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Comment

The art of abstraction
Comment on “Morphogenesis as Bayesian inference: A variational approach to pattern formation and control in complex biological systems” by F. Kuchling, K. Friston, G. Georgiev, M. Levin

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“In mathematical modeling, as in all of science, we always have to make choices about what to stress and what to ignore. The art of abstraction lies in knowing what is essential and what is minutia, what is signal and what is noise, what is trend and what is wiggle. It’s an art because such choices always involve an element of danger; they come close to wishful thinking and intellectual dishonesty.” [1] I adopt this reflective stance, expressed by Steven Strogatz, to comment on the genesis of a form [2]. My vantage point implies that we actually know the principle of self-organization, and we do know. It is the least-time consumption of free energy [3]—or, as the Authors prefer to say, a variational free-energy principle.

Free energy stands for imbalance. It forces an organism to “come to terms with its environment,” as Kurt Goldstein phrased the target state of balance. [4] While each individual attains its shape by the universal principle of consuming free energy in the least time, each path to a mature form is a unique and intractable process because everything depends on everything else. Therefore, a full-fettered flock following from proliferation, migration and specialization of cells, or speciation consists of a diversity of individuals (agents), or as physicists say, a skewed distribution of states.

This insight into morphogenesis urges us to focus on modeling’s tacit departures from reality rather than just to content ourselves with zooming into a model’s minute deviations from data. After all, the whole point about modeling is, as Strogatz said, instrumental, e.g., to provide us with means for controlling, manipulating, and predicting outcomes of processes—objectives that the Authors mention as well. Conversely, the whole point about explaining is, as Goldstein said, fundamental, i.e., to provide us with an understanding of why things happen. The paper at hand makes an exemplary case of how to cope with these irreconcilable differences between instrumentalism and realism.

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When forces, i.e., components of free energy that transform the present into the future, are modeled in terms of Bayesian probabilities, which are repeatedly updated against what actually happened, a resulting scenario, i.e., a Markov chain will follow the true course of events closely. When numerous chains are interwoven into a Markov blanket [5], a term coined by Judea Pearl, this decision network, familiar from artificial intelligence, mimics quite well natural learning machinery, e.g., a network of genes, cells, and organs, that generates internal responses to external stimuli. While the exterior influence through a mosaic of sensory and signaling mechanisms on the interior status can be modeled, as the paper demonstrates, the model, nonetheless, only correlates inputs with outputs, whereas in reality, causes lead to effects. [6]

Since a complex system is subject to uncountable forces, it is practical to model intractable causality by a stochastic distribution. True variation is, of course, not random but originates from forces, however feeble and fluctuating they might be. Still, symmetric, such as a Gaussian, distribution is an excellent model for courses of events that are on a well-trodden path. Already a long time ago, Aleksandr Lyapunov formulated this quest for an optimum, e.g., homeostasis, so that the further away the system has deviated from thermodynamic balance with its surrounding systems, the more it will be forced back—a property from which the Authors benefit in laying out the foundation of mathematical modeling of pattern formation. Only when factors in fat tails of free energy distribution hold the reins is the outcome of morphogenesis deemed to be anomalous, say malignant—a case that the Authors subtly deal with by adjusting the external milieu.

Computability necessitates stationarity de facto, but reality is evolving. [3] Therefore, the Authors include, along with conservative forces, also flows of energy but retain computability by attributing dissipation to random fluctuations and by steering the simulation, in a statistical sense, to a target state, viz., a random dynamical attractor. In reality, a morphing system does not know where it is on its way; it just consumes free energy, and so a steady state is approached. For example, a cell migrates in a chemical gradient until the gradient vanishes at the steady state, known as the attractor. It is rarely realized in a model that chemotaxis itself consumes its driving chemical potential, thereby altering the driving force of other agents too. Here, the Authors, however, effectively take this into account by defining the external dynamics as a generative process for the internal organization. Infotaxis not only parallels but equates chemotaxis [7] when information is understood as physical, i.e., free energy for a recipient [8]. Indeed, Kullback-Leibler divergence—as the Authors realize—models, in terms of information theory, a good part of the free energy that transforms the system during development.

It is an art to transcribe the inherently intractable morphogenesis into a conveniently computable model. The art of abstraction lies in knowing what is real and what is virtual, what is causal and what is random. It's an art—that the Authors master well—because such choices always involve an element of danger; they come close to obscuring rather than clarifying what is happening.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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