Project Description:

In this project we seek to:

- model coexistence and chaos in ecosystems,
- show the effects of adaptation and mutation on population dynamics,
- reproduce the results of Sprott et al [1], who employed the Lotka-Volterra Equations to model population dynamics,
- and to observe the effect that changes in adaptation have on the model.

Through the use of a computer simulation we hope to accurately model large numbers of species in an ecosystem.

Scientific Challenges

- To accurately capture the chaos amongst populations through a numerical simulation

Potential Applications

- Survival and extinction in the wild
- Financial markets
- Traffic flow

Methodology

To achieve our goals, we:

1. simulated population dynamics using the generalized Lotka-Volterra equation, which includes a competition matrix that dictates how the various species interact,
2. employed a classical Runge Kutta method in MATLAB,
3. simulated adaptation by altering the interaction matrix every twenty time steps. We increased the off-diagonal elements of the matrix by a small value to model increasing environmental stress, as well as enhanced competition,
4. prevented extinction by clamping a failing species at a small value,
5. investigated the role of adaptation by changing how often we altered the interaction matrix and changing the value at which we clamped a dying species.
6. In order to obtain easily understandable results, we generated the measures Biomass and Biodiversity.

Glossary of Technical Terms

Generalized Lotka-Volterra Equation:

$$\frac{dx_i}{dt} = r_i x_i \left( 1 - \sum_{j=1}^{N} a_{ij} x_j \right)$$

Biomass (M): the total mass of living organisms in a certain ecosystem divided by the total number of species, or the average population size

$$M = \frac{1}{N} \sum_{i=1}^{N} x_i$$

Biodiversity (D): the diversity of plant and animal life in a specific habitat

$$D = 1 - \frac{1}{2(N-1)} \sum_{i=1}^{N} \left| \sum_{j=1}^{N} r_{ij} - 1 \right|$$

Results

1. We were able to approximately replicate the results of Sprott [1] in terms of biomass and biodiversity.
2. For the modifications of mutation, noticeable visual differences were seen between the different mutation time steps. Higher mutation rates produced a lower biomass and a lower biodiversity. Fluctuations decrease as adaptation is simulated less frequently (as seen above). This mutation is due to environmental stress [1], and therefore with higher mutation rates, each species is less likely to flourish.
3. With our initial clamp size of $10^4$ there was a sharp decline in biodiversity over the initial few time steps. When the clamp size was changed by a factor of 100 in either direction, there was negligible change; this was most likely due to the fact that these values are still extremely small in comparison to the population levels of the various species.

References


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