributions may emerge from this project.

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