Complexity DTC Miniproject

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Adaptive Dynamics

Research objectives

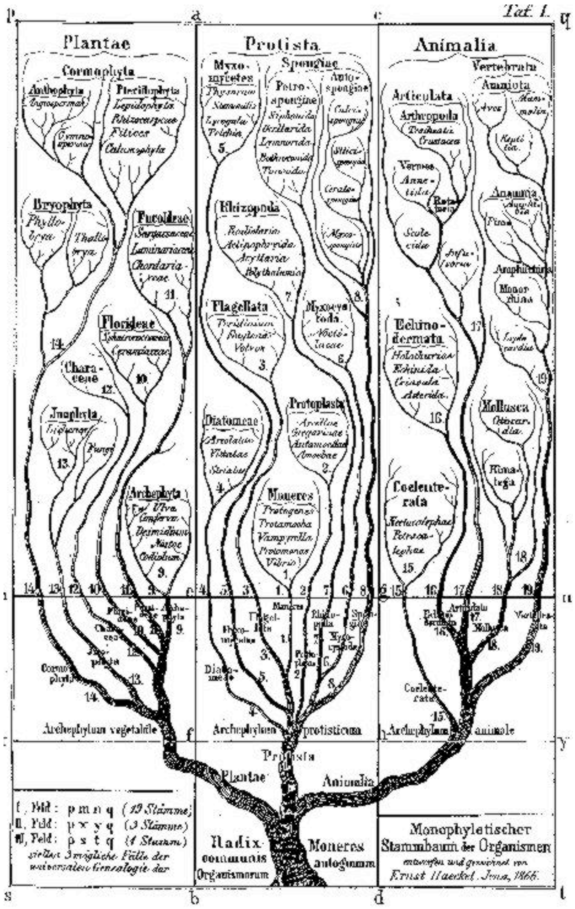
Inspired by the ideas of Darwinian evolution we like to understand better (by modeling and simulation) the connection between units (animal and plant species in Darwinian evolution) being able to mutate and evolve, and the opportunities created by the unit's environment, often called niches in the ecology literature. These two factors determine the shape of a phylogenetic tree (or better class of trees as all evolution is a random process) created by evolvable units and their branching. *The research objective is to find phylogenetic tree structures and their geometric representation given different assumptions on the evolutionary process itself*. Here we use different approaches to model evolution, in general a combination of adaptive dynamics, population dynamics, food web construction ('niche model') etc., but we are mainly interested in extensions of the current theory of adaptive dynamics (see reference). The project will collect the different methods that are needed for such an investigation and discuss their connection. We especially like to understand the stability of evolutionary branching patterns when changing essential evolutionary parameters, like mutation, selection and memory (i.e. genes or equivalents).

Why is it interesting?

Complex adaptive systems and their understanding are central to complex systems research. There are many evolutionary processes in biology, social systems and economics (for example the spread of 'innovation'), with Darwinian species evolution being the most genuine and most important example. Due to the current loss of biodiversity we must start to understand what kind of evolutionary pressures the new global environment imposes on the global ecosystem. The latter is best understood if we look at past ecosystems crisis and related data.

The idea of phylogenetic trees can be traced back to the 'Origin of

Species' by Charles Darwin, and have been a bit later advertised by Haeckel (see figure). We are now able with the help of modern data sampling (genetics etc.) and modeling techniques to reconstruct hereditary trees. But can we also give forecasts? There are a number of artificially evolving systems where such questions can be asked.



Techniques required.

- Graph theory (tree geometry) This is needed for representing the evolutionary process over time.
- Combinatorics
- Population dynamics (dynamical systems, short time scales)
- Adaptive dynamics (dynamical systems, long time scales)
- Stochastic processes
- Genetic algorithms
- Basic computing (with support).

Prospective deliverables.

- Building blocks and concepts to understand an evolving system.
- A small example of an evolutionary process and its representation on basis of simulation.

Who should benefit from this research?

- Complex systems scientists
- Biologists, both on molecular ('emergence of life') and species level (paleontology, ecology).
- Economists, social scientists.

Outline of avenues for a follow-up PhD project.

The project has potential for several PhD so a thesis must focus on some aspect of this research. A very fruitful research direction is to relate properties of the evolutionary process embedded into an 'environment' (as encoded by adaptive dynamics and a variation of 'niche' representations) to a probability distribution on the geometry of the resulting phylogenetic tree.

References:

Geritz, S. A. H., É. Kisdi, G. Meszéna, and J. A. J. Metz. 2004. Adaptive dynamics of speciation: Ecological underpinnings. Pp. 54-75 in U. Dieckmann, M. Doebeli, J. A. J. Metz, and D. Tautz, eds. Adaptive speciation. Cambridge University Press. PDF

Meszéna G., M. Gyllenberg, F. J. Jacobs & J. A. J. Metz. 2005. Link between population dynamics and dynamics of Darwinian evolution. Phys. Rev. Letters PRL 95, 078105.

D. D. Sleator, R. E. Tarjan, and W. P. Thurston. Short encodings of evolving structures. *SIAM J. Discrete Mathematics*, 5(3):428{450, 1992.

Hofbauer, J. and K. Sigmund. 1988. The Theory of Evolution and Dynamical Systems: Mathematical Aspects of Selection 341. p. Cambridge University Press. Cambridge.

From Plant Traits to Plant Communities: A Statistical Mechanistic Approach to Biodiversity

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