From ALife Plant Models toward Evolutionary FSPM

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Keywords: artificial evolution, artificial life, plant communities, population dynamics

The Plant Model

The complexity of current functional-structural plant models (FSPM) most often involves a computational cost per individual which renders simulations of large plant communities difficult to realize. Moreover, such models are typically designed or customized for scenarios of specific natural species without genetic change. Complementarily, an amount of studies on plants have been carried out within the research field of Artificial Life. Their primary objective is the application of bottom-up design, especially evolutionary algorithms, in the context of plant development. In such models, plants are typically represented as structures based on a set of morphological growth rules with no or only minimal physiology and interactions with their environment. Priority is given to simplification, and the emerging results are qualitatively compared to observations on natural plants.

To bridge the gap between these two approaches, a plant model of intermediate complexity has been developed and implemented as a simulation platform. Based on Artificial Life concepts, the virtual plants combine a physiological transport-resistance model [5] with a morphological model using the L-system formalism [4] and grow in a 3D artificial ecosystem which provides light and soil nutrients. The plant development is ruled by a set of genetic information which describes parameters concerning morphological as well as physiological processes. To reproduce, the virtual plants are able to grow flowers and seeds which hold, depending on the study, either an exact (population level) or a mutated (evolutionary level) copy of the mother plant genotype.

Simulations and Results

To illustrate the possibility of using the model as an investigation tool at population level, a series of simulations on intra- and interspecific competition for resources were conducted and subsequently compared to the corresponding Lotka-Volterra differential equations [3]. Despite its simplicity, the plant model was able to not only qualitatively reproduce the dynamics of the aggregate model, but also to assess the influence of various biotic and abiotic parameters such as the range of seed dispersal or the soil diffusion rate whose impact on population dynamics is difficult to describe in concise mathematical formulas.

The major advantage of the presented model is its potential to study evolution in plant communities. Two previous papers already discussed the evolutionary adaptation of some morphological and life history traits and compared the results to growth patterns of natural plants. In [2], the conducted simulations allowed to reveal developmental constraints on the placement of flowers within a plant architecture, and to observe morphological responses to different resource dispositions in the environment. The simulations in [1] addressed the trade-off between resource allocation to vegetative and reproductive structures. It was shown that the introduction of an age at maturity enhances both life history traits. Furthermore, depending on the competitive pressure plants evolved more investment of resources into growth than into reproduction.

As the results at both population and evolutionary levels corroborate some assertions and hypotheses of theoretical biology, the presented model may be a promising approach to capture important dynamics within plant communities and notably to broaden the scope of FSPM to evolution.

References

[1] Bornhofen S., Lattaud C. (2006) Life History Evolution of Virtual Plants : Trading off between Growth and Reproduction. Lecture Notes in Computer Science 4193, Springer-Verlag, 808-817
[2] Bornhofen S., Lattaud C. (2007) Evolution of Virtual Plants interacting with their Environment, in Proceedings of the 9th International Conference on Virtual Reality (VRIC'07), 172-176
[3] Lotka A.J. (1924). Elements of physical biology. Williams and Wilkins, Baltimore, Maryland, USA
[4] Prusinkiewicz P., Lindenmayer A. (1990) The Algorithmic Beauty of Plants, Springer-Verlag, Berlin
[5] Thornley J.H.M. (1998) Modelling shoot:root relations:the only way forward?, Ann.of Bot. 81,165-171