RÉPUBLIQUE FRANÇAISE
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INRAE

ALGO-ROOT

EXPLORATORY PROJECT

2021-2023

Modeling decision algorithms for root development in heterogeneous environments

Coordination

Sandrine Ruffel
UMR BPMP
sandrine.ruffel@inrae.fr

Key words

Phenotype modelling
Decision algorithms
Root development
Nutritional heterogeneity of environments

INRAE units involved

IPSiM

Partnerships

Simons Center for Quantitative Biology, Laboratoire du Cold Spring Harbor NY - United States

Institut Alan Turing - United Kingdom

Context and challenges

To survive, plants must take up water and many nutrients from the soil. These resources are unevenly distributed and plants must explore the soil to find them. This exploration requires the extension of roots, which is a development that comes at a cost for the plant. To minimise resource expenditure while maximising nutrient acquisition, decisions about where to explore and when to forage probably need to be optimised. How do plants manage this trade-off?

One way to study this question is to present plants with choices and examine their behaviour. For this purpose, the so-called two-armed (or one-armed) bandit problem provides an interesting mathematical framework because it allows us to determine the decision algorithms underlying decision making when faced with two competing choices with different (but unknown) rewards. For plants, the dilemma will be between exploiting low or medium quality but immediately available, resources or exploring new parts of the soil where better quality resources may (or may not) reside. The general problem of optimisation between exploitation and exploration has already been studied in various fields, including psychology and economics, where quantitative frameworks have been well described to evaluate the advantages and disadvantages of different forage methods. However, this framework has not yet been used to understand and predict plant behaviour.

Goals

The objective of the ALGOROOT project is to discover the algorithms (reflecting a succession of decisions) that plant roots use to search for nutrients in heterogeneous environments.

The project's approach is four-fold:

1. Identify the algorithmic basis of the branching used by plant root systems to explore the soil;
2. Develop mathematical models to predict how roots "decide" between exploiting an available resource or exploring new territory in the hope of finding a better resource;
3. Evaluate how search strategies and decision-making algorithms are genetically encoded;
4. Compare and contrast root search algorithms with those used in other fields (e.g. chemotaxis, infotaxis, random walks) and test whether lessons from plant biology can be applied to computer science.

The ALGOROOT project is an interdisciplinary project that integrates theory and experimentation to solve a fundamental biological problem.

Research units involved and partnerships

INRAE scientific division	INRAE research units	Expertises
Plant biology and breeding	IPSiM	Expertise provided: Plant physiology and development
External partners		**Expertises**
Simons Center for Quantitative Biology / Cold Spring Harbor Laboratory, NY (United States)		Theoretical computer science, machine learning, systems biology
Alan Turing Institute (United Kingdom)		Biology and modelling

Reference

- **Ruffel, S., Krouk, G., Ristova, D., Shasha, D., Birnbaum, K.D., and Coruzzi, G.M. (2011).** Nitrogen economics of root foraging: transitive closure of the nitrate-cytokinin relay and distinct systemic signaling for N supply vs. demand. Proc. Natl. Acad. Sci. U.S.A. 108, 18524-18529.