

Course of Research: Living Computation

Living computation is the hypothesis that, properly understood, living systems and computational systems will turn out to be the same thing. This core connection has drawn me toward robustness and security in computational architectures, distributed and bottom-up control, adaptation and evolution, and the uses of randomness. Here is a page of brief examples.

Robust-first computing (2010–present) As computers increasingly live among us “in the wild,” we need to elevate robustness to the primary design criterion. This impacts our entire approach to computing, because *efficiency costs robustness*. (2013 *CACM Viewpoint*: <http://nm8.us/1>)

Indefinite scalability (2008–present) For research insights and development potential, we should explore computer architectures designed to scale indefinitely, supporting open-ended computational growth without substantial re-engineering. (2011 *HOTOS*: <http://nm8.us/3>)

Diversity for security (1995–2006) Biological principles led us to explore deliberately engineering diversity into computing systems to increase their attack resistance. Through many people’s subsequent work, such artificial diversity is now standard in computing (1997 *HOTOS*: <http://nm8.us/g>)

Peer-to-peer social networking (1989–2002) Whatever you share with your Facebook friends you’re also sharing with Facebook. The **ccr** system offered deeply symmetric information dynamics, credible encryption, and minimal data centralization. (*Info, links*: <http://nm8.us/f>)

Evolution of feelings (1991) We developed *evolutionary reinforcement learning* (ERL) showing how evolution can bequeath us with ‘internal teachers’ that generate reinforcement signals—good and bad feelings—for us to learn from throughout our lives. (1991 *ALIFE II*: <http://nm8.us/h>)

Genetic algorithms (1985–1987) Though my dissertation focused on high-dimensional hypercube optimization, it included a low-dimensional example function that became a standard test in the field, and variants proliferated. (*Google image search*: <http://nm8.us/i>)

Selected Honors and Awards

- ◇ Award for “Most Outrageous Opinion”, 13th Workshop on Hot Topics in Operating Systems (HOTOS), Napa Valley, 2011, for the ideas and research reported in *Pursue robust indefinite scalability*.
- ◇ UNM School of Engineering Senior Teaching Excellence Award, 2000, 2008.
- ◇ Computer Science Students’ Favorite Faculty Award, 1999, 2000, 2001. (Award not presented since 2001.)
- ◇ UNM General Library’s Faculty Recognition Award, 1998.
- ◇ Conference award for “Most Lifelike Creatures”: The Second Artificial Life Workshop, August, 1990, for the research reported in *Interactions between learning and evolution*.
- ◇ Nomination for Publisher’s Prize at the National Conference on Artificial Intelligence (AAAI-82), for *The QBKG system: Generating explanations from a non-discrete knowledge representation*, August, 1982.

Dissertations Directed

- ◇ van Belle, Theodore, *Modularity and the Evolution of Software Evolvability*, Ph.D. Thesis, The University of New Mexico, Department of Computer Science, Albuquerque, NM. December, 2004.
- ◇ Helfman, Jonathan, *Image Representations for Access and Similarity-Based Organization of Web Information*, Ph.D. Thesis, The University of New Mexico, Department of Computer Science, Albuquerque, NM. December, 1999.

Selected Invited Talks

- ◇ **Brown University**, Computer Science, Sysread group. Providence, RI. April, 2013.
- ◇ **Google**, Tech Talk. Cambridge, MA. April, 2013.
- ◇ **Congress on the Future of Engineering Software**, Design for Resilience in Products and Strategy. Scottsdale, AZ. April, 2013.

- ◇ **University of Central Florida**, Electrical Engineering and Computer Science, Seminar. Orlando, FL. February, 2013.
- ◇ **Portland State University**, Computer Science, Colloquium. Portland, OR. October, 2012.
- ◇ **Google–Santa Fe Institute Intersection**, Topical Meeting. Mountain View, CA. September, 2010.
- ◇ **TTI/Vanguard**, Designing for Resiliency, Conference. Brussels, Belgium. July, 2002.
- ◇ **Santa Fe Institute**, Workshop on Computational Approaches to Evolutionary Biology. Santa Fe, NM. February, 1994.
- ◇ **NSF/AFOSR** Workshop on Self-Determination in Evolving Systems. Cambridge, MA. January, 1994.
- ◇ **Santa Fe Institute**, Workshop on Plastic Individuals in Evolving Populations. Santa Fe, NM. August, 1993.
- ◇ **NEC Research Institute**, Colloquium Series. Princeton, NJ. March, 1992.
- ◇ **Harvard University**, Computer Science, Colloquium. Cambridge, MA. May, 1993.
- ◇ **Siemens**, Research Seminar on Learning Systems. Princeton, NJ. November, 1990.
- ◇ **National Communications Forum**. Chicago, IL. 1989.
- ◇ **Snowbird Workshop on Neural Networks for Computing**. Snowbird, UT, April, 1989. (Also invited attendee, 1990 & 1991).
- ◇ **Columbia University**, Computer Science, Colloquium Series. New York. NY, November, 1987.
- ◇ **ORSA/TIMS Annual Meeting**. New Orleans, LA. May, 1987.
- ◇ **Bell Communications Research**, Human Information Processing Group, Seminar. November, 1986.

Selected Professional Service

- ◇ **Editorial boards:** *Journal of Adaptive Behavior* (1992–present); *Artificial Life* (1993–present).

- ◇ **Program committees:** *Workshop on Software Evolvability* (2005); *Neural Information Processing Systems 4* (1992); 4th *Workshop on Artificial Life* (1994).
- ◇ **Workshop co-organizer:** *Santa Fe Institute Workshop on the Road to Software Evolvability* (2005); *Symposium on Modeling the Evolution of Communication*, at the Cognitive Science Conference, (1996); *Genetic algorithms, neural networks, artificial life*, following the Neural Information Processing Systems conference, November, 1991.
- ◇ **Panel moderator:** "The Future of AI" Bellcore Artificial Intelligence Symposium, (1988); Bellcore-AT&T Bell Labs Joint Symposium on Neural Networks, (1987).
- ◇ **Journal and grant reviewing:** NSF, AFOSR, Nature, Journal of Information Theory, The Computer Journal, Computing Systems, Journal of Adaptive Behavior, Neural Networks, IEEE Transactions on Neural Networks.

Research funding

- ◇ **National Science Foundation.** Computer and Information Science and Engineering. *Understanding and surviving computation in the wild* Stephanie Forrest (Principal Investigator), David H. Ackley, (Co-Principal Investigator). 2000–2005. \$871,478.
- ◇ **Defense Advanced Research Projects Agency.** TASK Program. Computation in the Wild: Moving Beyond the Metaphor. Stephanie Forrest (Principal Investigator), David H. Ackley (Co-Principal Investigator). 2000–2005. \$1,100,000.
- ◇ **National Science Foundation.** Computer and Information Science and Engineering, Research Infrastructure. *Effective Information Access: Computer Science Research Fundamental to the Creation of a National Information Infrastructure*, Deepak Kapur, David H. Ackley, James D. Hollan (Principal Investigators). 1995–2002, \$1,250,000.
- ◇ **Defense Advanced Research Projects Agency.** Intelligent Collaboration and Visualization Program. *Collaborative Planning as Distributed Programming*, David H. Ackley, Principal Investigator. 1996–1999, \$938,250.

PUBLICATIONS

Books and book chapters

- Stephanie Forrest, Justin Balthrop, Matthew Glickman, and David H. Ackley. Computation in the wild. In Erica Jen, editor, *Robust Design: A Repertoire of Biological, Ecological, and Engineering Case Studies*, pages 207–230. Oxford University Press, 2004. Reprinted in K. Park and W. Willinger Eds. *The Internet as a Large-Scale Complex System*, pp. 227–250. Oxford University Press, 2005.
- Derek J. Smith, Stephanie Forrest, David H. Ackley, and Alan S. Perelson. Modeling the effects of prior infection on vaccine efficacy. In Dipankar Dasgupta, editor, *Artificial Immune Systems and Their Applications*, pages 144–153. Springer Berlin Heidelberg, 1999.
- Richard K. Belew, Melanie Mitchell, and David H. Ackley. Computation and the natural sciences. In Richard K. Belew and Melanie Mitchell, editors, *Adaptive individuals in evolving populations*, pages 431–440. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 1996.
- David H Ackley. An empirical study of bit vector function optimization. In L. D. Davis, editor, *Genetic algorithms and simulated annealing*, pages 170–204. Morgan-Kaufman, Los Altos, CA, 1987.
- David H Ackley. *A connectionist machine for genetic hillclimbing*. Kluwer Boston Inc., Hingham, MA, 1987.

Journal publications

- David H. Ackley. Bespoke physics for living technology. *Artificial Life*, 2013. To appear. Author preprint: <http://nm8.us/8>.
- David H. Ackley. Beyond efficiency. *Commun. ACM*, 56(10), October 2013. To appear. Author preprint: <http://nm8.us/1>.
- David H. Ackley, Daniel C. Cannon, and Lance R. Williams. A movable architecture for robust spatial computing. *The Computer Journal*, 2013. Open access: <http://nm8.us/2>.

- Elena Gabriela Barrantes, David H Ackley, Stephanie Forrest, and Darko Stefanović. Randomized instruction set emulation. *ACM Transactions on Information and System Security (TISSEC)*, 8(1):3–40, 2005.
- Derek J. Smith, Stephanie Forrest, David H. Ackley, and Alan S. Perelson. Variable efficacy of repeated annual influenza vaccination. *Proceedings of the National Academy of Sciences*, 96(24):14001, 1999.
- Derek J. Smith, Stephanie Forrest, David H. Ackley, and Alan S. Perelson. Using lazy evaluation to simulate realistic-size repertoires in models of the immune system. *Bulletin of Mathematical Biology*, 60(4):647–658, 1998.
- David H Ackley, Geoffrey E Hinton, and Terrence J Sejnowski. A learning algorithm for boltzmann machines. *Cognitive Science*, 9(1):147–169, 1985.

Refereed conference and workshop publications

- Sergiu Goschin, Michael L Littman, and David H Ackley. The effects of selection on noisy fitness optimization. In *Proceedings of the 13th annual conference on Genetic and evolutionary computation*, pages 2059–2066. ACM, 2011.
- David H. Ackley and Daniel C. Cannon. Pursue robust indefinite scalability. In *Proc. HotOS XIII*, Napa Valley, California, USA, May 2011. USENIX Association.
- David H. Ackley and Lance R. Williams. Homeostatic architecture for robust spatial computing. In *Spatial Computing Workshop at IEEE Self-Adaptive Self-Organizing Systems*, Ann Arbor, Michigan, USA, October 2011. IEEE.
- Terry Van Belle and David H. Ackley. Imitation and inequity in avoiding the tragedy of the commons. In *Artificial Life IX: Proceedings of the Ninth International Conference on the Simulation and Synthesis of Artificial Life*, pages 274–279. The MIT Press, 2004.

- Elena Gabriela Barrantes, David H. Ackley, Trek S. Palmer, Darko Stefanovic, and Dino Dai Zovi. Randomized instruction set emulation to disrupt binary code injection attacks. In *Proceedings of the 10th ACM conference on Computer and Communications Security*, pages 281–289. ACM, 2003.
- Terry Van Belle and David H. Ackley. Adaptation and ruggedness in an evolvability landscape. In Erick Cantú-Paz, James A. Foster, Kalyanmoy Deb, Lawrence Davis, Rajkumar Roy, Una-May O’Reilly, Hans-Georg Beyer, Russell K. Standish, Graham Kendall, Stewart W. Wilson, Mark Harman, Joachim Wegener, Dipankar Dasgupta, Mitchell A. Potter, Alan C. Schultz, Kathryn A. Dowsland, Natasa Jonoska, and Julian F. Miller, editors, *GECCO*, volume 2723 of *Lecture Notes in Computer Science*, pages 150–151. Springer, 2003.
- Terry Van Belle and David H. Ackley. Uniform subtree mutation. In James A. Foster, Evelyne Lutton, Julian F. Miller, Conor Ryan, and Andrea Tettamanzi, editors, *EuroGP*, volume 2278 of *Lecture Notes in Computer Science*, pages 152–161. Springer, 2002.
- Terry Van Belle and David H. Ackley. Code factoring and the evolution of evolvability. *Proceedings of the Genetic and Evolutionary Computation Conference*, pages 1383–1390, 2002.
- Terry Van Belle and David H. Ackley. Code factoring and the evolution of evolvability. In W. B. Langdon, E. Cantú-Paz, K. Mathias, R. Roy, D. Davis, R. Poli, K. Balakrishnan, V. Honavar, G. Rudolph, J. Wegener, L. Bull, M. A. Potter, A. C. Schultz, J. F. Miller, E. Burke, and N. Jonoska, editors, *GECCO 2002: Proceedings of the Genetic and Evolutionary Computation Conference*, pages 1383–1390, New York, 9-13 July 2002. Morgan Kaufmann Publishers.
- Terry Van Belle and David H. Ackley. Adaptation and ruggedness in an evolvability landscape. In Erick Cantú-Paz, James A. Foster, Kalyanmoy Deb, Lawrence Davis, Rajkumar Roy, Una-May O’Reilly, Hans-Georg Beyer, Russell K. Standish, Graham Kendall, Stewart W. Wilson, Mark Harman, Joachim Wegener, Dipankar Dasgupta, Mitchell A. Potter, Alan C. Schultz, Kathryn A. Dowsland, Natasa Jonoska, and Julian F. Miller, editors, *GECCO*, volume 2723 of *Lecture Notes in Computer Science*, pages 150–151. Springer, 2003.

- David H. Ackley. Real artificial life: Where we may be. In *Artificial Life VII. (Proceedings of the Seventh International Workshop on the Synthesis and Simulation of Living Systems)*, Cambridge, MA, 2000. The MIT Press.
- Stephanie Forrest, Anil Somayaji, and David H. Ackley. Building diverse computer systems. In *Workshop on Hot Topics in Operating Systems*, pages 67–72, 1997.
- David H. Ackley. ccr: A network of worlds for research. In C.G. Langton and K. Shimohara, editors, *Artificial Life V. (Proceedings of the Fifth International Workshop on the Synthesis and Simulation of Living Systems)*, pages 116–123, Cambridge, MA, 1996. The MIT Press.
- David H Ackley and Michael L Littman. Altruism in the evolution of communication. *Artificial life IV*, pages 40–48, 1994.
- David H. Ackley and Michael L. Littman. A case for Lamarckian evolution. In Christopher G. Langton, editor, *Proceedings of the Workshop on Artificial Life (ALIFE '92)*, pages 3–10. Reading, MA: Addison-Wesley, 1994.
- David Ackley and Michael Littman. Interactions between learning and evolution. *Artificial life II*, 10:487–509, 1991.
- Michael L Littman and David H Ackley. Adaptation in constant utility non-stationary environments. *Proceedings of the Fourth International Conference on Genetic Algorithms*, pages 136–142, 1991.
- David H Ackley and Michael L Littman. Generalization and scaling in reinforcement learning. *Advances in neural information processing systems*, 2:550–557, 1990.
- David H. Ackley. Associative learning via inhibitory search. In *Advances in Neural Information Processing Systems*, pages 20–28. Morgan Kaufmann Publishers Inc., 1989.
- David H Ackley. A connectionist algorithm for genetic search. In *Proceedings of the 1st International Conference on Genetic Algorithms*, pages 121–135. L. Erlbaum Associates Inc., 1985.
- David W Krumme and David H Ackley. A practical method for code generation based on exhaustive search. *ACM SIGPLAN Notices*, 17(6):185–196, 1982.
- Hans J. Berliner and David H. Ackley. The QBKG system: Generating explanations from a non-discrete knowledge representation. *Proceedings of the National Conference on Artificial Intelligence*, pages 213–216, 1982.