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Towards a Formal Understanding of Bateson's Rule: Chromatic Symmetry in Cyclic Boolean Networks and its Relationship to Organism Growth and Cell Differentiation

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Abstract

There has been considerable prior research on the biological processes of morphogenesis and cellular differentiation, and the manner by which these processes give rise to symmetries in biological structures. Here we extend our previous work on thermal robustness and attractor density in cyclic formal Boolean dynamical systems, introducing a new form of spectral analysis on digital organisms at the cellular level. We interpret the phenomena of radial and bilateral symmetry in terms of spatial periodicities in the color sequences, as manifested by an organism while it orbits in its attractors. We provide new results on the influence of various organism properties on its emergent color symmetries—providing initial insights toward an eventual formal understanding of metamerism and Bateson's Rule.

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1. Introduction

Since the seminal work of Von Neumann [1], the subject of cellular automata has received considerable and continued attention (see [2, 3] for brief surveys). Understanding how the structure of a cellular network impacts its behavior as a dynamical system is crucial to determining how networks should be built, how they evolve over time, and how they can be made to grow while still exhibiting desired dynamical properties. Biological networks (e.g. neural networks) are subject to preferential selection processes, which drive evolution over long time scales. It is reasonable to expect that this selection process will be sensitive to not only the structural properties [4] of networks, but to their dynamical properties as well [5]. Previous researchers have considered measures such as landscape ruggedness [6, 7] and redundancy [8] in evaluating dynamical systems. In this paper, we extend our previous work on attractor dynamics [16] to describe *the manner in which the requirement to maintain rotational chromatic symmetries in an organism's attractor dynamics might serve to structure its growth trajectory*.

In addition to evolution over long time scales, biological networks exhibit cellular differentiation over short

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function 6 organism and expanding the random sampling to include non-homogeneous organisms. The experimental data from the much larger set of non-homogeneous organisms should lead to a better understanding of cellular differentiation, symmetry, and morphogenesis.

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References

[1] J. V. Neumann, Theory of Self-Reproducing Automata, University of Illinois Press, Champaign, IL, USA, 1966.

[2] P. Sarkar, A brief history of cellular automata, ACM Computing Surveys 32 (2000) 80–107. doi:10.1145/349194.349202.

[3] N. Ganguly, B. K. Sikdar, A. Deutsch, G. Canright, P. P. Chaudhuri, A survey on cellular automata, Tech. rep. (2003).

[4] D. W. Thompson, On Growth and Form, canto Edition, Cambridge University Press, 1992.

[5] M. Ebner, M. Shackleton, R. Shipman, How neutral networks influence evolvability, Complex. 7 (2001) 19–33.

[6] T. Malloy, G. Jensen, T. Song, Mapping knowledge to Boolean dynamic systems in Batesons epistemology, in: Nonlinear Dynamics, Psychology, and Life Sciences, Vol. 9, 2005, pp. 37–60.

[7] T. Malloy, G. Jensen, Dynamic constancy as a basis for perceptual hierarchies, in: Nonlinear Dynamics, Psychology, and Life Sciences, Vol. 1(2), 2008, pp. 191–203.

[8] C. Gershenson, S. A. Kauffman, I. Shmulevich, The role of redundancy in the robustness of random boolean networks, Tech. Rep. nlin.AO/0511018. ECCO-2005-08 (Nov 2005).

[9] S. A. Kauffman, The Origins of Order: Self-Organization and Selection in Evolution, 1st Edition, Oxford University Press, USA, 1993.

[10] C. Gershenson, Classification of random Boolean networks (2002).

[11] K. Sutner, Linear cellular automata and the garden-of-eden, The Mathematical Intelligencer 11 (1989) 49–53.

[12] C. R. Shalizi, K. L. Shalizi, Quantifying self-organization in cyclic cellular automata, in: in Noise in Complex Systems and Stochastic Dynamics, Lutz Schimansky-Geier and Derek Abbott and Alexander Neiman and Christian Van den Broeck, Proceedings of SPIE, vol 5114, 2003.

[13] C. L. Nehaniv, Evolution in asynchronous cellular automata, MIT Press, 2002, pp. 201–209.

[14] T. Lundh, Cellular automaton modeling of biological pattern formation: Characterization, applications, and analysis, Genetic Programming and Evolvable Machines 8 (2007) 105–106.

[15] G. Bateson, A re-examination of "Bateson's Rule", Journal of Genetics ,V60, (1971) 230-240.
Bateson, G. (1972) A re-examination of "Bateson's Rule." In: Steps to an ecology of mind. Ballantine.

[16] Yuri Cantor, Bilal Khan, and Kirk Dombrowski, Heterogeneity and its impact on thermal robustness and attractor density. Procedia Computer Science, 6(0):15 – 21, 2011. Complex adaptive sysytems.