Refined Intro and Model

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1 Refined intro

Inspiration: Usage of evolutionary algorithms to optimise prey behaviour in presence of predators.

Aim: To explore the feud between homesickness and exploration, in the presence of hunger and predation.

2 Brief Description

Certain animals have a concept of home range, which divides the "world" into "home" region and "uncharted" region. The specific idea here is that home region is relatively devoid of predators. Resources are generated at random positions in the world, albeit with a constant rate. Animals have to consume resources above a minimum threshold rate in order to survive and pass on their genes to the next generation.

If the population around home region is high, or resource generation rate in the world is low, then sticking around the home region may prove detrimental. Hence, the animals have to venture into uncharted territory and expose themselves to predators. So there is a tradeoff between staying within the home range and exploring new territories for various resources (in this case food).

Each animal has a homesickness instinct and an exploration instinct. However, the extent to which each animal responds to these instincts is determined by genes they inherit, and how their predecessors have found success/failure in whatever strategy they've followed.

3 Framework for Evolution

We have already developed a framework that carries out evolution. The requirements are:

- **Expressed genes:** The behaviour of animals should be governed by specific set of gene(s) which are in turn made up of nucleotides. If we want to study particular aspect(s) of an animal's behaviour, then those aspect(s) need to be genetically determined.
- **Fitness function:** A fitness function that evaluates reproductive fitness of each organism, at the end of each generation.
- **Genetic operations:** We must define the manner in which genes pass on from the parents to an offspring, along with how mutation and recombination should take place (the framework automatically selects parents in a probabilistic manner, based on their fitness).

We have implemented this framework in a context wherein the aim is straightforward and the fitness can be calculated easily:

a) Each animal strives to go from point A to point B within the given timespan (500 frames), without colliding with obstacles or with boundaries of the world.

b) Fitness is determined on the basis of how close the animal came to point B. There are fitness penalties for colliding and fitness increments for reaching the target faster than others.

c) Each animal has a gene with 500 nucleotides. The i^{th} nucleotide dictates the direction in which the animal turns in the i^{th} frame. They virtually have no senses and initially perform random walks.

d) Each child gets a random half of it's gene from either parents. Mutation operates in the form of nudging few nucleotides.

The observation that the overall fitness of the population increases (on average) suggests that evolution is indeed taking place. Please check out the evolution framework here

4 Model

Please note that minute details presented below may change

a) The world has n animals. The position of an animal is represented by $\vec{p}$, which has X and Y components. Assuming that the home range is circular and is centered at $(0, 0)$, homesickness directs the animal in the direction given by $\vec{v}_h$ whereas exploration directs the animal in a direction given by $\vec{v}_e$, where:

$$\vec{v}_h = -\vec{p} \; and \; \vec{v}_e = [\cos\theta, \sin\theta] \; where \; \theta \in Unif(0, 2\pi)$$

b) The homesickness instinct is represented by $f(d)$ whereas the exploration instinct is represented by g, where:

$$f(d) = \frac{k_1 d^2}{d_0^2 + d^2} \; and \; g = (undecided)$$

d is the distance of the animal from the centre of the home range whereas d_0 is the distance at which homesickness instinct reaches half maximum.

c) Each animal has it's own values of (h, e), which are genetically determined. They dictate the extent to which an animal listens to it's homesickness and explorational instincts. The overall behaviour of an animal is dictated by the following equation:

$$\vec{v}(t) = h(f(d) \cdot v_h) + e(g \cdot v_e) \; \ldots \; (1)$$

$$\vec{p}(t+1) = \vec{p}(t) + v_a\vec{\hat{v}}(t)dt \; \ldots \; (2)$$

where v_a is the velocity of the animal whereas dt is the time step (will be chosen appropriately).

d) Each animal has a parameter l, which has a maximum value of l_{max}. It decrements for every frame that an animal goes without eating. When an animal eats, l resets back to $l_m ax$. When l becomes zero, the animal dies.

e) Every animal has the same sensory radius r_f for food. When food is present within this radius, the animal heads for it (ignoring all instincts) and consumes it. Food is generated at random positions in the world, at a rate r per frame (r doesn't necessarily have t be an integer).

f) The world also has m predators, all of which have the same sensory radius r_p for prey. When prey (aforementioned animals) is present within this radius, the predator heads for it and consumes it. Otherwise, the predator performs a random walk with some sort of a bias against entering home range of the prey. The predator also has behavioural equations like (1) and (2).

5 Progress so far

- We have gone through the references that you've advised us to read.
- The framework that carries out evolution is ready, and has been made quite robust
- The major details of the model are ready. A lot of minute details remain to be figured out. However, they will be quickly decided in a sensible manner once the necessity arises.
- We have completed a sizeable amount of code pertaining to behaviour of prey/animals, as explained by the model. All code is written in JavaScript, which is an easily understandable programming language. Our simulation can be made accessible online.

6 Further scheme

a) In order to incorporate the home-range + predation situation in our evolution framework, we will define a function that evaluates fitness. We will also figure out the way how genes and nucleotides are represented, passed on, mutated and recombined. We hope that the evolution framework will give us the fittest phenotype (h, e) after a few generations of simulation

b) We intend to observe the variation of the fittest phenotype (h, e) as various parameters are changed. The parameters we currently have in mind are rate of resource generation r_f, populations of predator and prey (m and n respectively), hunger tolerance l, and home-range parameter d_0.

c) We realise that there are umpteen avenues of exploration open. We haven't even figured out all the minute details yet. We will sincerely attempt to discern as many properties as available time entails to us. Our model is extremely flexible to change since they can be correspondingly reflected in the code with little effort.

7 Prospects

- One can study behavioural predator-prey interactions in other contexts, such as flocking (as presented in one of the papers you've referred us to).
- One can also study the phenomenon of Sun Compass and Colony Foraging with the same perspective of evolutionary algorithms (as presented in our project proposal). However, since you've advised us to concentrate on home-range only, we have abandoned those topics for now.