MONEURAN: A neuroethological model for prey catching and predator avoidance behaviors in anurans.

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Abstract

Through experimentation and simulation scientists are able to get a better understanding of the mechanisms involved in living organisms. These mechanisms, both structural and behavioral, serve as inspiration in the modeling of neural based architectures as well as in the implementation of robotic systems. Specifically we are interested in the study, simulation and robotic implementation of the mechanisms of visuomotor coordination of animals like frogs, toads, salamanders and praying mantis. This work make emphasis in the frog and toads action selection process in critical situations (presence of prey and predators) with the influences of motivational effects.

Keywords: Biological neural networks, neuroethology modeling, schema theory, frogs, toads, prey catching and predator avoidance behavior.

1 Introduction

The study of biological systems comprise a cycle of biological experimentation, computational modeling and robotics implementation, as depicted in Figure 1. This cycle serves as framework for the study of the underlying neural mechanisms responsible for behavior in animals and serving as inspirations in designing autonomous robot architectures.

Some examples of biologically inspired robotic systems studied in such a way are the computational frog (rana computatrix) [1] and the computational praying mantis [4] and the computational cockroach [5].

To address the underlying complexity in building such biologically inspired neural based systems we distinguish among behavior and structure.

1. At the behavioral level, neuroethological knowledge from living animals is gathered to generate single and multi-animal systems to study the relationship between a living organism and its environment, giving emphasis to aspects such as cooperation and competition between them [2, 7].
2. At the structural level, neuroanatomical and neurophysiological knowledge are used to generate perceptual and motor neural network models corresponding to schemas developed at the behavioral level. These models try to explain the underlying mechanisms for sensorimotor integration.

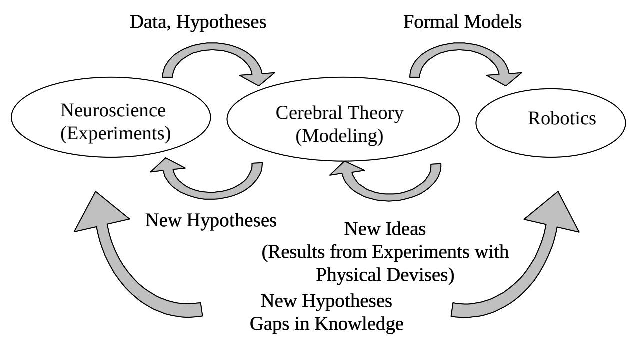

Fig. 1. Framework for the study if living organisms thtough cycles of biological experimentation, computational modeling and robotics experimentation.

2 Background

The software used to develop MONEURAN is explained in the section 2.2. First, we present the neuroethological background of our model.

2.1 Neuroethology

Amphibian, as frogs and toads, have inspired computational models because they own some special characteristics that simplify its study. For example, its activity is based, basically, by the visual stimuli they perceive [9]. This is too useful if we consider that it's easier study and analyze visual stimuli than others.

2.1.1 Prey catching behavior

Anrans feed basically with worms and other small insects. Wide studies [9] have shown that they respond to this kind of animals because they represent a visual stimulus with particular characteristics of shape, size and movement. It has been demonstrated that rectangular objects moving in the direction of its biggest axe ("wormlike") are identified as potential preys.
When a toad or a frog is motivated to catch a prey and there is a "wormlike" stimulus in its visual field, it respond with a sequence of motor responses that in order to catch the prey [12].

2.1.2 Predator avoidance behavior

On the other hand, frogs and toads are preys of animals like snake and birds, and for avoid be devoured, they exhibit a complete repertory of responses activated when a enemy object is present. Rectangular objects moving on the opposite direction of its biggest axe ("antiworm"), as in figure 2, are consider possible predators.

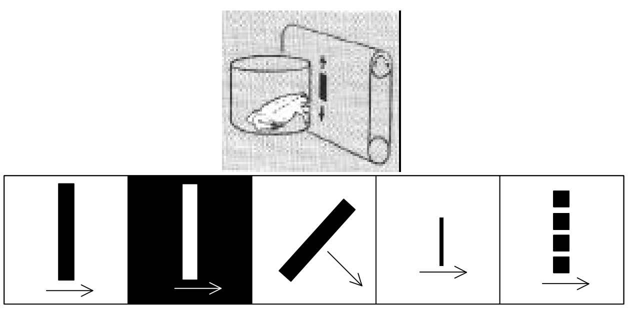

Fig. 2. "Antiworm" stimulus.

Depending on the shape, size, and moving parameters of the predator stimulus, and considering its position on its visual field of the frog, the animal can exhibit one of the next responses, related with the predator avoidance: stay immobile, jump away, or inflate itself for simulate a bigger size [10].

2.1.3 Motivation effect

In addition to the presence of sensorial stimuli, the behavior of the alive beings depend on internal and external factors that determine its disposition to carry out some responses. This effect is called *motivation* [10]. In the prey catching behaviors the motivation effect is clearer because if there is not an *advisable* motivation, a "wromlike" stimulus can be ignored. With *advisable* motivation we mean that there are some external and internal factors that make the animal to be alert for get food:

- Common frogs and toads hibernate on winter and mate on spring. Therefore the summer is the season in which this animals show more interest in "wormlike" stimulus [9].
- Besides the seasonal influence, the anuran behavior present a daylight influence Some studies show that toads and frogs have an intense predator activity during the twilight. From 18:00 hrs. to 6:00 hrs. of the next day, the prey catching behavior is more intense [10].
- Another motivational factor that has been identified is the hunger state. When an animal has been fed enough, its prey catching response is too week; but when it is hungry, the animal respond easily to many "wormlike" stimuli [9, 10].

2.1.4 Neurofisiología

Based on neurophysiological and neuroanatomical studies some researches [6, 9, 10] have identified the structures of the Central Nervous System (CNS) that possibly conform the base of the neural activity in this behaviors: the retina (RE), the optic tectum (OT), and the prethalamic tectum (PT). Many electrophysiological tests have shown how the TO and its cells (T5_2) are linked to the prey recognition process and, therefore, to the prey catching behavior, whereas the PT region and its cells (TH3) is related to the enemies recognition and, therefore, to the predator avoidance. The discrimination between preys and predators, and the selection of the most important stimulus (if both are present), depend on the interaction between the T5_2 and TH3 cells. The figure 3 shows this process. If there is a prey stimulus the OT, in addition with some TP signal, activate the catching motor responses. Meanwhile, when a predator stimulus is present, the TP sends inhibitory signals to the OT for start the avoidance behavior.

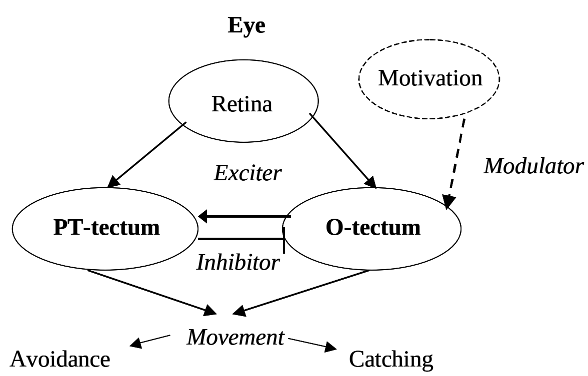

Fig. 3. Behavior selection as a result of the tnteraction between the Retina, the Optic-tectum, and the Prethalamic-tectum.

2.2 Representation: Schema theory and NSL

In this work we use schema theory [3] which lays down the conceptual framework for knowledge representation inspired from biological and cognitive studies. The implementation was made in the Neural Simulation Language (NSL) [11,12] that we explain next.

2.2.1 Schema Theory

Schema theory explains the behavior through the interaction of different concurrent activities of object recognition, planning and activity control. The behavior *emerge* as a result of the competence and cooperation between schemas instances [3]. The behavioral description of a schema describes how an instance of that schema will behave in response to external communications. As action and perception progress, certain schema instances need no longer be active, while new ones are added as new objects are perceived and new plans of action are elaborated. A schema assemblage, the basis for aggregation, is a network of schema instances, and it may be considered a schema for further processing. Since a schema may be decomposed into any number of component schemas, there may be virtually any level of abstraction.

2.2.2 The Neural Simulation Language (NSL)

NSL is a model development and simulation system for the creation and execution of scalable neural networks. In terms of neural modeling, NSL provides different levels of neural model details. Although the most important characteristic of NSL is the definition of neuronal modules, it also provides sufficient expressiveness for support single neuron modeling. The creation of a neural model in NSL allows to define: a set of modules defining the entire model; neurons comprised in each module; neural interconnections; neural dynamics; and numerical methods to solve the differential equations. In terms of simulation in NSL the user interacts with the model through rich graphics and a full menu oriented widow interface supporting creation of new models as well as their control and visualization.

3 MONEURAN development

MONEURAN was designed using a top-down methodology. First we explain the architecture of the model and afterwards we present some simulations.

3.1 Architecture

In the MONEURAN design we use a top-down methodology. First we explain the model since a global perspective an then we focalize to the frog schemas.

3.1.1 Global architecture

At the global level, MONEURAN describes the interaction between the agent (Frog), the stimulus (Prey and Predator) and the ambient (World). In the figure 4 we show this relationship in a basic way. Each entity give to World its coordinates (x, y, z) that define its position in a threedimensional space. As well, the World send to the Frog an image of the ambient in a time (t).

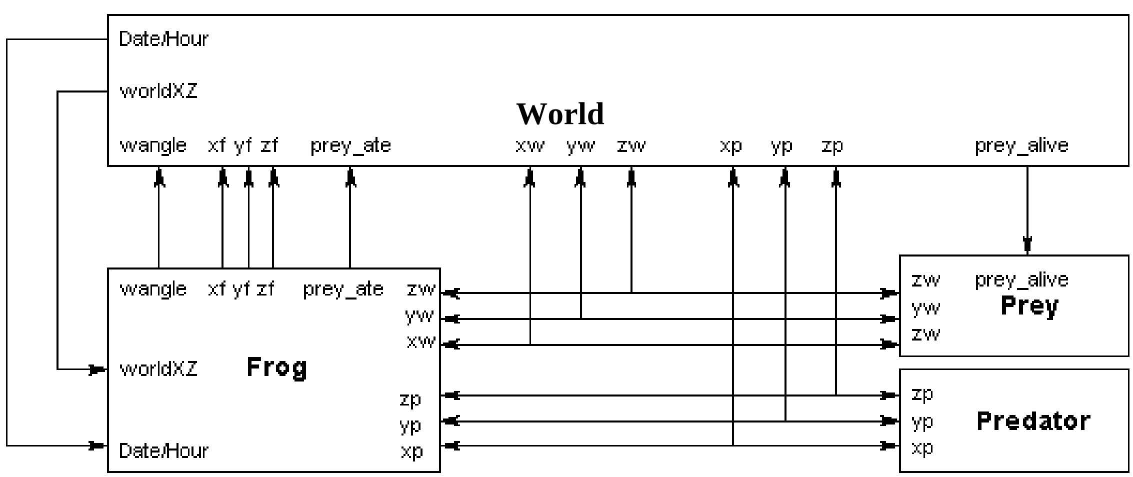

Fig. 4. Basic relationship between the World and its entities shown at the global level.

3.1.2 Agent architecture

The agent designed in MONEURAN incorporates schema modules (functional units) and neuronal modules (structural units) that can be classified depending on the function that perform. The modules that participate in the immediate processing of the sensorial information, in this case visual information, are called *perceptual* modules; those that activate any final move are called *motor* modules; and those that connect both functions are considered *sensorimotor* modules. Besides, there are one kind of module that perform a *motivational* function on the predator activity of the animal. In the figure 5 we show the interaction between the different modules, and the connection between the schema level and the neuronal level.

***Perceptual schemas**:* Perception for the grog is based on *Visual* sensors. In particular the frog perceives the prey, *PreyRecognizer*, and the predator, *PredatorRecognizer*.

As a example of the implementation we present part of the code of the *PreyRecognizer* module:

```
void PreyRec::simRun()
{
      t5_2 = filter(visual_field,2);
      if (t5_2.sum() >= 1)
            ps=0.7;
      else
            ps=0;
      updateLabel();
      triggerSchema();
}
```

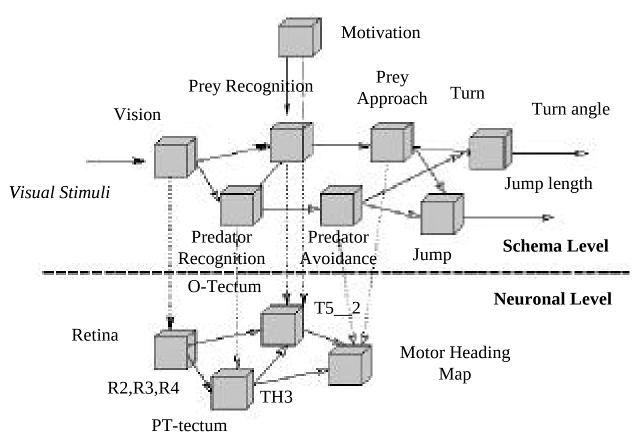

Fig. 5. MONEURAN schema level architecture.

T5_2 is a vector that represents the group of cells that are activated when a prey (coded by the number 2) is present in the frog's visual field. If one prey, or more, was recognized, a confidence level (*ps*) is activated as an input of other schemas.

Sensorimotor schemas: The frog model incorporates a number of sensorimotor schemas: *PreyApproach*, *PredatorAvoidance*, *Motor Heading Map and Heading Transform*.

Motor schemas: We have included two motor schemas that can define any movement of the frog: *Turn* and *Jump*.

Motivation schema: This schema receives, as an input from the *World*, the date and the day hour; then, jointly with the internal computing of the hunger state, gives a confidence level to the *PreyRecognizer* schema.

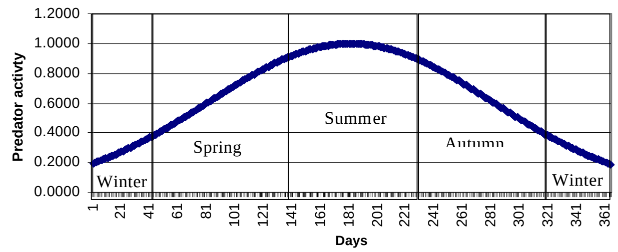

Fig. 6. Implementation of the variations in the predator activity during the year

To obtain the confidence level of the motivation influence, we calculate each (date, hour day and hunger state) element alone and then we sum this result in order to get just one level. For example, in the case of the date effect, we use a gaussian function for represent the variations in the motivation during the year:

$$M_d\,(d) = \exp\text{-}[\ (\ d - md\ )^2 / 2rd^2\ ] / 2pi\ rd$$

Where *d* is the number of the day in the year and *md* is the day with the highest predator activity.

As depicted in figure 6, this function have its maximum in the period where the confidence level is bigger (summer).

3.2 Simulations

In the figure 7 we present two experiments (A and B) that exemplify the frog's action selection (catching prey or avoid predator) process with prey and predator presence. Experiment A is developed in a normal situation of motivation (not very active for catching a prey), while experiment B is developed with a extreme condition of motivation (moth, day, hour and hunger state) that make the frog to be very alert for catching a prey, even in the presence of a predator. We can visualize the experiment through four windows: the *World* (top and left), the *Fields* (top and right), the *Visual Field* (down and right), and the C*onsole* (down and left) window. The *World* window shows a top view of the ambient. The square represents the position of the frog, the horizontal stimuli represents the prey and the vertical stimuli represents the predator. The numbers indicate the order of the movements and the narrows indicate the direction of the frog's sight. The *Visual field* window shows the actual visual field of the agent. In the *Fields* window appear the graphics that show the attraction and repulsion fields generated by the stimulus. The first graphic (from top to down) shows the field generated by the predator stimuli, the second shows the field generated by the prey stimuli, the third shows the sum o both stimulus, and the last graphic shows the position of the higher response (the position of the most important stimuli at that time).

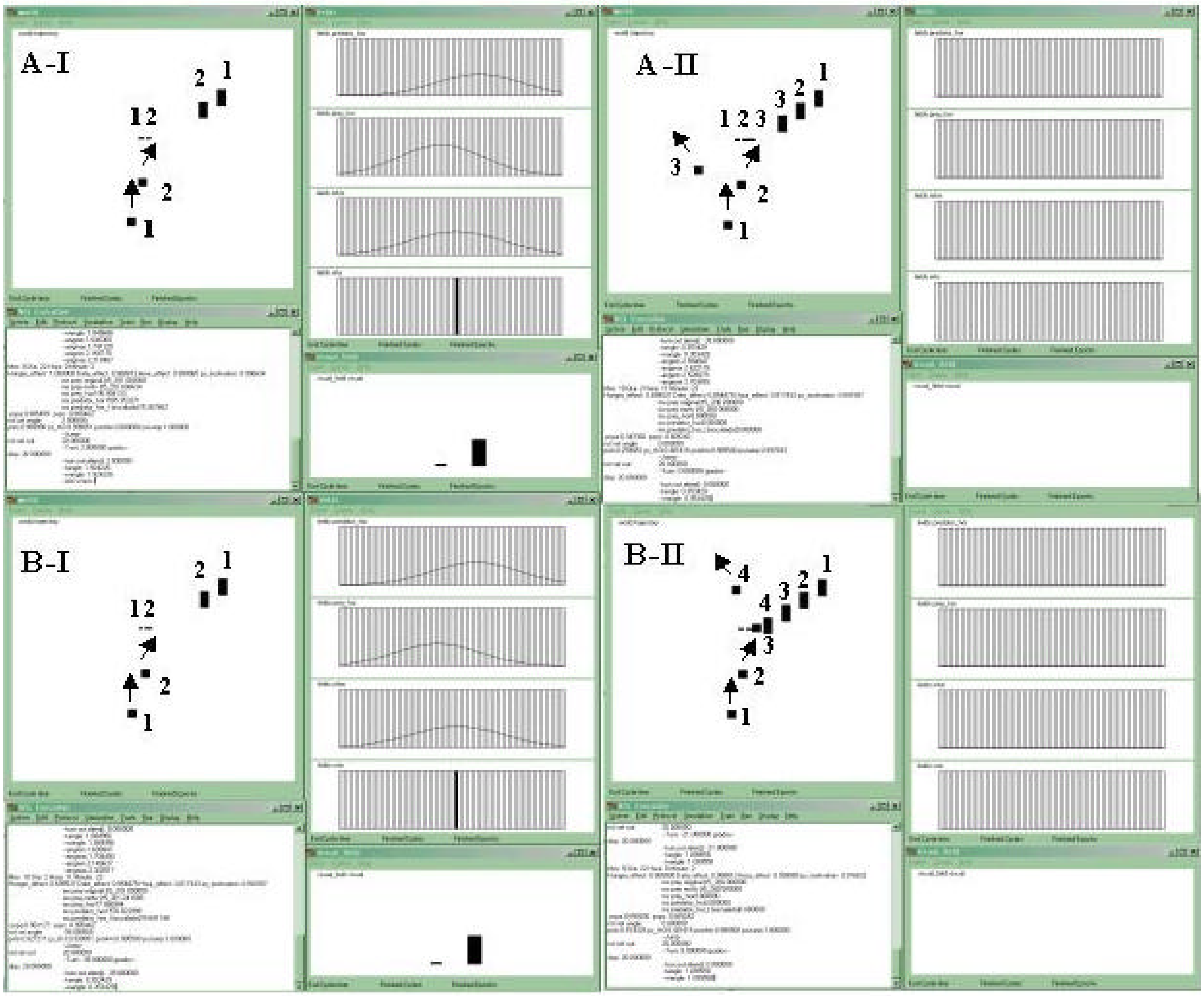

Fig. 7. Experiments view. In the part I of the experiment A, the frog is approaching to the prey, but in the part II the proximity of the predator make it go away. In the part I of the experiment B (with different motivational conditions that make the frog to be more active) the frog also goes for the prey, and in the part II, despite of the position of the predator, the frog catch the prey, showing the effect of the motivation in the frogs behavior.

4 Discussion

This work shows how the scientists of different disciplines can work jointly using useful representation methods and tools, that help them to abstract , represent and implement the entire knowledge. MONEURAN models and simulates an autonomous behavior inspired in biological neuronal networks and in ethological studies of anurans that can be used in the control of robotics systems. In particular we studied and simulated the possible neuronal mechanisms that support the visuomotor coordination of the frogs and toads in prey catching and predator avoidance behaviors. We made special emphasis on the effect that the external (season and day hour) and the internal (hunger state) factors have on the agent behavior. The visual information that an anuran receives is not enough for determine its conduct, instead, we have to consider the motivational factors.
This become very important if we pretend to construct robotic systems that interact in a closer way with the environment and, finally exhibit a better adaptation and more autonomy levels.

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