# Implementation and evaluation of simple artificial creatures using neural networks for perception interpretation

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**Abstract.** This paper contains both the description and the evaluation of a simple artificial creature system. The implemented model's perception system uses a color representation of smells which are recognized by a neural network by mapping RGB colors in drives variation vectors. The creatures behaviors are fully reactive and based on achievement of homeostasis. The drives the system seeks to balance are energy (eating), grouping(being close to other of same species), spacing (being sufficiently apart from other creatures) and fear (being far from other creatures of different species). The resulting behavior in the 3-dimensional world suggest the approach is reasonable due the seemingly natural tendency of grouping and seeking for food without the superposition of individuals with a simple criteria for action selection based on the search for homeostasis.

**Keywords:** homeostasis, grouping behavior, reactive behavior, neural network, emergency of behavior

**1. Introduction:** It's important for the student of cognitive sciences to understand the complexity involved in the emergency of behaviors. It would be relatively straightforward for the experienced programmer to implement an artificial creature so it exhibits a natural behavior given a finite set of sceneries. If that's so, then why expend so much effort trying to create the same result with emergency of behavior?

The more complex the creature, the bigger the set of possible actions given a situation. If the cognitive scientists ever intend to mimic such complex behaviors like those the human being is capable of performing, it is certainly necessary for them to be able to allow behaviors to naturally emerge. The first step to create such a complex and unpredictable creature is to be able to create the simpler ones, with a small set of easily predictable behaviors.

This work can be considered an application of various concepts defined in the literature and the simplification of ideas proposed by renowned authors so to create a simpler, and therefore more restrict, agent. Even as such, this a means for the comprehension of the basic principles for behavior emergency and how complex it can possibly be. Behavior in its most elementary form is purely reactive (Balkenius, 1995) and that's the kind of behavior explored/

Although the creatures are immerse in a three-dimensional world, it has no physics nor obstacles for them to avoid and their movement are limited to two dimensions. This was not the original idea but since the goal was to make things simple and to study the emergency of behavior, these features were put aside.

**2. Inspirations:** As previously said, several ideas and concepts were explored to create this system. First of all it was necessary to decide what would make the creature behave in a certain way. For this matter I was highly influenced by Damasio's idea that decision-making can be based on emotions (Damasio, 1994). The main idea applied was his theory of emotions as being body modifications driven by external stimuli. I use the term *sensation* to represent a body response to the perception of an object.

Since these sensations are related to an object, the body and a behavior, it was necessary to create a relation between these factors. Christian Balkenius (Balkenius, 1995) defines behaviors as being of four possible types: appetitive (directed toward an object), aversive (directed away from an object), exploratory (relates to objects that are unknown), and neutral (guided by objects that are neither appetitive nor aversive). To be able to decide which of these four types of behavior an object induces in the creature, every object in the world causes an alteration in the drives (internal needs, such as hunger) vector of the creature. If for a certain drive the variation is positive, the body creates a sensation that is appetitive for that object and, if negative, the behavior will be aversive. The alteration in the drives can be 0, 1 or -1. Due to time limitation, exploratory and neutral behaviors where not handled but, with a few modifications in the sensation creation system they could emerge.

For the reactiveness of behavior, the main inspiration was Lewin's topological psychology (Lewin 1936) and his view of behavior as controlled by force fields that can be generated by objects. In this work, these forces are vectors based on the body sensations. Their direction is defined by the difference of positions between the creature and the object and its intensity by the distance to the object and the current level of the related drive. Since the world has no obstacles, it is simpler to create force vectors that stirs the creature closer to an object it desires or away from something it wants to avoid.

**3. Perception:** The creature body needs to be able to foretell what kind of alteration to its drives an object will cause. For that purpose, the body has a nose that can sniff the near world. A smell is represented as a RGB color of a R-G-B-R gradient and objects of same type belong to the same cluster in the gradient. Figure 1 represents the gradient range for the three classes of object (two creatures and food). The set of smells close to the creature determine the behaviors that creature can perform. If in a given instant there nothing in the creature's nose's range it will be still and do nothing. This, again, was not the original idea but due to time limitation there is no default behavior implemented. Even so, being still can be considered a behavior and is not an absurd. Since the *Umwelt* (the world as perceived by an animal) of the creatures are only based on smells and there is none within the reach of its nose, there is no object for a behavior to be directed towards. Simply make the creature

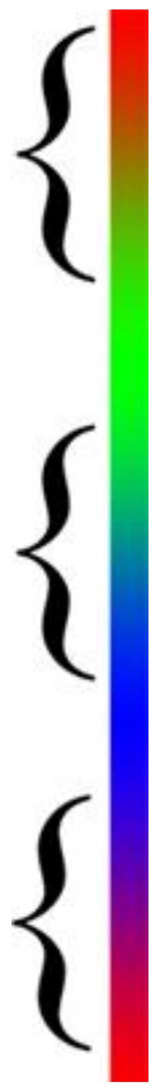

**Figure 1: Colors ranges for three classes**

wander around would injure both the emergency principle and the directedness character of behaviors. A study regarding why creatures wander if there's no object of interest in its *Umwelt* must be made to overcome this limitation.

Once a smell is sniffed by the creature, the Neural Network is responsible for estimating the drives variation it will cause once experienced.

**4. Learning:** The creatures learning is regarded to the estimation of drives variations caused by a certain smell. Once an object is experienced, the Neural Network is trained using as input the smell (its RGB color) and, as output, the drives variation it caused to the creature.

**6. Material:** This work was developed using Unity3D game engine over C-sharp language. This engine provides an useful set of tools for creating the 3D environment and updating objects every frame. For the later purpose, the engine provides a base class called MonoBehavior. An object that extends this class can implement an Update() method which is called every frame by the engine.

**7. Experiments:** Two types of experiments were made for this work. The first one is to evaluate the quality of the behavior of the creature given that it can accurately preview the drives variation caused by an object in the world. For this set of experiments, the neural network was replaced by a perfect foreteller which would give as output for a RGB color the exact variation it would cause to the creature once it experiments the related object.

The second experiment type is the evaluation of the neural network: the quality of such previsions and the learning capacity given an experimentation. The evaluation of these aspects of the neural network would attest the possibility of the creatures to be born with a poor neural network that would be enhanced as the creature experienced the world.

**8. Operation:** Every creature is defined as having a body system and a cognition system. The body is responsible for sniffing the surrounding world and creating a set of related sensations. The cognition system decides which of the sensations are more advantageous and then take an action towards its source.

The body has a nose and a neural network. The nose has a range that defines how far objects can be perceived. Objects (creatures and food) have smells which have an intensity and a range they can reach. Basically, an object's smell is perceived by a creature if the distance between the creature and the object is less or equal then the sum of the nose range and the smell range.

While the nose sniffs the objects, the neural network evaluates the smells and estimates a vector with the variation each source will provide for the body drives. Once this process is finished, the body system creates the sensations.

In order to take best advantage of the environment configuration (disposition of objects), instead of creating one sensation for every object sniffed, the world is divided in circular sectors regions of which the creature is the center. For each of these regions one sensation for every drive-behavior pair is created. For example, if a region has more than object that affects positively the energy drive, only one sensation is created for the energy-appetitive pair.

Since there is a need for the sensation to have an associated object (for the behavior is directed), the body creates a fake object that represents that sensation source. This object's position is calculated using a weighted average of the objects directions and their distances. The closer a smell source object is, the bigger it's influence in the position of the fake object. Figure 2 illustrates this calculation.

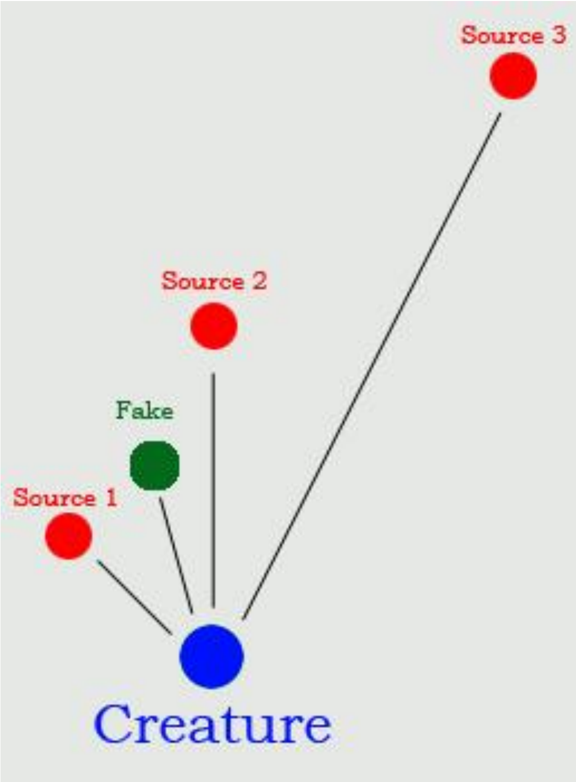


**Figure 2: The fake object position is more influenced by the position of the object Source 1 since it's closer than the other objects.**

When a creature is very close to an object, the fake source position will be very close to the real object's position. If there is only one object in that region for that drive-behavior pair, then the fake object will have the exact same position as the source.

The intensity of the sensation is a function of the sum of the intensity of the smells that composed that sensation and the distance between the fake source and the creature. This calculation is probably the most important in the final result of the behaviors and is very hard to balance.

Once all regions sensations have been calculated, the cognition system will decide what action will be taken. To do that, it calculates a intensity for each region. This intensity is the weighted sum of the intensities of each sensation in that region. For this sum, the weights are the lacking percentage of the sensations' related drive in the creature body. For example If the energy drive of a creature is at seventy percent and there is a sensation S of intensity I in region R that is related to the energy drive, the contribution of S for the intensity of the region R will be thirty percent of I.

After all that calculation, the cognition system choses the region with higher intensity. Then it defines as its target the fake source that had more influence in the choice of the region. If the related behavior is appetitive, the target will be the fake object itself. If it's an aversive behavior, an avoidance target is created and it is located far from the creature in a direction two degrees away from the fake source. By doing that the creature slowly stirs away from the object until this sensation is not the top priority.

If the creature is not close enough to the target, it gives a step towards it. Otherwise, its target becomes the real source of that sensation and the creature can experience that object. It is important to make it clear that the creature will never reach a target that was created for avoidance purpose because it's created and destroyed every frame in a position far from the creature, in the avoidance direction.

**9. Experimentation:** In the current version of the system, only the food objects are actually experimented in simulation time. It is possible to define what it means to experiment being close to other creatures but, again, for lack of time this was not made. In the tests of the neural network performance (not in simulation time), the neural network is trained with the creature smells and related drives alteration as well.

In the food case, the experimentation during simulation causes the energy drive to increase, the amount of food of that source to decrease and the neural network to be trained with the smell's RGB color as input and the resulting drives alteration as output.

**10. The neural network:** The neural network used in the system is a multilayer perceptron with regular backpropagation learning algorithm. The configuration of the network is defined by a vector of integers defining how many neurons are in each layer. The network is then created given this layer configurations and initial weights ranging from -0.05 to 0.05. The intent was to use different configurations and compare the behavior each one created in the creatures. Unfortunately, as it will be explained further, the usage of a non-trained or partially trained networks caused unwanted behaviors in the creatures. Because of that, only one configuration was selected for providing the least mean error in the predictions and convergence time.

The chosen configuration (figure 3) has one input layer with three neurons (one for each RGB component of the smells), a hidden layer with three neurons and the hyperbolic tangent as activation function and one output layer with four neurons (one for each drive) and linear activation function.

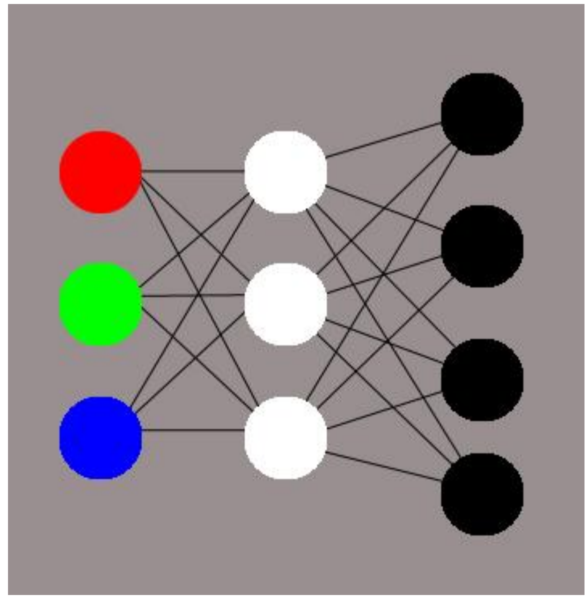

**Figure 3: The Neural Network configuration with one RGB input layer, a three neuron hidden layer and a four drives variation output layer.**

**11. Results:** The first important thing the results showed is that the Neural Network takes an impracticable time to adjusts its weights so the prediction is close to what is expected. For testing purposes, one creature was fed two sets of smells and related drives variations. The first set with 96 colors equally spaced in the color gradient and the second with all 384 existent colors. The training of the 96 colors set, that could represent an experienced creature, took almost twenty thousand training epochs to reach a mean error of 0.19 for each prevision. This means that the average sum of absolute errors for each drive of each prevision was of 0.19 in a range from 0 to 1. The set with the 384 colors, which would represent the most experienced creature possible, took around four thousand epochs to converge to a 0.14 mean error for the training set. The 96 colors error evolution is represented in figure 4. Since there are objects that do not have any relation to certain drives (the prediction of the drive alteration for those should be zero) but there is an error in the prediction, the creature behaves weirdly. For example, a source object with the smell of a creature could seem to be favorable for its energy drive in a small level. This is not true but the creature will try to eat the other creature since the decision is taken regarding the drives variations previewed and the associated behavior (remember that in this context there is no such thing as eating another creature even for energy increase purposes since it was not defined).

To work around that problem, every drive variation that was close to the neural network mean error after a prediction was rounded to zero. This created a better scenario. Both the 384 colors set and the 96 one could foretell the drives variation of a given smell satisfactorily.

**12. Conclusion:** Unfortunately the number of epochs that took for the training of the network to have a reasonable small error and the necessity for accurate prediction of zero alteration in drives makes it impossible for creatures to increasingly enhance the network with experimentation of the world. It is possible this problem can be overcome if, instead of colors, the smells were represented by some odor vector with more possible combinations then only RGB elements. This would make the classes clusters more far apart from each other and therefore the convergence of the mean error become faster.

In the tests of the system that treated the network as a perfect predictor, the results are very interesting. The creatures tend to approach those of the same species but in the process of doing so they tend to eat the food they find on the way. Once they are grouped they walk close together without, however, overlapping each other due the spacing drive that causes the generation of an avoiding target away from other creatures. The groups have no leader, but If a creature decides to seek a target away from the group, there is a tendency for the others to follow this creature after some resistance in maintaining the current target. Other mean of enhancing the system would be to make the target selection more complex taking into consideration, for example, which drives level are more important to raise.

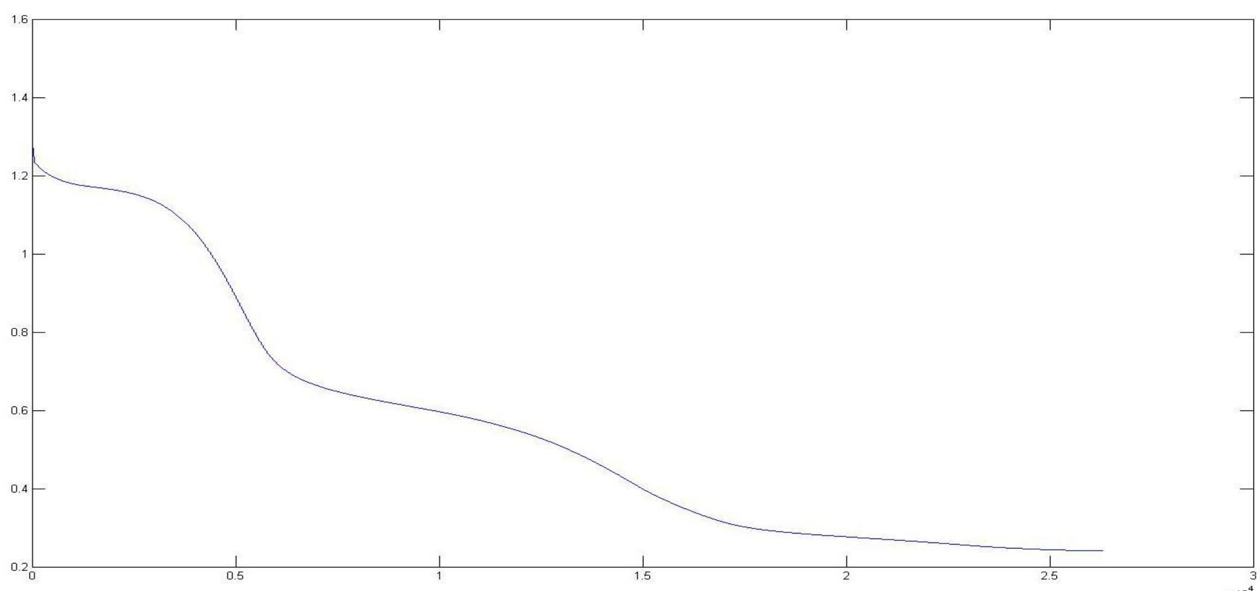


**Figure 4: Evolution of mean error X training epochs x $10^4$**

**References**

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