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Book Review

Exploring Discrete Dynamics
By Andrew Wuensche
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THE DDLAB UNIVERSE

The book "Exploring Discrete Dynamics", written by Andrew Wuensche, now in its second edition, is a very complete description of the study of discrete networks using the Discrete Dynamics Lab system. The origins of Discrete Dynamics Lab (DDLab) was to calculate pre-images in Cellular Automata (CA). Pre-images in CA are fundamentally important because they permit the study of CA in terms of injective, surjective and bijective mapping, and its applications in reversible cellular automata, cryptography, and in the characterisation of global properties as Chaotic, Ordered and Complex behavior, as proposed by Wuensche and Lesser with basin of attractions[15]. The theoretical biologist Kauffman was very interested in the work of Wuensche, mainly in its applications in the field of genetics, because the results provided a model of genetic regulatory networks[10]. In order to do that DDLab was expanded to model Random Boolean Networks (RBN). Now in the course of 25 years of development, DDLab has become an interactive graphical software platform for the study of networks of inter-connected elements with discrete values and updating in parallel, not just to model CA and RBN but in general for discrete dynamical networks (DDN).

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One of the most powerful characteristics of DDLab is its ability to very quickly test different kinds of rules, configurations, neighborhood topologies and to interchange between these parameters and options with just a click of a key. The system allows the analysis of thousands of rules, travelling from one rule to another, to see the evolution, with filter options in order to distinguished special patterns of space-time, basins of attraction, entropy analysis, and a wide variety of measures, data, analysis and statistics. It permits saving past configurations—this characteristic is very useful because it lets us know the pre-image of any pattern that we consider interesting. And because the rules are the main subject, they can be represented in very meaningful ways, for example when the rules are represented as dots in a plot, if some rule is interesting the user only has to select the dot and obtain all the information about this rule and analyse it in a very complete way.

DDLab can be considering in two ways, as a powerful tool to do research, and as an explorer tool, to understand the theoretical and phenomenological framework of any system from CA to DDN in general. DDLab is a great tool for the investigation of computation universality[18], the study or research about the classification problem in CA[13, 17, 11], the design of automata networks[1], Garden-of-Eden configurations[17], neural nets and cognition[16], cryptography[21], and even cosmology and the arrow of time[4], amongst other topics.

Many researchers have taken advantage of the characteristics of DDLab. To give just some examples, David Burraston used DDLab in his thesis about music[3], Kauffman in genetic regulatory networks[10], Adamatzky and Wuensche[2] found computation in a 2D CA with three states[19], and gliders and glider-guns were found in 3D with three states[20] using DDLab. Recently the author of this review and Wuensche found two binary cellular automata in 2D, as in the Game of Life, capable of Universal Computation[7, 8].

Also, DDLab has inspired several lines of research. Professor Harold V. McIntosh in [9] wrote about the book “The Global Dynamics of Cellular Automata”, which was an early result of the facilities of DDLab: “To begin with, the book is a real work of art, with something like 200 pages of carefully drawn evolution diagrams, for binary rules with 3 and 5 neighbors. All the symmetry classes of the former, and mostly the totalistic rules of the latter are shown, for rings of up to 15 cells. All in all, a tremendous collection of data, a vastly expanded version of Holly Peck's Table 13 in Wolfram's Theory and Applications of Cellular Automata[14]”. Professor Kauffman said that Exploring Discrete Dynamics “is by far the most advanced tool for simulating such systems and has become widely important in the field of complexity”, and today a special discussion has started on the application of “Smoothiness to classify rules” in “Other Cellular Automata” at in the game-of-Life community[6].

A great update is that DDLab can now interact with Mathematica, so its now possible to have the facilities that DDLab offers to study CA and symbolic processing representation of data, and get the benefits of a Computer Algebra System. Also DDLab can interchange rules and configurations with Golly which links it to the study of CA as a topic of interest in the game-of-Life community forum[6]. Greater system sizes are allowed that depend on the RAM memory of the computer (32-bit or 64-bit). Each time DDLab has been updated it has become more interactive. For example, when defining parameters in the "wiring graphic", the default corners of a "block" can be defined with the mouse. Its possible to have a neighborhood size up to 27 in all dimensions. New 2D hex/triangular neighborhoods have been introduced with 3 and 4 neighbors. Its now possible to reproduce and analyse "Non Trivial Collective behavior in Cellular Automata"[5] with the "return map by density" plot, and study problems related to the density of global behavior. DDLab supports basins of attraction for 2D, and can build basins of attraction for bigger configurations, and if this is not enough DDLab lets us investigate basins of attraction statistically. The Derrida Plot, the DDLab tool that measures chaos on large discrete networks analogous to the Lyapunov exponent, also allows automatic plots of sets of rules listing equivalence classes and rule clusters.

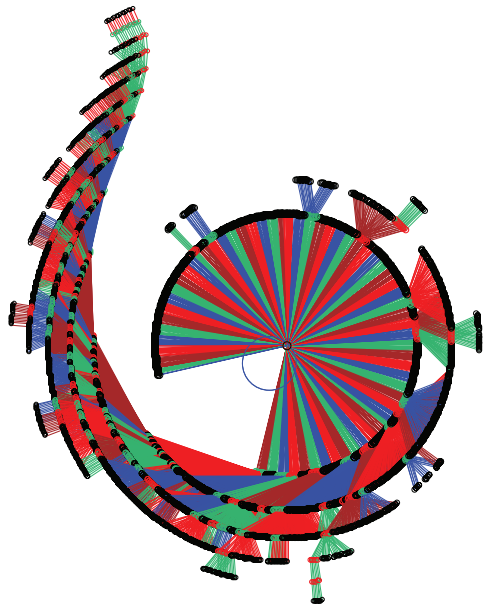

FIGURE 1
The beauty of a typical Basin Atractor generated by DDLab.

The book "Exploring Discrete Dynamics, second edition", is well written and is illustrated with more than 300 beautiful images. Many images look like mathematical art pieces (see for example Figure 1) in a way that adds to the clarity and enjoyment of reading. Also the book explains how to reproduce experiments very easily. I strongly recommend it to researchers and students who are interesting in discrete dynamical networks. The book, 576 pages in paperback, is available from online bookstores. The PDF version of the book is free from the DDLab website http://www.ddlab.org/, and the DDLab open source software, for Linux, MacOSX, and DOS, can also be downloaded from this site.

DDLab is a "universe" full of subtle details in each topic that the expert will appreciate because her task will be made easier. The book "Exploring Discrete Dynamics" is at the same time an operating manual and also a compendium of theory and methods. In this brief review I have mentioned some details that to me are the main characteristics of the system, and of course the user will discover many more. The final two characteristics about DDLab I want to mention is its efficiency and flexibility. In my research in Universal Computation[7, 8], DDLab has given me the opportunity to test interesting patterns in several rules on-the-fly, where the rules were chosen from a plot which classified them by some particular characteristics and allowed changing at will from combinations between rules and configurations in a very efficient way.

REFERENCES

[1] Adamatzky, A., "Automatic programming of cellular automata: identification approach", Kybernetes, Vol. 26, pp. 126-39, 1997.

[2] Adamatzky, A. and Wuensche, A. "Computing in spiral rule reaction- diffusion cellular automaton", Complex Systems 16(4) 277-297, 2006.

[3] Burraston, D., "Generative Music and Cellular Automata", PhD Thesis, Univ. Technology Sydney, Australia. 2006. http://noyzelab.com/research/research.html

[4] Cortés Marina and Smolin Lee, "Reversing the Irreversible: from limit cycles to emergent time symmetry", Arxiv:https://arxiv.org/pdf/1703. 09696.pdf, 2017.

[5] Chaté Hughes y Manneville Paul, "Evidence of collective behaviour in cellular automata", *Europhysics Letters*, 14, 409-413, 1991.

[6] ConwayLife forum, "A community for Conway's Game of Life and related cellular automata", Other Cellular Automata—Use Smoothiness to classify rules. http://www.conwaylife.com/

[7] Gómez Soto, J.M., and A.Wuensche,"The X-rule: Universal Computation in a Non-Isotropic Life-like Cellular Automaton", JCA, Vol 10, No.3-4, 261-294, 2015. Preprint: http://arxiv.org/abs/1504.01434/

[8] Gómez Soto, J.M., and A.Wuensche, "X-Rule's Precursor is Also Logically Universal", JCA, Vol 12, No.6, 445-473, 2017. Preprint: https://arxiv.org/abs/1611.08829/

[9] McIntosh Harold V, "The collection of commentaries on the book: The Global Dynamics of Cellular Automata by Andrew Wuensche and Mike Lesser" , 1993. http://matematicas.reduaz.mx/~cellularautomata/cellularautomata/Working_Papers_files/global.pdf

[10] Kauffman, S.A., "The Origins of Order", Oxford University Press, 1993.

[11] Langton, C.G., “Computation at the Edge of Chaos: Phase Transitions and Emergent Computation, Physica D, 42, 12-37, 1990.
[12] Von Neumann John, “Theory of Self-reproducing Automata”, (edited and completed by A. W. Burks), University of Illinois Press, 1966.
[13] Wolfram, S., “Universality and complexity in cellular automata”, Physica D, Vol. 10, pp. 1-35, 1984.
[14] Wolfram, S., “Theory and Applications of Cellular Automata”, World Scientic Press, Singapore, 1986.
[15] Wuensche, A., and M.J. Lesser. “The Global Dynamics of Cellular Automata”, Santa Fe Institute Studies in the Sciences of Complexity, Addison-Wesley, Read- ing, MA, 1992.
[16] Wuensche A, “Attractor Basins of Discrete Networks”, Cognitive Science Research Paper 461, Univ. of Sussex, D. Phil thesis, 1997.
[17] Wuensche, A., “Classifying Cellular Automata Automatically; Finding gliders, ltering, and relating space-time patterns, attractor basins, and the Z parameter, COMPLEXITY, Vol.4/no.3, 47-66, 1999.
[18] Wuensche.A., “Finding Gliders in Cellular Automata, in Collision-Based Computing, ed. A. Adamatzky. Springer, London, (2002).
[19] Wuensche, A., “Glider Dynamics in 3-Value Hexagonal Cellular Automata: The Beehive Rule”, Int. Journ. of Unconventional Computing, Vol.1, No.4, 2005, 375-398, 2005.
[20] Wuensche, A., A. Adamatzky, “On spiral glider-guns in hexagonal cellular automata: activator-inhibitor paradigm”, International Journal of Modern Physics C,Vol. 17, No. 7,1009-1026, 2006.
[21] Wuensche A. (2009), “Cellular Automata Encryption: The Reverse Algorithm, Z-Parameter and Chain-Rules”, Parallel Processing Letters,Vol 19, No 2, 283-297, 2009,