The Population Suite

Claes Andersson 2020 ©

Purpose

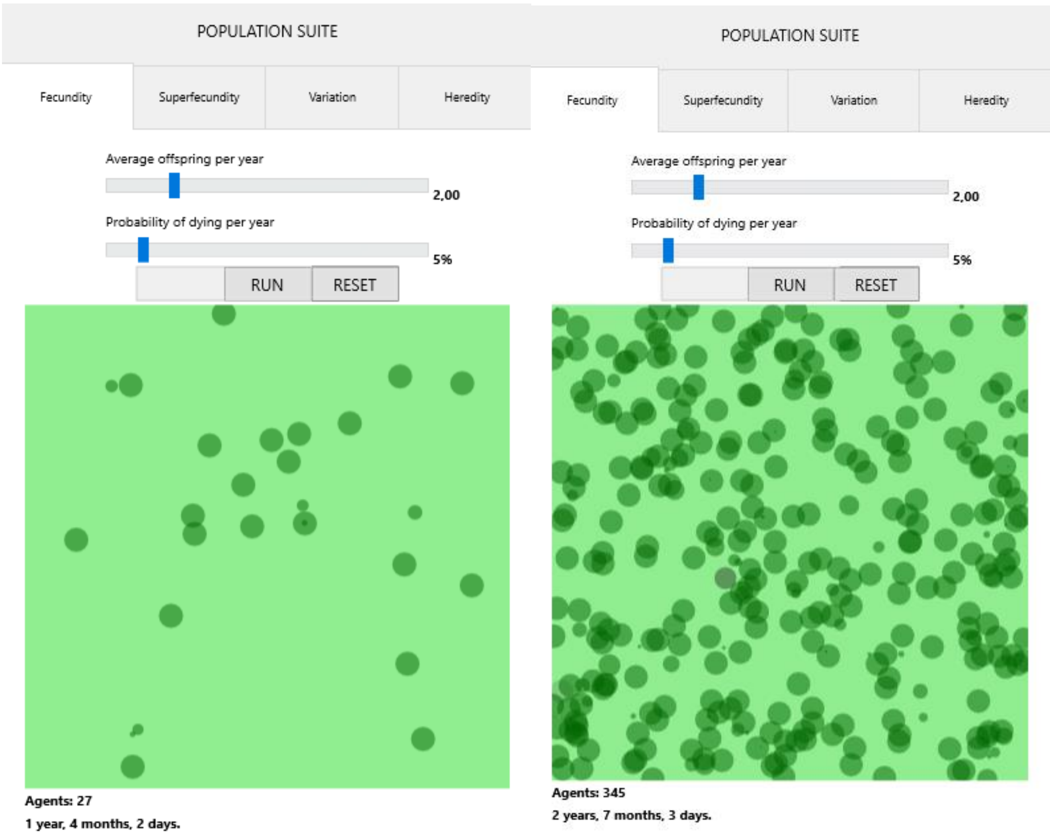
"The Population Suite" is an educational software designed to interactively simulate and visualize how (i) overproduction of offspring, (ii) limited resources, (iii) variation, and (iv) heredity together cause evolution by natural selection.

Overview

Four different setups are accessible via tabs that are logically organized from left to right so that the model under the next tab represent an elaboration.

Fecundity

The left-most and most basic model simply implements a collection of agents that live, die and reproduce at rates specifiable using sliders. The agents do not interact in any way, either with each other or their environment.



Early and later configuration of agent in the basic "fecundity" model, including view of the interface.

The point of this "fecundity" model is to demonstrate that no matter how the parameters are set there are only two outcomes: the extinction of the population or an explosive geometric growth. So unless the organism dies out, its numbers would explode. This is, of course, not what actually happens since real biological agents need resource, which in turn are limited.

Superfecundity

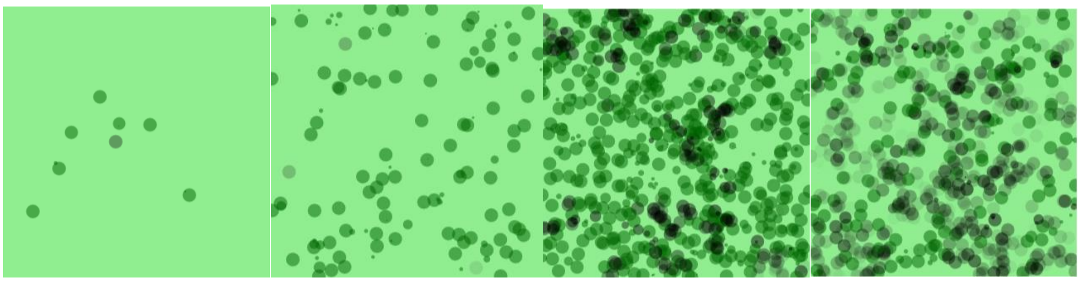
This model introduces a resource that the agents extract and spend at a fixed rate for being alive. The resource is divided into a regular 10×10 grid (invisible) across the space in which the agents move. Each regional resource regrows independently at a fixed rate as it is extracted by agents located within its boundaries. When the agent divides, a third of its energy goes to the offspring while two thirds remain in the parent agent.

The simple harvesting sub-model allocates 50% of the current resources as accessible in the resource grid region, equally distributed between the present agents. The agents extract their part, up to a maximum, before the fixed cost of living is subtracted. The resources left after the cost of living is deducted then undergoes a decay by a fixed discount factor.

The resource $x(t)$ regrows over time t via a time-discrete logistic growth function, with a carrying capacity *K* (value set with slider control) and a fixed rate of regrowth *r*:

$$x(t+1) = x(t) + r\, x(t)\, (1 - \frac{x(t)}{K}).$$

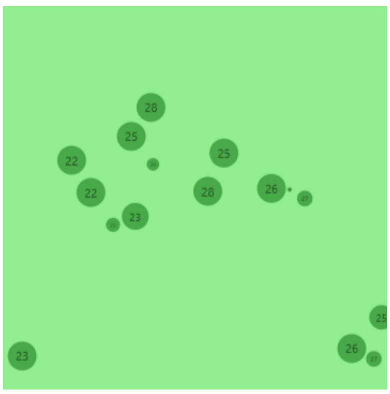
The effect is that, as the population surges, the resource is depleted, leading to starvation and death (grey fading agents) – which in turn allows the resource to grow back, and the population to rebound. If the rate of reproduction is high, the population of agents will undergo periodic oscillations.



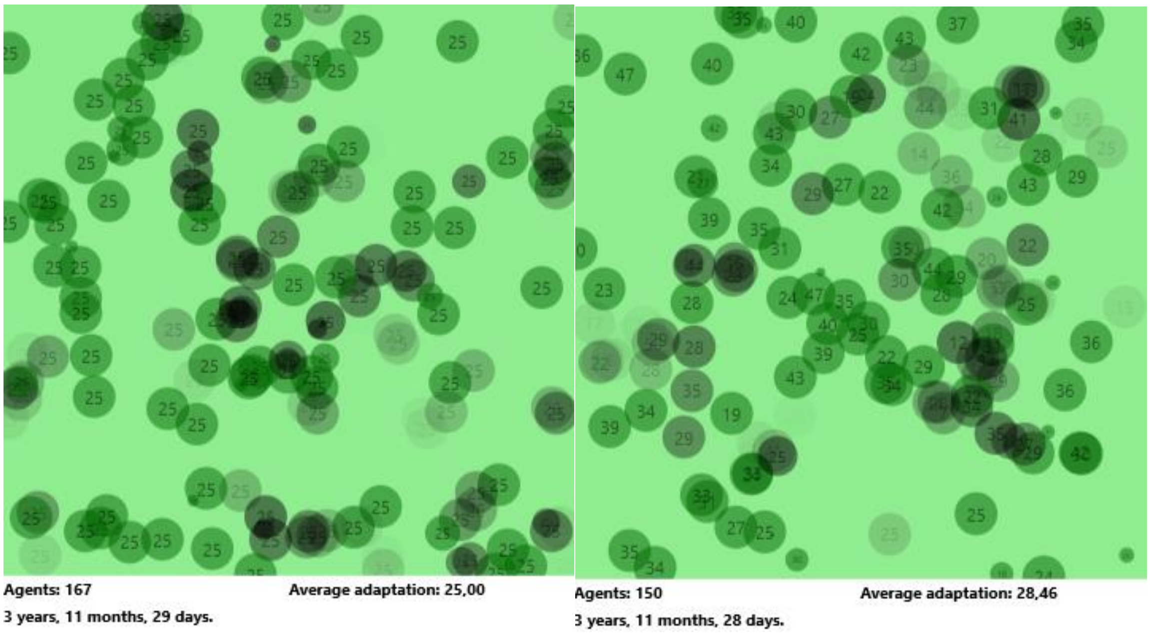
Series of configurations where a population grows, depletes resources, dies in large numbers, and begin to rebound again in the first oscillation of a cyclic population pattern.

Variation

The “variation” model introduces a variable rate of energy expenditure such that some agents expend energy faster than other agents. We say that they have a specific level of adaptation. This property is, however, not inherited, but is drawn independently from a normal distribution, centered at a fixed value (arbitrarily chosen to be 25), with a standard distribution set using a slider in the interface.



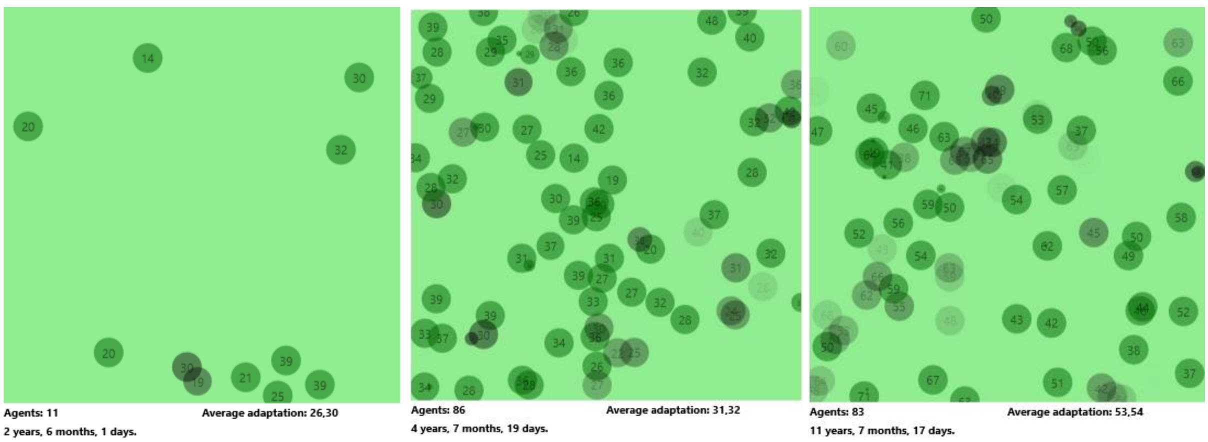
Agents in the “variation” model are displayed with a number quantifying their degree of adaptation, which means that the higher the adaptation the lower the rate of energy expenditure.



Increasing the variability leads to a “false increase” in fitness that is not due to evolution by natural selection. Instead it is due to variants with lower adaptedness having shorter life spans than variants with higher adaptedness so that the concentration of the latter persistently remains higher. While no evolution takes place here, the effects of variation itself can be observed.

Heredity

In the final model version, the degree of adaptation is inherited from parent to offspring, such that the offspring has a degree of adaptation that is normally distributed, with the parent fitness as mean and the variation parameter as standard deviation.



With the final piece of the Darwinian puzzle in place, the agents undergo cumulative evolution by natural selection and the average degree of adaptation increases steadily.