Optimal growth in an uncertain environment

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We propose to study optimal strategies used by biological or ecological populations to cope with uncertain environments by drawing analogies with gambling and financial investments in economy.

A central model for financial investment is Kelly's horse race model. A gambler strives to optimize his/her capital growth by placing appropriate bets. Kelly showed that optimal strategies correspond to a maximization of the long term growth rate which is risky in practice. Recently, we have revisited this model by also including a penalization depending on the variance of the growth rate, i.e. the risk, and we have studied the corresponding trade-off between growth and risk [1]. We believe that this trade-off has broad relevance, because we also observed it in a model of a biological population stochastically switching between two phenotypes in a stochastic environment [2].

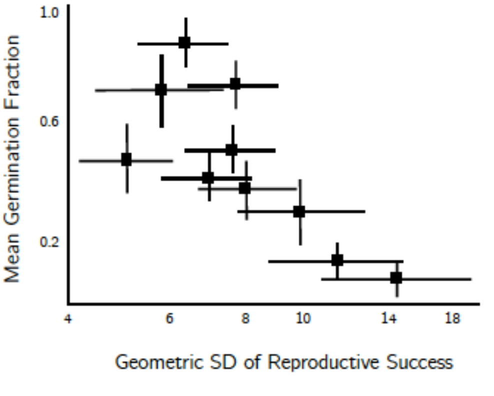

Figure. Left: Eriophyllum lanosum, a species of wildflower prominent in the southwestern United States, is one of many plants believed to implement a bet-hedging strategy. Right: An inverse relationship between the germination fraction and the standard deviation in reproductive success in deserts. From D. Venable, Ecology (2007)

In biology, individuals take decisions (such as germinating or not for seeds in desert plants as illustrated in figure below) in order to adapt to a specific environment. Individuals typically sense their environment and adjust their response accordingly in a process called adaptive sensing. Similar adaptive strategies exist in models of financial investments. In an interesting variant of Kelly's model mentioned above, the gambler uses Bayesian inference to learn progressively from past race results how to play optimally [3].

The goal of this internship/thesis is to further extend these analogies between finance/economy and biology. In the context of adaptive strategies, we ask what are the fundamental limits of adaptation from the point of view of thermodynamics and information theory ? How general is the trade-off between growth and risk mentioned above ? To address these questions, we rely on recent methods of non-equilibrium Statistical Physics, Stochastic Thermodynamics and Information theory, to study complex strategies used by biological systems to cope with fluctuating environments.

The candidate should also benefit from the expertise of O. Rivoire who is also working at Gulliver and is interested in these questions and from interactions with the group of N. Desprat at ENS, in which an experiment with yeast cell populations in a controlled stochastic environments has started this year.

References :

[1] Phase transitions in optimal betting strategies, L. Dinis, J. Unterberger and D. L., Eur. Phys. Lett., 131, 60005 (2020).

[2] Pareto-optimal trade-off for phenotypic switching of populations,L. Dinis, J. Unterberger and D. L., J. Stat. Mech. (2022) 053503.

[3] Adaptive strategies in Kelly's horse race model, A. Despons, L. Peliti, and D. L., J. Stat. Mech. (2022) 093405.