Universidad
Carlos III de Madrid
www.uc3m.es

TESIS DOCTORAL

La descentralización estructural y la heterogeneidad funcional en la producción colectiva de conocimiento: Una justificación teórica y computacional del paradigma P2P

ANEXOS

Autor:

Diego González Rodríguez

Director/es:

Mercedes Caridad Sebastián

José Rodolfo Hernández Carrión

Tutor:

Mercedes Caridad Sebastián

DEPARTAMENTO DE DOCUMENTACIÓN

Getafe, Noviembre de 2015

Apéndice A

Posters

En este primer anexo se adjuntan algunos pósters que han sido presentados durante el desarrollo de esta tesis y que guardan relación con la investigación presentada.

- En primer lugar hemos incluido el póster *Biological Peer-to-Peer Networks: From Bacterial Communication to the Development of Synthetic Distributed Systems*, presentado en la conferencia *Biology of plastids: Towards a blueprint for synthetic organelles. EMBO-ESF, 2014.* http://hdl.handle.net/10016/22341

- En segundo lugar, se incluye el póster *P2P Societies: The impact of Decentralization and Heterogeneity in Complex Systems*, presentado en *Design and Control of Self-Organizing Systems, 16th Congress of the World Organization of Systems and Cybernetics, 2014.* http://hdl.handle.net/10016/22349

Apéndice B

Publicaciones

En este segundo anexo se adjuntan algunos de los artículos que han sido publicados durante el desarrollo de esta tesis, y que guardan relación con la investigación presentada, sirviendo como complemento a los aspectos aquí descritos.

- D. Gonzalez-Rodriguez and J. R. Hernandez-Carrion, "A Bacterial-Based Algorithm to Simulate Complex Adaptive Systems," *Lecture Notes in Artificial Intelligence (LNAI)*, vol. 8575, pp. 250–259, 2014. http://hdl.handle.net/10016/22371

- D. Gonzalez-Rodriguez and V. Kostakis, "Information literacy and peer-to-peer infrastructures: An autopoietic perspective," *Telematics and Informatics*, vol. 32, pp. 586– 593, 2015. http://hdl.handle.net/10016/22360

- D. Gonzalez-Rodriguez and J. R. Hernandez-Carrion, "Decentralization and Heterogeneity in Complex Adaptive Systems," *Kybernetes*, accepted: K-01-2015-0030.R1, 2015. http://hdl.handle.net/10016/22450

- D.González-Rodríguez, "Modelización de Sistemas de Computación Distribuida

con Bacterias Sintéticas mediante Autómatas Celulares," *Revista Internacional de Sistemas*, vol. 19, pp. 62–74, 2014. http://hdl.handle.net/10016/22356

- J. R. Hernandez-Carrion and D. González-Rodriguez, "Modelling Complex Dynamics and Distributed Generation of Knowledge with Bacterial-Based Algorithms," in *Economics and Bussiness Communication Challenges*, Katowice: University of Economics in Katowice, 2014, pp. 138–148. http://hdl.handle.net/10016/22871

Bibliografía

[1] M. Bauwens and R. Sussan, "P2P and Human Evolution: Peer to peer as the premise of a new mode of civilization," 2005.

[2] P. Baran, "On Distributed Communications Networks," *IEEE Transactions on Communications*, vol. 12, no. 1, pp. 1–9, 1964.

[3] V. Kostakis, "The advent of open source democracy and wikipolitics: challenges, threats and opportunities for democratic discourse," *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments*, vol. 7, no. 1, pp. 9–29, 2011.

[4] V. Kostakis, "At the turning point of the current techno-economic paradigm: commons-based peer production, desktop manufacturing and the role of civil society in the Perezian framework," *tripleC: Communication, Capitalism & Critique. Open Access Journal for a Global Sustainable Information Society*, vol. 11, no. 1, pp. 173–190, 2013.

[5] V. Kostakis, V. Niaros, and C. Giotitsas, "Production and governance in hackerspaces: A manifestation of Commons-based peer production in the physical realm?," *International Journal of Cultural Studies*, pp. 136–178, 2014.

[6] V. Kostakis, *The Political Economy of Information Production in the Social Web: Towards a partner State Approach.* Tallinn: Tallinn University of Technology, 2011.

[7] M. Caridad-Sebastián, A. M. Morales-García, and F. García-López, "La alfabetización digital en España como medio de inclusión social: aplicación de un modelo de medición a través de indicadores," *Historia y Comunicación Social*, vol. 18, pp. 455–469, 2014.

[8] D. Gonzalez-Rodriguez and V. Kostakis, "Information literacy and peer-to-peer infrastructures: An autopoietic perspective," *Telematics and Informatics*, vol. 32, pp. 586–593, 2015.

[9] F. Heylighen, "The Global Superorganism : an evolutionary-cybernetic model of the emerging network society," *Journal of Social and Evolutionary Systems*, vol. 6, pp. 1–37, 2007.

[10] J. R. Hernández-Carrión, "Quo Vadis Complexity Science? Una vision de la complejidad a partir del enfoque sistémico.," *Revista Internacional de Sistemas*, vol. 10, pp. 58–67, 2000.

[11] D. Gonzalez-Rodriguez and J. R. Hernandez-Carrion, "A Bacterial-Based Algorithm to Simulate Complex Adaptive Systems," *Lecture Notes in Artificial Intelligence (LNAI)*, vol. 8575, pp. 250–259, 2014.

[12] D. Doucette, R. Bichler, W. Hofkirchner, and C. Raffl, "Toward a New Science of Information," *Data Science Journal*, vol. 6, no. April, pp. S198–S205, 2007.

[13] G. Piccinini and A. Scarantino, "Information processing, computation, and cognition.," *Journal of biological physics*, vol. 37, pp. 1–38, Jan. 2011.

[14] G. Piccinini and A. Scarantino, "Computation vs. information processing: why their difference matters to cognitive science," *Studies in History and Philosophy of Science Part A*, vol. 41, no. 3, pp. 237–246, 2010.

[15] L. Floridi, *Information: A very short introduction.* New York: Oxford University Press, 2010.

[16] L. Ma, "Information as discursive construct," *Proceedings of the American Society for Information Science and Technology*, vol. 47, no. 1, pp. 1–4, 2010.

[17] M. K. Buckland, "Information as thing," *JASIS*, vol. 42, no. 5, pp. 351–360, 1991.

[18] K. R. Koedinger and A. Corbett, *Cognitive tutors: Technology bringing learning sciences to the classroom.* New York: Cambridge University Press, 2006.

[19] J. Greenberg and E. Rodriguez, *Knitting the semantic web.* Binghamton: Haworth Information Press, 2013.

[20] R. Melero, "Acceso abierto a las publicaciones científicas: definición, recursos, copyright e impacto," *El Profesional de la Informacion*, vol. 14, no. 4, pp. 255–266, 2005.

[21] M. J. Zomorodian and S. Jamali, *LaTeX: A Document Preparation System*, vol. 3. 2013.

[22] I. Erickson, L. Nathan, N. Jafarinaimi, C. Knobel, and M. Ratto, "Meta-making: Crafting the Conversation of Values and Design," *Interactions*, vol. 19, p. 54, 2012.

[23] V. Kostakis and M. Papachristou, "Commons-based peer production and digital fabrication: The case of a RepRap-based, Lego-built 3D printing-milling machine," *Telematics and Informatics*, vol. 31, no. 3, pp. 434–443, 2014.

[24] F. Heylighen, M. Heath, and F. Van, "The Emergence of Distributed Cognition: a conceptual framework," *Proceedings of collective intentionality IV*, vol. IV, p. 20, 2004.

[25] F. Heylighen and F. V. Overwalle, "The Self-Organization of Distributed Cognition: a connectionist approach," *Research Proposal for a "Geconcerteerde Onderzoeksactie"*, pp. 1–53, 2006.

[26] J. Hollan, E. Hutchins, and D. Kirsh, "Distributed cognition: toward a new foundation for human-computer interaction research," *ACM Transactions on Computer-Human Interaction*, vol. 7, no. 2, pp. 174–196, 2000.

[27] J. H. Holland, "Studying Complex Adaptive Systems," *Journal of Systems Science and Complexity*, vol. 19, pp. 1–8, 2006.

[28] S. L. Lytinen and S. F. Railsback, "The evolution of agent-based simulation platforms: a review of NetLogo 5.0 and ReLogo," in *Proceedings of the fourth international symposium on agent-based modeling and simulation (21st European Meeting on Cybernetics and Systems Research. EMCSR 2012)*, pp. 1–11, 2012.

[29] D. A. Robertson, "Agent-Based Modeling Toolkits NetLogo, RePast, and Swarm.," *Academy of Management Learning & Education*, vol. 4, pp. 524–527, 2005.

[30] R. Weiss, S. Basu, S. Hooshangi, A. Kalmbach, D. Karig, R. Mehreja, and I. Netravali, "Genetic circuit building blocks for cellular computation, communications, and signal processing," *Natural Computing*, vol. 2, pp. 47–84, Mar. 2003.

[31] D. Krol and H. S. Lopes, "Nature-inspired collective intelligence in theory and practice," *Information Sciences*, vol. 182, pp. 1–2, Jan. 2012.

[32] S. Wright, "The roles of mutation, inbreeding, crossbreeding and selection in evolution," in *Proceedings of the Sixth International Congress on Genetics*, vol. 1, pp. 356–366, 1932.

[33] L. Booker, D. Goldberg, and J. Holland, "Classifier systems and genetic algorithms," *Artificial Intelligence*, vol. 40, pp. 235–282, Sept. 1989.

[34] J. H. Holland, *Hidden order: How adaptation builds complexity*. New York: Helix Books, 1995.

[35] D. Goldberg and J. Holland, "Genetic Algorithms and Machine Learning," *Machine Learning*, vol. 3, pp. 95–99, 1988.

[36] M. Mitchell, *An introduction to genetic algorithms*. London: A Bradford Book The MIT Press, 1998.

[37] S. M. Thede, "An introduction to genetic algorithms," *Journal of Computing Sciences in Colleges*, vol. 20, pp. 115–123, 2004.

[38] S. A. Levin, "Complex adaptive systems: Exploring the known, the unknown and the unknowable," *Bulletin of the American Mathematical Society*, vol. 40, pp. 3–20, Oct. 2002.

[39] F. Heylighen, "Accelerating Socio-Technological Evolution: from ephemeralization and stigmergy to the global brain," 2007.

[40] F. Heylighen, "The Global Brain as a New Utopia," in *Zukunftsfiguren*, pp. 1–11, 2002.

[41] F. Heylighen, "Building a Science of Complexity," *Proceedings of the 1988 Annual Conference of the Cybernetics Society.*, no. 32, pp. 1–20, 1988.

[42] F. Heylighen, "Collective Intelligence and its Implementation on the Web: algorithms to develop a collective mental map," *Computational & Mathematical Organization Theory*, vol. 5, pp. 253–280, 1999.

[43] F. Heylighen, "The growth of structural and functional complexity during evolution," in *The evolution of complexity* (F. Heylighen, J. Bollen, and A. Riegler, eds.), pp. 17–44, Dordrecht: Kluwer Academic, 1999.

[44] M. Castells and G. Cardoso, *The network society: from knowledge to policy*. Washington, DC: Johns Hopkins Center for Transatlantic Relations, 2006.

[45] L. Rainie and B. Wellman, *Networked: The New Social Operating System*. Cambridge: MIT Press, 2012.

[46] D. Easley and J. Kleinberg, *Networks, Crowds, and Markets: Reasoning about a highly connected world*. Cambridge: Cambridge University Press, 2012.

[47] A. Church, "A Note on the Entscheidungsproblem," *The Journal of Symbolic Logic*, vol. 1, no. 1, pp. 40–41, 1936.

[48] K. Gödel, *On undecidable propositions of formal mathematical systems*. Michigan: Institute for Advanced Study, 1965.

[49] A. Turing, "On computable numbers, with an application to the Entscheidungsproblem," *Proceedings of the London mathematical society*, vol. 38, no. 1931, pp. 173–198, 1936.

[50] J. Bradley, "Logic of Analog and Digital Machines.," *Literary and Linguistic Computing*, vol. 27, no. 4, pp. 467–470, 2012.

[51] P. J. Denning, "Ubiquity Symposium 'What is Computation?': Opening Statement," *Ubiquity*, vol. 2010, no. November, 2010.

[52] K. Zuse, "Calculating Space," in *A Computable Universe*, Cambridge: MIT, 2012.

[53] J. Schmidhuber, "A computer scientist's view of life, the universe, and everything," *Foundations of Computer Science*, pp. 201–208, 1997.

[54] G. Hooft, "Quantum gravity as a dissipative deterministic system," *Classical and Quantum Gravity*, pp. 1–20, 1999.

[55] Wolfram, *A new kind of science.* Champaign: Wolfram Media, 2002.

[56] P. W. Anderson, "More is different," *Science*, vol. 177, no. 4047, pp. 393–396, 1972.

[57] F. Varela, H. Maturana, and R. Uribe, "Autopoiesis: The organization of living systems, its characterization and a model," *Biosystems*, vol. 5, no. 4, pp. 187–196, 1974.

[58] P. L. Luisi, "Autopoiesis: a review and a reappraisal," *Die Naturwissenschaften*, vol. 90, no. 2, pp. 49–59, 2003.

[59] M. Radosavljevic, "Autopoiesis vs. social autopoiesis: critical evaluation and implications for understanding firms as autopoietic social systems," *International Journal of General Systems*, vol. 37, no. 2, pp. 215–230, 2008.

[60] P. Razeto-Barry, "Autopoiesis 40 years later. A review and a reformulation," *Origins of life and evolution of the biosphere : the journal of the International Society for the Study of the Origin of Life*, vol. 42, no. 6, pp. 543–67, 2012.

[61] M. Arnold and F. Osorio, "Introducción a los conceptos básicos de la teoría general de sistemas," *Cinta de Moebio*, vol. 3, 2013.

[62] E. Cohen, "Entropy, probability and dynamics," *Boltzmann's Legacy*, pp. 1–12, 2008.

[63] B. C. Eu, "Boltzmann entropy, relative entropy, and related quantities in thermodynamic space," *The Journal of Chemical Physics*, vol. 102, no. 18, p. 7169, 1995.

[64] D. Dennett, "Content and consciousness," 1969.

[65] G. Northoff, *Philosophy of the Brain: The Brain Problem.* John Benjamins Publishing, 2004.

[66] R. Schmidt, "Deconstructing consciousness in search of useful definitions for applied linguistics," *AILA review*, vol. 11, pp. 11–26, 1994.

[67] J. Heil, *Philosophy of mind: A contemporary introduction.* London: Routledge, 2013.

[68] E. Thompson, "The Enactive Approach," in *Mind in Life*, pp. 3–65, 2007.

[69] R. Kop and A. Hill, "Connectivism: Learning theory of the future or vestige of the past?," *The International Review of Research in Open and Distance Learning*, vol. 9, no. 3, 2008.

[70] P. Kidwell, "The universal turing machine: a half-century survey," *IEEE Annals of the History of Computing*, vol. 18, 1996.

[71] W. J. Rapaport, "Semiotic Systems, Computers, and the Mind," *International Journal of Signs and Semiotic Systems*, vol. 2, no. 1, pp. 32–71, 2012.

[72] W. S. McCulloch and W. Pitts, "A logical calculus of the ideas immanent in nervous activity," *The Bulletin of Mathematical Biophysics*, vol. 5, no. 4, pp. 115–133, 1943.

[73] R. W. Williams and K. Herrup, "The control of neuron number," *Annual review of neuroscience*, vol. 11, pp. 423–453, 1988.

[74] M. Martín-Loeches, *La mente del Homo sapiens.* Madrid: Aguilar, 2007.

[75] L. P. Hickey, "The 'Brain in a Vat' Argument," *Web resource: http://www.iep.utm.edu/brainvat/*, 2005.

[76] D. Bollen, *A Dynamical System Analysis of an Embodied and Situated Model.* PhD thesis, University Maastricht, 2004.

[77] A. R. Damasio, "How the brain creates the mind.," *Scientific American*, vol. 281, pp. 112–117, 1999.

[78] D. Dennett, "Review of Damasio, Descartes' Error," *Times Literary Supplement*, 1995.

[79] C. Lozares, "La teoría de redes sociales," *Revista Papers*, 1996.

[80] D. M. Hogan and J. R. H. Tudge, "Implications of Vygotsky's theory for peer learning.," *Cognitive perspectives on peer learning*, pp. 39–65, 1999.

[81] L. Vygotsky, *The Collected Works of L.S. Vygotsky: Volume 1: Problems of General Psychology, Including the Volume Thinking and Speech.* Springer Science & Business Media, 1987.

[82] S. D. Mitchell, "Biological complexity and integrative pluralism," *Cambridge studies in philosophy and biology*, p. 244, 2003.

[83] T. Turner, "Piaget's Structuralism. Genetic Epistemology," *American Anthropologist*, vol. 75, no. 2, pp. 351–373, 1973.

[84] M. Ratto and R. Ree, "Materializing information: 3D printing and social change.," *First Monday*, vol. 17, no. 7, 2012.

[85] A. Smith, *Goodbye Gutenberg: The newspaper revolution in the 1980's.* New York: Oxford University Press, 1980.

[86] H. Inose and J. Pierce, *Tecnología de la información y civilización.* Barcelona: Labor, 1985.

[87] J. Rifkin, *The biotech century. Harnessing the Gene and Remaking the World.* New York: Penguin Putnam, 1999.

[88] M. L. Dertouzos, *What Will be: How the New World of Information Will Change Our Lives.* New York: Harper Collins Publishers, 1997.

[89] M. Castells, *La galaxia Internet.* Barcelona: Plaza & Janés, 2001.

[90] Jeremy Rifkin, *El fin del trabajo. Nuevas tecnologías contra puestos de trabajo: el nacimiento de una nueva era.* Barcelona: Paidós Ibérica, 1996.

[91] M. C. Sebastián, A. M. M. García, and F. L. García, "La estrategia Europa 2020 y la Sociedad de la Información como instrumentos de cohesión e integración en época de crisis. ¿Utopía o realidad?," *Investigación Bibliotecológica: Bibliometría, Archivonomía e Información*, vol. 28, no. 64, pp. 101–115, 2014.

[92] M. Caridad-Sebastián, A. M. M. Garcia, and F. G. López, "Las políticas de información europeas como acción clave para el desarrollo de la ciencia de la información," *Ciência da Informação*, vol. 40, no. 3, 2013.

[93] N. Moore, "La sociedad de la información," in *UNESCO (1997): Informe Mundial sobre la Información*, pp. 287–300, Madrid: CINDOC /CSIC, 1997.

[94] M. Bauwens, N. Mendoza, and F. Iacomella, "Synthetic Overview of the Collaborative Economy," *Orange Labs/Peer to Peer Foundation*, vol. 112, Jan. 2012.

[95] David De Ugarte, *El poder de las redes.* Madrid: Ediciones El Cobre, 2007.

[96] M. Bauwens, "The political economy of peer production," *CTheory*, vol. 1, 2005.

[97] P. Klipp, "The Scrum Team," *Web resource: http://www.paulklipp.com/articles/Chapter2(v0.07).pdf*, 2009.

[98] S. Savarimuthu and M. Purvis, "Self-Organization of Peers in Agent Societies," *2009 IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology*, pp. 74–77, 2009.

[99] F. Heylighen, "A cognitive-systemic reconstruction of Maslow's theory of self-actualization," *Behavioral Science*, vol. 37, no. 1, pp. 39–58, 1992.

[100] M. Mitchell, *Complexity: A Guided Tour*. OUP USA, 2009.

[101] F. Heylighen, "Fitness as Default: the evolutionary basis of cognitive complexity reduction," *Cybernetics and Systems' 94*, 1994.

[102] F. Heylighen and D. Campbell, "Selection of organization at the social level: Obstacles and facilitators of metasystem transitions," *World Futures*, vol. 45, no. 1, pp. 181–212, 1995.

[103] A. Barabási, "Emergence of Scaling in Random Networks," *Science*, vol. 286, no. 5439, pp. 509–512, 1999.

[104] F. Heylighen, "Evolutionary psychology," *Encyclopedia of Quality of Life Research*, 2011.

[105] B. Goertzel, C. Pennachin, S. Araujo, F. Silva, M. Queiroz, R. Lian, W. Silva, M. Ross, L. Vepstas, and A. Senna, "A General Intelligence Oriented Architecture for Embodied Natural Language Processing," *Proceedings of the 3d Conference on Artificial General Intelligence (AGI-10)*, pp. 1–6, 2010.

[106] U. Faghihi and S. Franklin, "The LIDA Model as a Foundational Architecture for AGI," *Theoretical Foundations of Artificial General Intelligence*, vol. 4, pp. 103–121, 2012.

[107] S. Franklin, S. Strain, R. McCall, and B. Baars, "Conceptual Commitments of the LIDA Model of Cognition," *Journal of Artificial General Intelligence*, vol. 4, pp. 1–22, Jan. 2013.

[108] J. Bach, *Principles of Synthetic Intelligence PSI: An Architecture of Motivated Cognition*, vol. 1. 2009.

[109] J. de León and M. Blázquez, "Arquitecturas cognitivas y cerebro: hacia una teoría unificada de la cognición," *Journal of Psychological Research*, vol. 4, no. 2, pp. 38–47, 2011.

[110] J. Duffy, J. M. Epstein, and R. Axtell, "Growing Artificial Societies: Social Science from the Bottom Up," *Southern Economic Journal*, vol. 64, no. 3, p. 791, 1998.

[111] L. R. Izquierdo, J. M. Galán, J. I. Santos, and R. del Olmo, "Modelado de sistemas complejos mediante simulación basada en agentes y mediante dinámica de sistemas," *EMPIRIA. Revista de Metodología de Ciencias Sociales*, vol. 16, pp. 85–112, 2008.

[112] F. Heylighen, "Complexity and Information Overload in Society: why increasing efficiency leads to decreasing control," *Technological Forecasting and Social Change*, pp. 1–44, 2004.

[113] A.-L. Barabási and Z. N. Oltvai, "Network biology: understanding the cell's functional organization.," *Nature reviews. Genetics*, vol. 5, pp. 101–113, 2004.

[114] K. Suto, H. Nishiyama, X. Shen, and N. Kato, "Designing P2P Networks Tolerant to Attacks and Faults Based on Bimodal Degree Distribution," *Journal of Communications*, vol. 7, no. 8, pp. 587–595, 2012.

[115] M. P. H. Stumpf, C. Wiuf, and R. M. May, "Subnets of scale-free networks are not scale-free: sampling properties of networks," *Proceedings of the National Academy of Sciences of the United States of America*, vol. 102, no. 12, pp. 4221–4, 2005.

[116] D. Raman, "Scale-Free Networks to Search in Unstructured Peer-To-Peer Networks," *Journal of Computer Engineering*, vol. 12, no. 4, pp. 12–17, 2013.

[117] U. Wilensky, "NetLogo Preferential Attachment model," *Center for Connected Learning and Computer-Based Modeling, Northwestern Institute on Complex Systems, Northwestern University, Evanston, IL.*, 2005.

[118] M. C. Schut, *Scientific Handbook for Simulation of Collective Intelligence.* http://www.sci-sci.org/, 2007.

[119] D. González-Rodríguez, "Modelización de Sistemas de Computación Distribuida con Bacterias Sintéticas mediante Autómatas Celulares," *Revista Internacional de Sistemas*, vol. 19, pp. 62–74, 2014.

[120] J. M. Calabrese, G. Deffuant, and V. Grimm, *Viability and Resilience of Complex Systems*, vol. 2011 of *Understanding Complex Systems.* Berlin: Springer, 2011.

[121] R. Ihaka and R. Gentleman, "R: A Language for Data Analysis and Graphics," *Journal of Computational and Graphical Statistics*, vol. 5, no. 3, pp. 299–314, 1996.

[122] J. C. Thiele, W. Kurth, and V. Grimm, "RNETLOGO: an R package for running and exploring individual-based models implemented in NETLOGO," *Methods in*

Ecology and Evolution, vol. 3, pp. 480–483, June 2012.

[123] J. C. Thiele, "R Marries NetLogo: Introduction to the RNetLogo Package," *Journal of Statistical Software*, vol. 58, no. 2, 2014.

[124] J. C. Thiele, W. Kurth, and V. Grimm, "Agent-based modelling: Tools for linking NetLogo and R," *JASSS*, vol. 15, June 2012.

[125] "NetLogo 4.1 User Manual," *Interface*, vol. 2, pp. 1–414, 2009.

[126] R. M. Smith and M. a. Bedau, "Is Echo a complex adaptive system?," *Evolutionary computation*, vol. 8, pp. 419–42, Jan. 2000.

[127] J. H. Miller and S. E. Page, *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*. Princeton: Princeton University Press, 2007.

[128] R. Laubenbacher, A. S. Jarrah, H. Mortveit, and S. S. Ravi, "A mathematical formalism for agent-based modeling," *Web resource: http://arxiv.org/abs/0801.0249*, Dec. 2007.

[129] A. B. Downey, *Think Complexity*. Needham: Green Tea Press, 2012.

[130] T. Szuba, *Computational Collective Intelligence*. New York: John Wiley & Sons, Inc., 2001.

[131] R. J. Kolbusz, R. Kotowski, and K. Kasianiuk, "Meta-game HOLOS as a Multi-agent Decision-Making Laboratory," in *Computational Collective Intelligence. Semantic Web, Social Networks and Multiagent Systems* (N. T. Nguyen, R. Kowalczyk, and S.-M. Chen, eds.), vol. 5796 of *Lecture Notes in Computer Science*, ch. Meta-game, pp. 229–239, Berlin: Springer, 2009.

[132] P. Smith, "Conjugation-a bacterially inspired form of genetic recombination," *Papers at the Genetic Programming 1996 Conference*, pp. 1–8, 1996.

[133] P. Trieu-Cuot, C. Carlier, P. Martin, and P. Courvalin, "Plasmid transfer by conjugation from Escherichia coli to Gram-positive bacteria," *FEMS Microbiology Letters*, vol. 48, pp. 289–294, 1987.

[134] M. Llosa, F. X. Gomis-Rüth, M. Coll, and F. de la Cruz Fd, "Bacterial conjugation: a two-step mechanism for DNA transport.," *Molecular microbiology*, vol. 45, pp. 1–8, 2002.

[135] C. M. Thomas and K. M. Nielsen, "Mechanisms of, and barriers to, horizontal gene transfer between bacteria.," *Nature reviews. Microbiology*, vol. 3, pp. 711–721, 2005.

[136] V. L. Waters, "Conjugation between bacterial and mammalian cells.," *Nature genetics*, vol. 29, pp. 375–376, 2001.

[137] E. Mezura-Montes and B. Hernandez-Ocan, "Modified Bacterial Foraging optimization for engineering design," *Optimization*, pp. 1–8, 2009.

[138] I. Harvey, "The microbial genetic algorithm," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 5778 LNAI, pp. 126–133, 2011.

[139] S. Muller, J. Marchetto, S. Airaghi, and P. Kournoutsakos, "Optimization based on bacterial chemotaxis," *IEEE Transactions on Evolutionary Computation*, vol. 6, no. 1, pp. 16–29, 2002.

[140] S. Das, A. Chowdhury, and A. Abraham, "A Bacterial Evolutionary Algorithm for automatic data clustering," in *2009 IEEE Congress on Evolutionary Computation*, pp. 2403–2410, IEEE, 2009.

[141] R. Stallman, "What is free software?," *Web resource: https://www.gnu.org/philosophy/free-sw.html*, 2014.

[142] L. Gabora, "The cultural evolution of socially situated cognition," *Cognitive Systems Research*, vol. 9, no. 1-2, pp. 104–114, 2008.

[143] D. Tapscott and A. D. Williams, *Wikinomics: How Mass Collaboration Changes Everything.* Portfolio, 2008.

[144] D. Boud and A. Lee, "'Peer learning' as pedagogic discourse for research education," *Studies in Higher Education*, vol. 30, no. 5, pp. 501–516, 2005.