

# Retina-based foraging strategies in an open-ended evolution of Splinoids

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In natural ecosystems, the complexity of observed behaviors and interactions only relies on low-level signals such as light or sound-waves. However, such a fine-grain approach does not translate well to the field of Artificial Life given the inherently prohibitive computational cost as noted in Cliff and Miller (1996). Indeed while there are instances, in the literature, of virtual ecosystems relying on low-level components such as vision Yaeger (1994) or competition Miconi (2008); Gras et al. (2009) these are limited to either the agents' perceptions or actions. It is thus common practice to use high-level primitives for instance to locate and move towards a potential partner Ventrella (2005) or to detect potential predators Metivier et al. (2002).

In this work, we describe a model, of so-called splinoids, in which all perceptions and actions are performed by low-level components. A preliminary experiment is briefly detailed to show the potential of this approach on a simple foraging task in an open-ended evolutionary protocol.

## Splinoids

Given the scope and aims of this model, numerous aspects are of particular interest. However, in the spirit of concision, only those relevant to the experiment described afterwards will be detailed: their morphology, life-cycle and brain.

The eponymous component of this model is the use of bezier curves to encode the morphological portion of the critter involved in active combat. As is in Miconi (2008), individuals can damage one another by colliding with sufficient speed, though, in this setting, there is a distinction between the fragile body and the harder horn-like artifacts. This produces a continuum between defensive and aggressive strategies.

The second component, the metabolism, encompasses the complete life-cycle: from a vulnerable young state (with a size 1/10th that of an adult) to adulthood, where it can engage in reproduction, down to old age, where its motile capabilities slowly degrade. In this work, reproduction was performed asexually by progressive accumulation of energy in a dedicated reserve, under control of a neural output. Energy is consumed via numerous pathways (growth, motion,

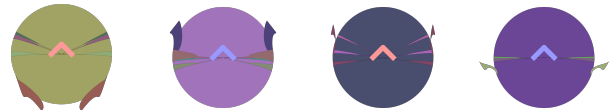


Figure 1: Examples of splinoids. Horn-like protuberances are obtained through interpolation of genetically-encoded bezier curves.

regeneration ...) and its obtention is thus required to prevent starvation. This is achieved by colliding with a food source which will then slowly be consumed. Additionally all the energy depleted by the splinoids is collected into the environment and used to renew the plant population, thereby forming a closed system with a constant energy level.

Perception is currently performed in two manners. Proprioceptors provide knowledge of the energy level, reproductive reserve, age and health (one neuron each placed at  $z = -.25$  on HyperNEAT's substrate). Vision is controlled genetically by parameters influencing the disposition of the eyes (in a symmetrical manner) and the precision of the retina (from 1 to 11 cells, per eye). Every time step, a ray-cast is performed for each such retina cell and fed into the ANN with the input for the red, green and blue components being located at  $z = 1, 0, -1$ , respectively. In this manner, individuals can discern food objects (a light shade of green) from obstacles (black) or other individuals (whose colors are constrained in  $[-.25, .75]^3$ ). In the event that a ray does not encounter any object the color white is returned. The relevant outputs control motor response (one on each side to provide torque) and reproductive behavior. With this model, we argue that complex demeanor can emerge, although not without intense and variable environmental stress.

## Environment and experimental protocol

In order to validate the basis of the Splinoid model, we performed a straightforward experiment, akin to an initialisation phase in which we aim to obtain viable starting points for complex behavior. It results that the constraints imposed on evolution are very mild: 100 splinoids are placed in the central area of the environment with enough resources to

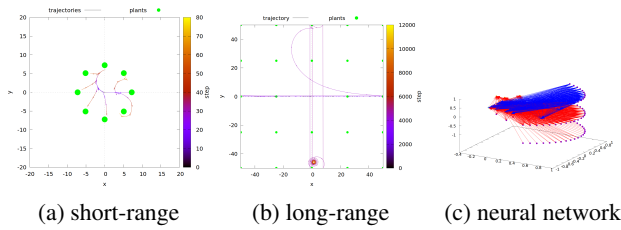


Figure 2: Behavioral evaluation of best individual in short-range foraging. Trajectories are color-coded according to the scale on the right with arrows indicating forward direction. a) All 8 individual evaluations are shown simultaneously demonstrating the polyvalence of this foraging strategy. b) Evaluation on long-range foraging is less successful with the individual locking itself in an infinite loop. c) Neural network with blue and red edges indicating negative and positive connections, alpha value indicates magnitude.

sustain a population of about 150% that size. Plants are sparsely distributed, requiring active foraging. The neural substrate of the splinoids relies on the MultiNEAT<sup>1</sup> implementation of HyperNEAT. A total of 450 runs are performed for a maximal duration of 1K generations starting from randomly generated genomes. As one might expect not all runs are, initially, capable of self-sustaining behavior. However, we do not use a backup SSGA to maintain population so as not to introduce undue bias via hand-crafted fitness functions. This results in 141 runs in which random weights initialisation produced functional enough demeanor upon which natural selection could operate.

### Preliminary results

Analysis of performance was done in two manners: short- and long-range foraging. In the former case, an individual from the evaluated population is placed at the center (0,0) of the environment, facing right. A food source is also provided at position  $(\theta, l)$  with  $l$  being equal to 75% of the critter’s vision range. The simulation is run for about a tenth of the critter’s lifespan. This test is performed for 8 angle values ( $\theta = \{0, 45, \dots, 315\}$ ) to determine the polyvalence of the strategy. The resulting score is the sum in all 8 conditions, taking into consideration the time taken to reach the foodlet and its relative angle (e.g.  $\theta = 135$  is harder to reach). In the latter case, 24 food sources are disposed uniformly across the surface and removed as soon as a collision occurs. The tested individual is spawned as an infant and allowed to explore for the duration of its natural lifespan. The score is then simply the number of items “collected”.

From these evaluations, two types of strategies can be discerned, which will be illustrated by the behavior of each type’s champion. The key characteristics of these individuals are shown in figure 2 and 3 for top-ranking individuals of short- and long-range foraging tasks, respectively.

<sup>1</sup><https://github.com/peter-ch/MultiNEAT>

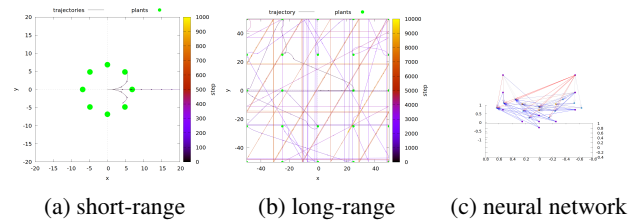


Figure 3: Behavioral evaluation of top-ranking individual in long-range foraging. Legend is the same as in figure 2. a) Low proficiency in short-range foraging. b) The individual explores the whole environment and successfully collects all items. c) Sparse network using only red cells.

As can be seen in panel 2a, the splinoid reaches each goals through slightly convoluted trajectories. Its strategy is decomposed in three phases: a) circular backward motion until a foodlet is detected b) forward approach and c) feeding. However, this behavior seems to be tweaked towards food-rich environment given that, in the second type of evaluation (fig 2b), it quickly stops searching and locks itself in an infinite loop. Indeed, when looking at the neural network controlling this individual, one can see a brute-force approach to the problem of optimal connectivity. All red visual inputs have a negative weight (fig. 2c, in blue), favoring symmetrical backward motion, while the green component is positively integrated to promote rotation.

The other type of strategy is demonstrated by figure 3: while poorly performing in the first task (only 3 foodlets are reached) it is capable of successfully collecting all but one of the items in the second task. Such a result is obtained by a more conventional forward-facing search. As can be seen in figure 3b, the individual alternates between periods where no food sources are detected resulting in straight-line trajectories. However, as soon as a foodlet enters visual range, it is capable of very quickly homing on it, with flawless efficiency. Surprisingly, this strategy relies on a much sparser use of neural connections: only three visual neurons (all on the red channel) are queried. This implies that such an individual does not find food by looking for green objects but, instead, by being attracted to non-red ones.

### Conclusion and perspectives

This preliminary experiment has already gone some way to demonstrating the viability of the Splinoids model by showing how retina-based brains can develop functional, and sometimes surprising, strategies of foraging. Additionally, given the arbitrary nature of these evaluations, they only provide a lower boundary on the complexity of obtained strategies. Further studies are required regarding predatory behavior, splines use, etc. Future applications plan on leveraging such low-level components for perception/action to study the emergence of higher capabilities including, but not limited to, predation, altruism and sexual selection.

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