# Computational Modeling for a Creature Editor in the Educational Game Calangos

Jairo Henrique Calmon
Mestrado Multi-institucional em Ciência da Computação, UFBA/UEFS
Salvador, BA, Brazil
jairocalmon@gmail.com

Angelo Loula
Universidade Estadual de Feira de Santana (UEFS), DEXA
Feira de Santana, BA, Brazil
angelocl@uefs.br

Leandro de Castro
Universidade Presbiteriana Mackenzie, PGEE
São Paulo, SP, Brazil
lnunes@mackenzie.br

Pedro L. B. Rocha, Charbel El-Hani
Universidade Federal da Bahia (UFBA), IB
Salvador, BA, Brazil
[charbel,peurocha]@ufba.br

***Abstract*— A character editor associated with a simulation game can provide a rich gaming experience in games for science teaching and learning. Here we to present the computational models developed for an editor of the players character in the game Calangos. In the games second level, the player can edit morphological and physiological characteristics of the lizard so he can experiment with them and achieve more deep understanding of underlying biological concepts related to these changes. Computational models were associated with the creature editor in order to allow such changes to affect game dynamics, what allows the player to verify the possible consequences of each change.**

***Keywords*— educational game; science education; creaure editor; computational modeling**

## I. INTRODUCTION

Electronic games attract attention and a great time from players, making it one of the most important practices of entertainment nowadays. The use of electronic games, however, can go beyond entertainment, reaching applications with educational goals [5][2].

One way to build educational games is by incorporating simulations, developing educational games simulation. The complexity and flexibility of computer simulations allow educators to plan games with more power and instructional precision [6].

One of the areas with the greatest potential to benefit from simulation games is science teaching and learning [1]. Particularly, it is recognized the difficulty in teaching and learning the biological concepts of ecology [9], demanding new ways to contribute to the teaching and learning processes. Ecology is a central subject in biology, when one considers the relationship between ecology and key environmental issues, as well as its the role both in the structure of biology and in citizenship education, given its bearing on important socioscientific issues [7].

The Calangos game project is an educational simulation game for teaching and learning of biology, 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). Involving researchers and developers from several universities (MACKENZIE, UEFS and UFBA), the project's overall objective is to develop and test in classroom situations where an electronic game aids teaching and learning of core concepts of biology related to ecology and evolution.

The objective of this paper is to present the computational models developed for an editor of the player's character in the game Calangos. A key aspect involved in specifying this editor was seeking for the educational relevance and biological plausibility of each characteristic and its possible values. Early results were described in [4] and this paper presents final and detailed results from the computational models developed.

The paper is organized as follows. Section II presents related works with respect to simulation games that have the objective of teaching/learning biology. Section III details the Calangos game and the important aspects of the model. Section IV presents the methodology, which shows the method used to construct the model and details the pedagogical aspects involved. Section V presents the simulation model developed. In Section VI the model and the process is discussed and the final remarks are presented.

## II. RELATED WORK

As examples of educational videogames involving biology and ecology that are similar to Calangos, Web Earth Online™ and SimForest™ deserve attention. Web Earth is an online multiplayer strategy game in which each player interacts 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. SimForest is a forest development simulator that focuses on modeling different aspects of an ecosystem, like Calangos, such as humidity, rainfall, temperature and soil conditions. However, this is not exactly a game, but a simulator for educational purposes.

There are also games that seek to convey the essence and dynamics of the game through characters and propose a character/creature editor. In some cases the changes made by these character editors are only aesthetic, but it is also common that these changes may lead to changes in the dynamics of the game, allowing, for example, that a player gains particular advantage in some aspect of the game (while possibly having some associated disadvantages).

An example of a simulation game that makes large use of character editor is Spore™, which consists, among other things, of creating life and making it evolve, form tribes, build civilizations, modeling worlds and even exploring the universe. It has a robust character editor, and the parameters involved can be visual or have a role in the dynamics of the game, causing serious consequences, since the success or failure also depend on certain features. The editable parameters include the number of legs/paws, wings, number of arms, and other physical characteristics, such as color.

## III. THE GAME CALANGOS

Calangos[1] is a simulation and action game, with 3D visualization, in first or third person, situated in the dunes of the São Francisco, Bahia, Brazil, in which the player controls a lizard (Fig. 1). It is an educational computer game that aims to serve as a tool to support teaching and learning of ecology and evolution at the secondary education level.

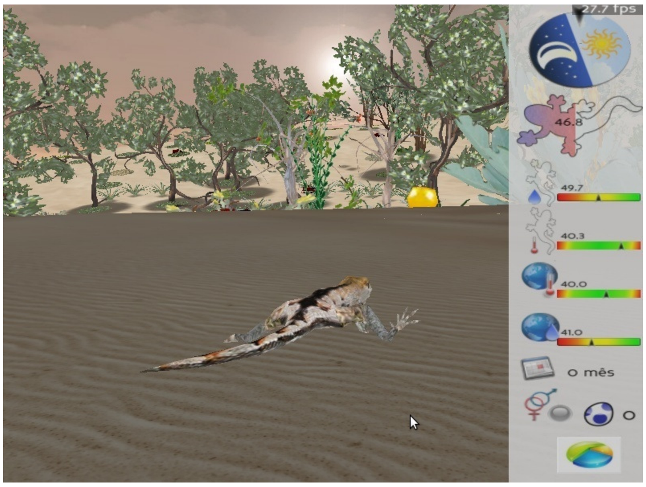


Fig. 1. Screenshot of the game Calangos. The main lizard appears in the foreground, while the background shows the local vegetation. In the right hand side of the figure is the UI, which displays information about the lizard and the world.

Calangos is not a game of direct exposure to contents to be learned by the student-player, but a game in which learning is obtained through the experience of trying to solve problem situations. The game consists of four levels, which are intended to present different concepts through their problem situations. The next section describes the first two levels of Calangos, since the other two levels are still under development and beyond the scope of this paper.

### A. Level I

In this first level, the student-player acts as the main character, a lizard, whose goal is to survive, develop and reproduce. The player chooses a lizard from one of three endemic species: *Tropidurus psammonastes, Cnemidophorus sp. nov.,* and *Eurolophosaurus divaricatus*. The game begins with the lizard in its early life, set in the grounds of the dunes, where the relevant elements of the ecosystem are present, which may be involved in ecological relationships with the lizard controlled by the player. The lizard grows over time and can reproduce when sexual maturity is reached.

Among these elements, there are several species of flora, many typical preys, species of predators and some animals not involved in the food chain of the lizard. Other lizards of the same species, with which ecological relationships can be established (e.g. competition for territory, for prey and mates), are also present in the environment. The player's goal is to survive until adulthood and reproduce, generating offspring. The player's success is related to the amount of descendants that the lizard managed to generate and how long it lived.

Besides fauna and flora, there is also an environmental modeling focused on the simulation of lizard-climate relationships [3]. Such environmental simulations in the game are based on the ecological case and include air temperature, ground temperature, burrows temperature, rainfall and air relative humidity, considering their spatial and temporal variations. These climate variables affect the lizard's internal state, such as body temperature, lizard's energy expenditure, stored energy and hydration. Fig. 2 shows some of the relations between the external and internal variables of the lizard.

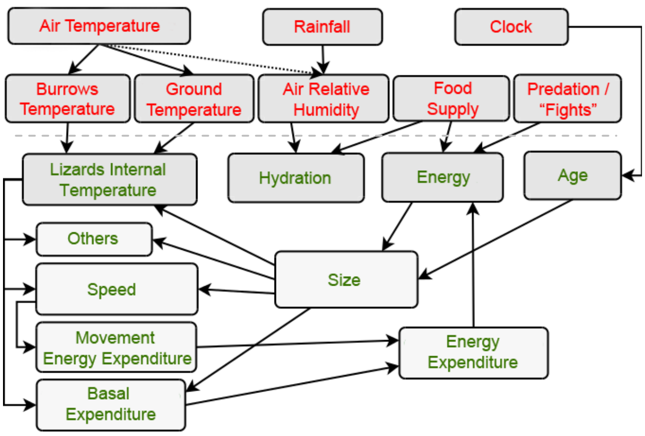



Fig. 2. Diagram with some relations between the external influences (in red, above the dashed line) and internal variables of the lizard (in green, below the dashed line).

### B. Level II

Building upon the first level of the game, the second level allows the player to edit morphological and physiological characteristics of the lizard, such that he/she can experiment with them and achieve a deeper understanding of the underlying biological concepts related to these changes, since it would be possible to test multiple possibilities and verify the consequences by playing the game. This was the motivation for creating a character editor with such features and consequences mapping, because it is a playful way of presenting such concepts to the players, fulfilling the proposed pedagogical objective.

By playing the first level, the player would learn important concepts involved in keeping the lizard alive (survival) and mating (reproduction). In the second level he will have the op-

[1] The Calangos game is freely available at http://calangos.sf.net .

portunity to test his initial strategy and knowledge, and acquire a better understanding of the game rules and simulation dynamics by changing the physical characteristics of the lizard and playing with it. Thus, he/she may, for example, want to increase the size of the lizard in the editor, since he/she noted from the first level that the bigger the lizard, the faster it will move, and the greater its success in disputes over females. However, the player will also realize, for instance, that bigger lizards have greater energy expenditure and become more visible to predators.

## IV. BUILDING THE CREATURE EDITOR

A starting point in the development of the character editor involves an interaction cycle for the user in the second level. Every feature modified by the player had to change the game dynamics somehow and this change should be observed or noticed while playing. However, there should be no trivial ways of improving the character, making the player try different values for the features so as to understand their outcomes (consequences).

Fig. 3 shows this constant cycle of formulating hypotheses about how the current features in the editor affect the lizard, the environment and the game dynamics, then applying such assumptions using the editor, trying to improve success in playing the game. The consequences of these changes made in the editor are tested by playing and receiving feedback given by the game as a way to validate and refine the player's hypotheses and knowledge.

In the first level the player controls a given lizard and interacts with the game environment (other characters, vegetation, climate, etc.), perceiving the ecological relationships that determine the problem situation of survival and reproduction (Fig. 4). Among the various relationships present, the player may realize that, over time, as the lizard becomes older and bigger, its features are slowly modified and thus ecological relationships are also changed.

In the second level the player has the opportunity to explicitly edit various features of the lizard, so he/she could observe more clearly the concepts related to each change, since it would be possible to repeat and control the cycle of feature editing and consequence observation (Fig. 5). The player starts to make changes in the features of the main character (lizard) and the environment by using an editor, and such changes are reflected in the game.

It is important to note that to follow this approach, it is of great importance to carefully define the set of features to be edited. To achieve this, it was necessary to work in conjunction with a multidisciplinary team, including science educators and biologists, to map and follow the educational prerequisites of the game and target audience (high school students), and to verify the scientific plausibility based on the ecological case, through the several rounds of specifying, modeling and validating the features and their consequences to be brought into the game.

The editable features of the lizards include size, speed, and diet preference, as detailed in Section V. The changes made in the editor produce different impacts on different game entities, changing settings and attributes as well as altering their interaction dynamics (as shown in the arrow pointing to another arrow in Fig. 5). The feedback from these changes is given by the simulation and should thus be perceived by the player through the act of playing.

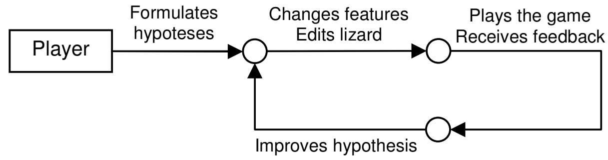



Fig. 3. Interaction cycle expected by including the editor in the second level of the game.

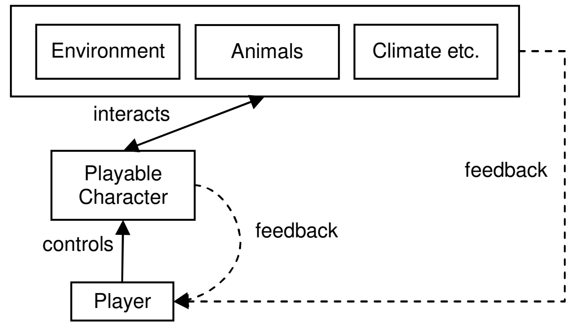



Fig. 4. Relationship between player and game in the first level of Calangos.

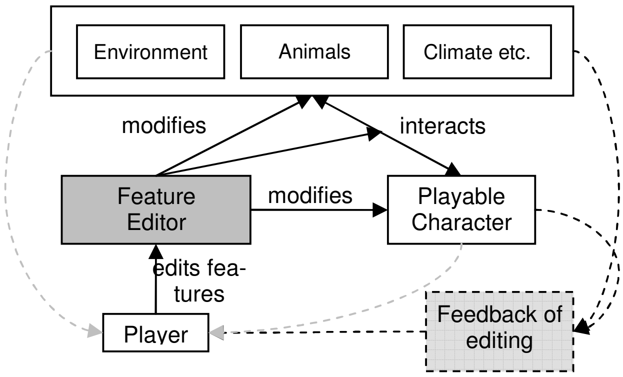



Fig. 5. The relationship between player and game changed for the second level of the game.

## V. SIMULATION MODELS

The creature editor developed for the educational game Calangos allows the player to change several lizard's feature, including body size, head width, color pattern and camouflage, burying in the sand, ideal internal temperature, dietary preference, maximum speed, and density and aggregation of cospecifics. Each of these features was planned to have both positive and negative consequences at all its possible values, so the player would not have a trivial choice but would have to search for balance between the features and the game strategy adopted.

Each feature and consequences were modeled in the game through mathematical equations and algorithmic procedures, as described next.

*A. Body Size*

The size of the lizard is a key feature of the game mechanics. The larger the body, the greater its speed and ability to inhibit the attack of predators, but the greater the difficulty in regulating the body temperature, the demand for food and water, and the time necessary to reach maturity.

In the first level, the ultimate size that the lizard could reach was fixed. The lizard started with a given size, was able to grow monthly according to its average energy during each month. If energy was kept above 90% every month, the lizard would reach its maximum possible size in the last month of life. Otherwise, growth was proportional to the average energy level.

In the second level of the game, the player can use the editor to change the final size of the lizard (growth calculation followed the same procedure as before) in order to allow the player to observe, by playing, the impacts and consequences of his/her decision. A lizard with a bigger body consumes more energy and food intake should be greater, since the basal metabolic rate of the lizard is also increased, as will be described later.

The player uses the editor to choose the adult size of the lizard. There is a range of possible lizard sizes, which varies from $S_{min}$ to $S_{max}$. Note that this is the final potential *adult* size at highest growth, which is not the initial size at the beginning of the game, but the initial size is proportional to the final adult size. Fig. 6 shows the relation between the lizard sizes.

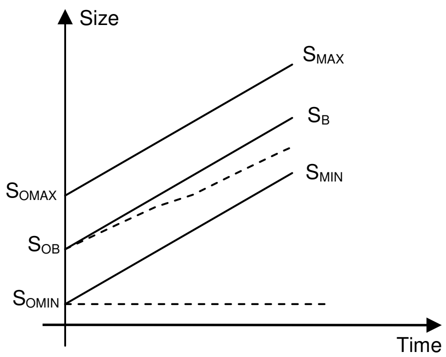



Fig. 6. Chart showing the relation between the sizes of the lizard. $S_{OB}$ and $S_B$ are the minimum and maximum sizes in the first level of the game. The dashed line represents a possible growth trajectory of a lizard that does not keep energy at highest levels. $S_{MIN}$ and $S_{MAX}$ are the final adult lizard size for the second level, as chosen using the editor. The lizard starts its life with a percentage of its final adult size, represented by $S_{OMIN}$ and $S_{OMAX}$.

From the size parameters shown in Fig. 6 and the current lizard size $S$, it is possible to obtain a normalized size $\delta$, a value between 0 and 1, calculated by Eq. (1). This factor has an impact over several aspects of the simulation dynamics, as it is shown next.

$$\delta = \frac{S - S_{OMIN}}{S_{MAX} - S_{OMIN}} \quad (1)$$

*1) Consequences in the Thermal Equilibrium Time*

Thermoregulation is a factor of great importance for the lizard, since it is an ectothermic animal, which regulates its internal temperature through behavior. According to the climate-lizard relationship model, the ground temperature influences the lizard's internal temperature. Eq. (2) shows how the thermoregulation dynamics is done.

$$T_L(t+1) = T_L(t) + TE(t) \cdot (T_G(t) - T_L(t)), \quad (2)$$

where $t$ is the time instant, $T_L$ is the lizard's internal temperature; $T_G$ is the ground temperature; and $TE$ is a thermal equilibrium factor that represents how fast the lizard internal temperature reaches thermal equilibrium with the ground temperature.

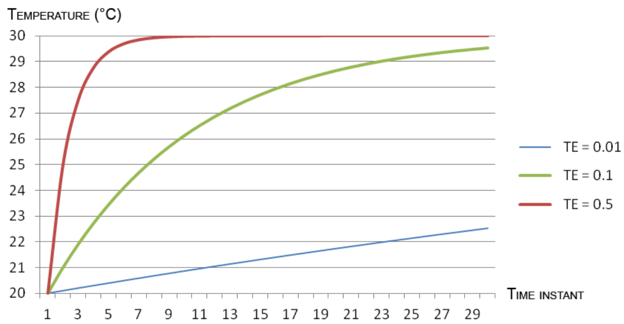



Fig. 7. Chart showing the effects of different TE values in the thermoregulation dynamics. In this instance, the ground temperature remains 30°C and the lizard's internal temperature at $t = 0$ is 20ºC.

According to [10] the shape and size of the body substantially affect the physiological thermoregulation control. Considering only the physical features, larger animals should warm up and cool down more slowly than smaller animals, and the reason for this phenomenon is called *thermal inertia*, which was also modeled in Calangos.

The lizard's thermal inertia increases as the lizard grows, being one of several properties affected by increasing the size of the lizard in the second level. It was modeled here as the aforementioned thermal equilibrium factor, as shown in Eq. (3).

$$TE(t) = C_{TI} + [1 + (\delta_{NN}(t) \cdot K_{BE})], \quad (3)$$

where $C_{TI}$ is a thermal inertia constant, empirically determined; $\delta_{NN}(t)$ is the bipolar normalized size of the lizard, as shown in

Eq. (4), in the range (−1, 1), and $K_{BE}$ is a constant representing a percentage of influence of the size factor.

$$\delta_{NN}(t) = (\delta(t) - 0.5) \cdot 2, \quad (4)$$

where $\delta(t)$ is the normalized size of the lizard at the respective time using the range (0, 1).

It is possible to note that the size factor has its gain modulated by some value (80%, for instance) and has the effect of increasing or decreasing the chosen $C_{TI}$ up to the chosen percentage, which, lastly, affects the time to achieve the thermal equilibrium.

*2) Consequences in Basal Energy Expenditure*

According to [8], basal energy expenditure refers to the minimum energy expenditure for an animal to maintain its basic functions in a condition of fasting, physical and mental rest in a quiet environment with controlled temperature (disregarding the possible external variables).

In the first level, it was provided by the team of biologists that a lizard should survive a certain number of days without any food intake, once it is not exposed for prolonged periods at high temperatures, and remains most of that time in rest. With this reference, basal energy expenditure was modeled by Eqs. (5) and (6).

$$E(t + 1) = E(t) - \beta(t), \quad (5)$$

where E is the energy score of the lizard; and $\beta$ is the basal energy expenditure, calculated as follows:

$$\beta(t) = (E_0 / P) \cdot (1 + \delta_{NN}(t) \cdot K_{BE}), \quad (6)$$

where $E_0$ is the initial energy score; P is the maximum period of time the lizard can live without food; $\delta_{NN}(t)$ is the bipolar normalized size of the lizard (Eq. (4)); and $K_{BE}$ is the desired influence (in percentage) of the size factor.

Fig. 8 shows a scenario with different sizes of lizards and all other effects disregarded.

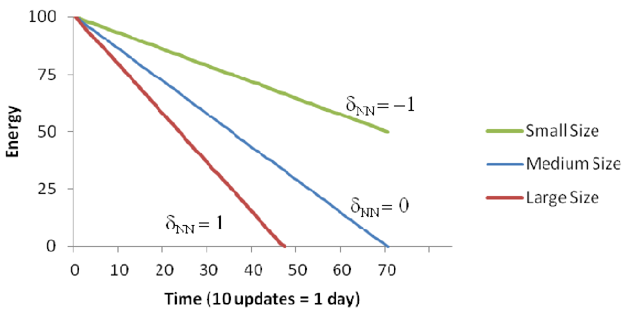



Fig. 8. Chart showing the effects of the size in basal energy expenditure by comparing three different sizes of lizards (small, medium and large-sized). It is considered $K_{BE}$ as being 50%, $E_0$ = 100. It is possible to see, then, the impacts of the size in $\beta$ as the constants are set. The medium sized lizard will live a week, the big lizard will live two weeks and the small one almost five days.

In other words, once the lizard gets bigger, so does its basal energy expenditure. Thus, the lizard will have its energy levels decreasing at a higher rate, which implies the need to consume more food in order to accomplish one of the basic objectives of the level: to survive.

*3) Consequences of Size in Food Intake*

As discussed before, an increase in the size of the lizard implies an increase in the basal energy expenditure, which will cause the energy level of the lizard to decrease at a higher rate. Thus, bigger lizards need to consume more food in order to stay alive in the game.

*4) Probability of Predator Attack*

Another consequence of the change in the size of the lizard is that it changes the predator-prey dynamics. As the lizard grows it becomes more easily seen by predators. However, depending on the size of the predator, bigger lizards offer greater resistance to predation and may even react to it.

With this information, it was decided that there should be an increased likelihood of attack inversely proportional to the size of the lizard, but the lizard should have a new feature of attacking predators. This functionality was modeled by altering the lizard's visibility to predators, as will be described in Section V.C.

*5) Change in Sexual Maturity Age*

The sexual maturity of the lizard is defined by the age at which it will be able to reproduce. In the first level of the game, the lizard starts young, and struggle to survive up to 12 months of age (the lizard lives up to 36 months in the game). Thus, upon reaching 12 months of age, the lizard, regardless of size or energy levels during that life time, gains the ability to reproduce, which does not mean it will succeed in courting a female.

In the second level of the game, the sexual maturity age is not fixed and depends on the ultimate adult size chosen in the editor. The lizard now is mature when it reaches a certain percentage (currently 70%) of its ultimate adult size, which depends on the growth rate, that depends on the monthly average energy level.

## B. Head Width

Different head sizes promote different restrictions on the types of food that are consumed. Larger heads can catch larger food, but have difficulty manipulating small ones, while small heads have difficulty in handling big food.

This feature intrinsically needs a visual feedback, and that was made by handling the skeleton of the main character to reflect the user input. Fig. 9 shows a preliminary visual feedback using one of the playable lizards.

Upper and lower limits for head size were defined and the user can choose a size within these limits. The chosen value is applied to the lizard 3D model. For food size restriction, the mouth size is estimated (using the lizard size and head size) and then it is determined the smallest size of food the lizard can consume (a factor of 0.2 means, for instance, that it is only possible to eat a prey greater than 20% the size of the mouth).

(a)
(b)
(c)

Fig. 9. Lizards with different head sizes. In (a) a lizard with a normal head size. In (b) a lizard with a larger head. In (c) a lizard with a smaller head.

### C. *Color Pattern and Camouflage*

Different coloring patterns may favor the camouflage of the lizard or make it more visible to predators. Depending on the choice of colors, the location and the ambient light, the lizard may become harder or easier to be seen by predators, but also more or less visible to co-specific females, hindering or facilitating reproduction. This was a new element modeled in the game, changing the relationship lizard-predator and lizard-lizard.

The camouflage of the lizard in the game is a feature that basically defines how indistinct from the surrounding environment it looks. This is a feature that depends on the viewer's perception and, therefore, was modeled as "visibility to predator" ($\upsilon$). The characteristics that influence the visibility level to predators are the following:

- Distance between the predator and the lizard (*d*).
- Predator's sight efficiency at current time of day ($\gamma$).
- Lizard's normalized body size ($\delta$).
- How "hidden" in the environment is the lizard ($\varphi$)

Eqs. (7) and (8) show how the modeling was done.

$$\upsilon = s\left(1 - \frac{d}{D_{max}}\right) \cdot \gamma \cdot \delta \cdot \varphi \qquad (7)$$

$$s(x) = \begin{cases} 0, \text{ if } x < 0 \\ 1, \text{ if } x > 1 \\ x, \text{ otherwise} \end{cases} \qquad (8)$$

Table I shows predators sight efficiency used by the model.

TABLE I. SIGHT EFFICIENCY OF THE PREDATORS

| Predator | Sight Efficiency (%) (Day/Night) |
|---|---|
| S C Carcara | 100 / 70 |
| Seriema | 100 / 100 |
| Owl | 20 / 100 |
| Tegu (Tupinambis) | 100 / 100 |
| Fox | 100 / 80 |
| Cat | 100 / 80 |
| Colubridae | 100 / 100 |
| Jararaca | 100 / 100 |

The player's camouflage factor $\varphi$ given by Eq. (9) is obtained by taking the maximum value among camouflage features, which varies from 0 to 1:

1. How well the colors of the lizards (chosen in the texture editor) match the current location of the lizard. It is a range in which a value 0 means the lizard is very different from the background and a value 1 means the lizard is perfectly camouflaged ($\sigma$).
2. If the player is buried in the sand or in a burrow, in which case the player is considered totally or somewhat camouflaged ($\eta$).
3. A distance factor from the closest vegetable in the environment, meaning that the player can hide by being close to vegetation. This value is calculated using the relation between the closest vegetable distance and the maximum distance to consider the player camouflaged.

$$\varphi = max\left(\sigma, \eta, s\left(1 - \frac{d_{p \to v}}{D_{maxV}}\right)\right) \qquad (9)$$

To allow the player to change the visual aspect of the lizard, a lizard texture editor was developed (Fig. 10), in which the player can choose the pattern (there are currently four patterns) and colors to be applied to the pattern (different patterns require different numbers of colors – up to three).

### D. *Burying in the Sand*

This feature allows the lizard to hide from predators, thereby reducing the chances of being attacked. By selecting this feature, the player's lizard acquires the ability to bury, but the thermal equilibrium time is decreased, causing the lizard to heat up more quickly when not buried, with greater reduction when buried, besides not being able to move while buried and a decrease in movement during a small period of time after the lizard unearths.

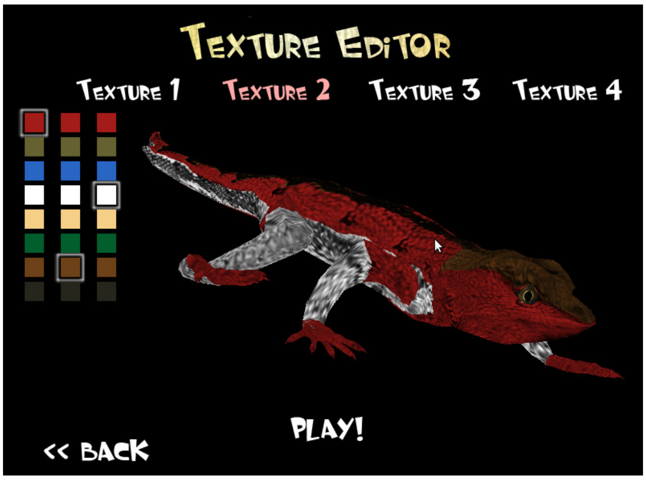
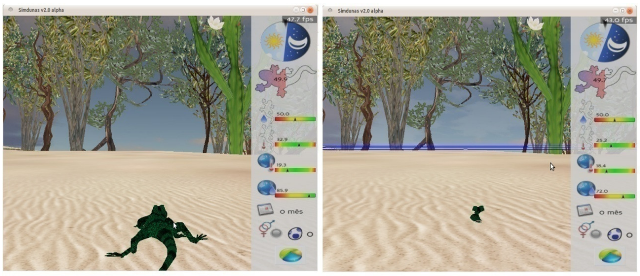



Fig. 10. Screenshot showing the Texture Editor. The user can choose the pattern (from the four textures available, at the top) and the colors of the lizards depending on the texture the player chooses (color pallete at the left side). In the screenshot the player chose "Textura 2", which allows three colors.

The decrease in thermal equilibrium is achieved by modulating the term TE (Section V.A.1) by a factor ω. Thus, a lizard without the burying ability has ω = 1.0 (causing no change in the time to reach equilibrium), and a lizard with the ability to bury could have ω = 1.2 (indicating an increase of 20% in the thermal equilibrium, which indicates that a shorter time to reach thermal equilibrium with the ground). While buried, this factor is further increased (ω = 1.5).

Fig. 11 shows the visual feedback of this feature in the game, comparing the lizard standing over the ground at an idle state and the state after the bury action (after the sink animation).



(a) (b)

Fig. 11. Comparison between (a) the lizard over the ground and (b) the buried lizard. Note that in (b) only the head of the lizard is outside the sand.

### E. *Ideal Internal Temperature*

The ideal internal temperature is another important element of the lizard's internal dynamics, since one of the goals is an effective thermoregulation of the playing lizard. The lizard should thermoregulate by seeking the sun when the internal temperature is low, and shadows when the internal temperature is high. It is noteworthy that the optimal internal temperature of the lizard (at which it has no negative consequences) is actually a range, which is simply defined as an ideal value and a given tolerance.

The lizard also has attributes that define the extreme minimum and maximum temperature supported. Thus, achieving such temperatures means that the lizard may die due to either low or high temperature (two of the causes of death of the lizard in the game).

Fig. 12 shows an example of the various temperature attributes of a possible lizard. The ideal temperature in this case is indicated by the arrow and corresponds to 35°C. There is a range of ±5 degrees (for instance), where the temperature is considered ideal. If the temperature is smaller than this range, the lizard begins to undergo a type of lethargy (slower movement and possible failure in actions) applied linearly from the minimum temperatures that the optimal range allows (30°C) to the minimum temperature supported (15°C) by the lizard, in which case the lethargy will be maximum and the lizard will die. In that range, there is also a decrease in energy expenditure by the lizard, causing it to spend gradually less basal energy as it approaches the 15°C point. In case the temperature is higher than 40°C, the lizard will spend more energy until it reaches a temperature of 55°C, when the lizard will die. For more details on internal temperature equations see [3].

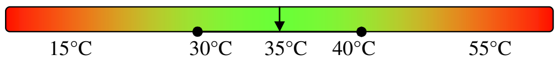



Fig. 12. Range of lizard's temperature. Note the minimum and maximum temperature limits of a lizard (15°C e 55°C, respectively). The center holds the chosen ideal temperature (35°C) and the ±5°C margin.

The player can set the ideal temperature value (retaining the same tolerance range of Level I and within the biological limits specified by the team of biologists), in order to verify changes and difficulties caused by this choice during game play, adapting to it and noting that, depending on the strategy chosen, a certain temperature range would be more beneficial.

A simple example of a player strategy would be that, during the day, there is a greater necessity for thermoregulation, and since it is desirable to explore the environment, the lizard would have to go to the sun (raising the lizard's internal temperature), and, after a short period of time, it would have to go back to shadows (returning to the acceptable temperature range). If the ideal internal temperature of the lizard was greater, a player may think his/her lizard could stay longer under the sun, exploring the environment, without the urge to cool down the lizard under a shadow. This kind of thinking would force the player to change the feature in the character editor, causing it to test his/her hypothesis and realize, during gameplay, whether his/her hypothesis was actually valid or other important factors were not taken into account, as, for instance, how this choice would influence the night period.

### F. *Maximum Speed*

The lizard speed is also a relevant factor in the game. Survival depends in part on the successful escape from predators and a good speed is an important feature in prey-predator dynamics, despite the fact that all predators are larger and faster than the lizard. Nevertheless, a faster escape can lead to less energy loss, since there would be a smaller number of predator attacks, each of which reduces energy.

Another advantage is that the lizard can explore the environment quickly and may even contribute to a greater reproductive success, since the lizard may find more females given a certain amount of time.

However, there are also disadvantages in having higher speed. In such case, the energy expenditure of the lizard becomes larger (it consumes more energy as its speed is increased), while increasing basal cost due to its fast metabolism. Thus, the lizard will disadvantage of having a higher demand for food.

The modeling was simplified. In the editor, minimum and maximum parameters limit the range of velocities the player can choose from. Once the player has chosen the speed of his/her lizard, it is possible to calculate a normalized speed (factor varying from 0 to 1, based on the minimum and maximum values), which will then be applied to the features that are affected by the speed, as, for instance, the energetic cost per speed unit.

### G. Dietary Preference

The diet, or dietary habit, of the lizard is another relevant factor in the game, due to the very nature of such a characteristic, since an animal must eat to survive, as well as the simulation nature that the game proposes. Throughout the game the lizard can consume a variety of food items (insects, flowers and fruits), each one contributing with a given amount of energy and hydration to the lizard. Table 2 indicates the reference values of hydration and nutritional values of prey, flowers and fruits.

TABLE II. ENERGY AND HYDRATION PROVIDED BY DIFFERENT FOOD ITEMS.

| Food Item | Energy | Hydration |
|---|---|---|
| Ants | 2.0 | 2.0 |
| Termites | 3.5 | 2.0 |
| Spider | 2.5 | 3.0 |
| Beetle | 3.0 | 3.5 |
| Larva | 5.0 | 3.5 |
| Cricket | 2.5 | 3.0 |
| Flowers | 2 | 6.0 |
| Fruits | 5 | 7.5 |

Based on information given by the biologists' team, it was decided that the lizard could have three distinct types of diet preferences in the game: (a) ants, (b) fruit and flowers, and (c) other types of food.

In the second level, the player defines the lizard diet by choosing a percentage for each type of dietary preference, defining the lizard specific dietary preference. The energy value of each food consumed by the lizard is modulated to reflect the diet preference chosen by the player (as seen in Fig. 13). If the lizard diet is "ant-specialist", for example, an ant will have greater nutritional value, while other types of food will have a lower nutritional value.

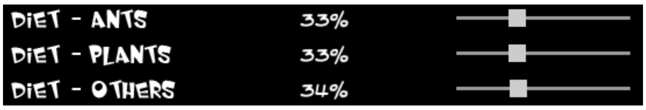



Fig. 13. Diet parameters in the lizard feature editor.

Thus, the player can evaluate various dietary strategies based on his/her observations during the game and verify whether such strategies worked or not. A player, for instance, could have the perception that ants are usually found in groups, but are not much frequent in the environment and their nutritional value is small. If this lizard was specialist in consuming ants, this could have an advantage since once it finds a group of ants it would recover enough energy despite the fact that it is not much common to find them.

This feature was modeled as a modulation in the nutritional values of each food type eaten (Eq. (10)). Thus, as each food has its respective nutritional value, depending on how the player has chosen the diet, it is possible to assign a higher or lower value to the original one:

$$F_C(a) = F_E(a) \cdot \sigma(a) \cdot 3, \quad (10)$$

where $a$ is the type of food to be consumed, $F_C(a)$ is the value after modulation for that type of food; $F_E(a)$ is the energy value before modulation for that type of food; and $\sigma(a)$ is the value chosen in the editor for that type of food.

Assume, for example, that the user chose the following sliders values: 80% for ants; 6% for plants; and 14% for others. In the Level 1, if the player eats 10 ants, it will gain 20 points of energy (see Table II). With this new model the consumed value for individual ants will be 4.8, and the total for the 10 ants will be 48 points in energy. However, as can be noted, if this same lizard consumes only 10 fruits in the game, it would have 50 points of energy in the first level and only 21 points of energy with this new dietary preference. In other words, this model works by increasing the nutritional value of the preferred diet items at the cost of reduced nutritional value for the remaining items.

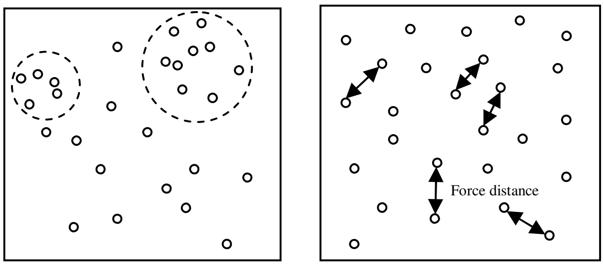
### H. Density of Species and Aggregation of Lizards

The lizard's population density alters gameplay. Among the consequences caused by the rise in the number of lizards is the growth of competition and lack of food. On the other side, the more lizards in a given region, the lower the chances of the lizard controlled by the player being chased by a predator (since the predator can now pursue other lizards). Although females should also be more easily found, more male lizards will be around to compete for them (reproduction dynamics). As for aggregation, it causes the emergence of groups of lizards, changing how the player will interact with other lizards.

Lizards' density is modeled by how many lizards are present in the game. The player influences a density value indirectly, by choosing the total number of lizards present in the environment, given upper and lower limit values.

Aggregation was modeled, first, by defining three different distributions:

1. **Random**: lizards have no specific distribution patterns (Fig. 14.a).
2. **Dispersed**: lizards have an explicit tendency to move away from other lizards (Fig. 14.b).
3. **Grouped**: lizards have a tendency to approach each other and stay grouped, and the number of lizards that have this trend is set by a slider.




(a) (b)

Fig. 14. Different types of aggregation. In (a) the random aggregation (which supports groups and individual lizards). In (b) the strongly dispersed type of aggregation, in which the lizards are purposefully pushed away from one another.

The number of lizards per group is chosen by the player and the number of existing groups is a direct relationship with chosen density:

$$numGroups = \frac{chosenDensity}{numLizardsPerGroup} \quad (11)$$

It was also decided that the aggregation would be modeled by changing the radius of the groups. Thus, it was established a minimum and maximum radius for the group of lizards. The aggregation factor, ranging from 0 to 1, works by modulating the radius using the simple linear interpolation of Eq. (12), as shown in (13).

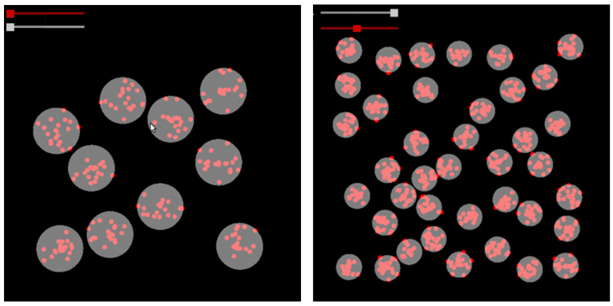
$$lerp(a, b, \alpha) = (1.0 - \alpha) \cdot a + (b \cdot \alpha), \quad (12)$$

where $a$ is a minimum value; $b$ is a maximum value; and $\alpha$ is the desired factor. For example, for $a = 12$, $b = 20$; $\alpha = 0.5$, the result would be 16.

$$R = lerp(R_{min}, R_{max}, aggregation), \quad (13)$$

where $R_{min}$ is the minimum radius; $R_{max}$ is the maximum radius; and *aggregation* is the modulating factor.

To test the aggregation patterns, a separate simulator was developed, so as to optimize the development time and to provide a way to better visualize this feature (Fig. 15). After validation, the solution was added to the game.



(a) (b)

Fig. 15. Simulation with two sliders on the top that control, respectively, the density and aggregation. In (a) the density and aggregation control at their minimum values. In (b) the maximum density value, and 50% aggregation.

### *I. The Editor*

The editor was then implemented in the game (Fig. 16), and once the player chooses to play the second level, the editor is available for him/her to make changes and observe the consequences of those changes in the game play.

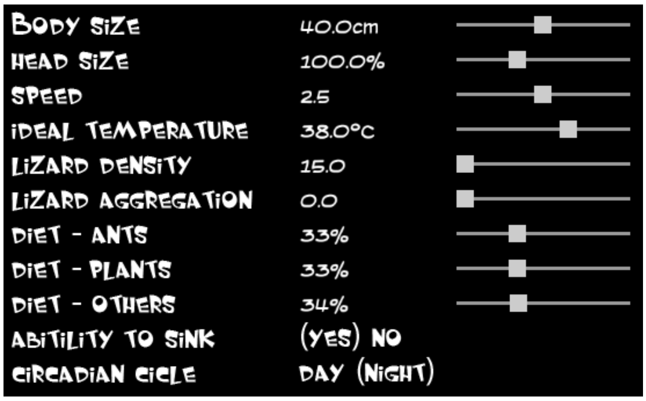



Fig. 16. The editor implemented, showing the parameters modeled in this paper. Note that the second part of the editor corresponds to the Texture Editor, already shown in Fig. 10.

## VI. Discussion and Final Remarks

The proposed creature editor allows the student-player to vary many features of the player's lizard in Calangos. Computational models were associated with the creature editor so that such changes affect game dynamics, what allows the player to verify the possible consequences of each change.

The most relevant aspects of the editor, as a result, are the computational models behind it, which translate character editing into game rule changes. The editor allows free changes of lizard's features, with no points or costs in editing, as in a racing car game editor where the players needs more points to get better car features. In the creature editor in Level 2 of Calangos, the player objective is not to search for the best lizard in a hill climbing manner. The student-player is confronted with a great set of lizard features with complex tradeoffs and his/her objective is to understand those tradeoffs and, by doing so, understand the underlying biological concepts.

To build the simulation model for the creature editor, it was necessary to have a solid understanding of the concepts involved, so as to fulfill the educational purposes. It is important to note that works regarding the modeling and production of editors or other artifacts for educational games are rarely found in the literature. The present work had, therefore, several challenges due to its specific nature and the concern with the pedagogical and biological constraints and adequacy with reality, since it expected, in the context of an educational simulation game, content to be presented in a responsible and non-misleading manner.

In this context, it is important to state the importance of Calangos' multidisciplinary team to the development of this work, and for the game as a whole. The team is composed basically of some roles: biologists, educators and programmers. The team of biologists helped in mapping the requirements for the editable parameters and consequences caused by those changes, and during the process it was possible to visualize the importance of the concepts studied. The biologists and educators also helped testing and validating what was being implemented.

Regarding the educational evaluation of the game, the educators of the team have already begun a study on the use of the game. Level I had an initial evaluation in a public high school, where, in the first moment, experiments were conducted in three classes. The results of the experiments are being analyzed and Level II, presented here, will also be evaluated soon.

## ACKNOWLEDGMENTS

The authors would like to thank FINEP, CNPq, Fapesp, Fapesb, UEFS and Capes for the financial support. CNPq granted PLBR and CNEL, a research fellowship during the development of this work.

## REFERENCES

[1] M. Honey, and M. Hilton. "Learning science through computer games and simulations". Washington, DC: National Academies Press. (Eds). 2011.

[2] J. Kirriemuir, and A. Mcfarlane, "Report 8: Literature review in games and learning". Futurelab Series. 2004.

[3] A. C. Loula, E. S. Oliveira, Y. J. Munoz, M. M. F. Vargens, A. L. Apolinário; L. N. Castro, P. Rocha, C. N. El-Hani. "Modelagem ambiental em um jogo eletrônico educativo". Simpósio Brasileiro de Jogos e Entretenimento Digital - SBGames. 2009

[4] A. Loula, J. Calmon, L. Castro, C. El-Hani. "Modelagem ecológica para um editor de criaturas de um jogo educativo". X Simpósio Brasileiro de Jogos e Entretenimento Digital (SBC – Procedings of SBGAMES 2011). 2011.

[5] M. J. Mayo. "Games for science and engineering education". Communications of the ACM 50(7), 30-35. 2007.

[6] L. P. Rieber, and D. Noah. "Games, simulations, and visual metaphors in education: antagonism between enjoyment and learning". Educational Media International, 45(2), 77-92. 2008.

[7] T. D. Sadler. "Evolutionary theory as a guide to socioscientific decision-making". Journal of Biological Education, 39 (2), 68-72. 2005

[8] M. L. Costa, P. G. L. Speridião, U. Fagundes Neto. "Gasto Energético". The Eletronic Journal of Pediatric Gastroenterology, Nutrition and Liver Disease, 11(1). 2007.

[9] E. Sanders, P. Jelemenská, U. Kattmann, "Towards a better understanding of ecology," Journal of Biological Education, vol.40, pp.119-123, 2006

[10] R. D. Stevenson. "Body size and limits to the daily range of body temperature in terrestrial ectotherms." American Naturalist, p.102-117, 1985.