Neuroevolution

Neuroevolution: Harnessing Creativity in AI Model Design

Sebastian Risi, Yujin Tang, David Ha, Risto Miikkulainen

The MIT Press Cambridge, Massachusetts London, England

This book was set in ——— by ———. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data is available.

ISBN:

10 9 8 7 6 5 4 3 2 1

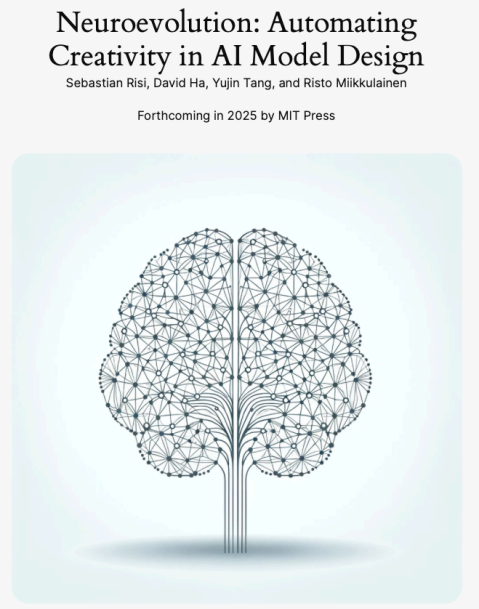
To our families

Contents

Foreword

Melanie Mitchell

Website



https://neuroevolutionbook.com/

We created the above website to accompanying this book, which provides many additional supplementary material that we hope will be useful to readers and instructors. These include demos, tutorials, exercises, and lecture slides. This website will also be the place we list corrections of mistakes found in the book.

Preface

Artificial intelligence has surged into mainstream popularity, with generative AI technologies such as large language models (LLMs) capturing the public's imagination. Conversations about AI's potential and power are everywhere, as these models compose text, generate images, and mimic human language at an unprecedented scale. Amid this boom, however, lies another field with equally transformative potential: neuroevolution. The field of neuroevolution has develop unique approaches and capabilities that have yet to capture the same level of mainstream attention.

Neuroevolution, combining principles of neural networks with evolutionary processes, has been around for decades. It offers solutions that go beyond imitation and pattern recognition, extending into areas of adaptability, creativity, and resilience. While traditional AI often relies on predefined objectives and vast datasets, neuroevolution excels in environments where goals are ambiguous, rewards are sparse, and conditions are ever-changing. This approach introduces a method of designing and evolving AI systems that can handle complex, high-dimensional problems with minimal human intervention, and it's precisely this adaptability that is set to bring neuroevolution to the forefront of AI in the coming years.

As AI advances into realms requiring flexibility and open-ended problem-solving, neuroevolution has sown great promise in evolving robust, adaptive, and creative solutions. It is particularly promising for applications where the optimal solution is unknown or hard to define, such as robotics, dynamic systems, and even art and design. With neuroevolution, we can create agents that not only evolve but also continiously learn during their lifetime, much like biological organisms do in nature.

This book serves as a gateway into the world of neuroevolution, providing readers with both a foundational understanding and practical tools for harnessing its potential. It covers the core concepts, algorithms, and applications of neuroevolutionary systems, with each chapter containing examples and questions that encourage readers to critically engage with the material. By offering insights into synergies with generative AI, reinforcement learning, and other domains, we hope to demonstrate the relevance of neuroevolution to the future of AI.

Acknowledgments

This book would not have been possible without the contributions of researchers and pioneers in neuroevolution and evolutionary computation, whose insights and innovations have laid the foundation for this work. We are also grateful to our colleagues, students, and readers who have inspired us with their curiosity and feedback, helping us to refine and expand upon the ideas presented here. We would also like to thank our MIT Editor Elizabeth Swayze who believed in this project early on and was a pleasure to work with.

Additionally, we would like to thank all the people that read all or parts of the book. We also would like to express our gratitude to all everybody that gave us permission to reproduce images and figures from their publications. We indicate the figure sources throughout the book in the figure captions.

Writing this book has been a long journey and we would like to thank your families and friends for their support, which who this book would have not seen the light of day. We would also like to thank Sakana.ai and Cognizant AI Labs for the financial support, which allowed this book to be enjoyed in color.

References

Adami, Christoph, Jory Schossau, and Arend Hintze. 2016. "Evolutionary game theory using agent-based methods." *Physics of Life Reviews* 19:1–26.

Agogino, Adrian, Kenneth Stanley, and Risto Miikkulainen. 2000. "Online Interactive Neuro-evolution." *Neural Processing Letters* 11:29–38.

Agogino, Adrian, Kagan Tumer, and Risto Miikkulainen. 2005. "Efficient Credit Assignment Through Evaluation Function Decomposition." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Aharonov-Barki, R., T. Beker, and E. Ruppin. 2001. "Emergence of memory-driven command neurons in evolved artificial agents." *Neural Computation* 13:691–716.

Akiba, Takuya, Makoto Shing, Yujin Tang, Qi Sun, and David Ha. 2024. "Evolutionary optimization of model merging recipes." *arXiv preprint arXiv:2403.13187.*

Akopyan, Filipp, Jun Sawada, Andrew Cassidy, Rodrigo Alvarez-Icaza, John Arthur, Paul Merolla, Nabil Imam, et al. 2015. "TrueNorth: Design and Tool Flow of a 65 mW 1 Million Neuron Programmable Neurosynaptic Chip." *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems* 34:1537–1557.

Alden, Matthew, Aard-Jan van Kesteren, and Risto Miikkulainen. 2002. "Eugenic Evolution Utilizing a Domain Model." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO-2002),* 279–286.

Alden, Matthew, and Risto Miikkulainen. 2016. "MARLEDA: Effective Distribution Estimation through Markov Random Fields." *Theoretical Computer Science* 633:4–18. http://nn.cs.utexas.edu/?alden:theoreticalcs16.

Anil, Rohan, Sebastian Borgeaud, Yonghui Wu, Jean-Baptiste Alayrac, Jiahui Yu, Radu Soricut, Johan Schalkwyk, Andrew M Dai, Anja Hauth, Katie Millican, et al. 2023. "Gemini: A family of highly capable multimodal models." *arXiv preprint arXiv:2312.11805* 1.

Anil, Rohan, Andrew M Dai, Orhan Firat, Melvin Johnson, Dmitry Lepikhin, Alexandre Passos, Siamak Shakeri, Emanuel Taropa, Paige Bailey, Zhifeng Chen, et al. 2023. "Palm 2 technical report." *arXiv preprint arXiv:2305.10403.*

Arjovsky, Martin, Soumith Chintala, and Léon Bottou. 2017. "Wasserstein Generative Adversarial Networks." In *Proceedings of the 34th International Conference on Machine Learning,* edited by Doina Precup and Yee Whye Teh, 70:214–223.

Ba, Jimmy, Geoffrey E Hinton, Volodymyr Mnih, Joel Z Leibo, and Catalin Ionescu. 2016. "Using fast weights to attend to the recent past." *Advances in neural information processing systems* 29.

Banzhaf, Wolfgang, Frank D. Francone, Robert E. Keller, and Peter Nordin. 1998. *Genetic programming: an introduction: on the automatic evolution of computer programs and its applications.* San Francisco, CA, USA: Morgan Kaufmann.

Batali, J. 1998. "Computational Simulations of the Emergence of Grammar." In *Approaches to the Evolution of Language: Social and Cognitive bases,* edited by J. Hurford, C. Knight, and M. Studdert-Kennedy, 405–426. Cambridge: Cambridge University Press.

Baxter, J. A., D. A. Merced, D. J. Costinett, L. M. Tolbert, and B Ozpineci. 2018. "Review of electrical architectures and power requirements for automated vehicles." In *IEEE Transportation Electrification Conference and Expo,* 944–949.

Beane, Wendy Scott, Junji Morokuma, Joan M Lemire, and Michael Levin. 2013. "Bioelectric signaling regulates head and organ size during planarian regeneration." *Development* 140 (2): 313–322.

Beer, Randall D., Hillel J. Chiel, and John C. Gallagher. 1999. "Evolution and Analysis of Model CPGs for Walking: II. General Principles and Individual Variability." *Journal of Computational Neuroscience* 7:119–147.

Belew, R. K. 1990. "Evolution, learning and culture: Computational metaphors for adaptive algorithms." *Complex Systems* 4:11–49.

Belew, Richard K., John McInerney, and Nicol N. Schraudolph. 1990. *Evolving Networks: Using the Genetic Algorithm with Connectionist Learning.* Technical report CS90-174. Cognitive Computer Science Research Group, Computer Science and Engineering Department, University of California, San Diego.

Ben-Iwhiwhu, Eseoghene, Pawel Ladosz, Jeffery Dick, Wen-Hua Chen, Praveen Pilly, and Andrea Soltoggio. 2020. "Evolving inborn knowledge for fast adaptation in dynamic POMDP problems." In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference,* 280–288. New York, NY, USA: Association for Computing Machinery.

Benson-Amram, S., V. Heinen, A. Gessner, M. L. Weldel e, and K. E. Holekamp. 2014. "Limited social learning of a novel technical problem by spotted hyenas." *Behavioural Processes* 109:111–120.

Benson-Amram, S., and K. E. Holekamp. 2012. "Innovative problem solving by wild spotted hyenas." *Proceedings of the Royal Society of London B* 279:4087–4095.

Bickerton, Derek. 1990. *Language and Species.* Chicago, IL: The University of Chicago Press.

Bickerton, Derek. 2007. "Language evolution: A brief guide for linguists." *Lingua* 117:510–526.

Bickerton, Derek, and Eörs Szathmáry. 2011. "Confrontational scavenging as a possible source for language and cooperation." *BMC Evolutionary Biology* 11:261–261.

Bindra, Dalbir, Francine G. Patterson, H. S. Terrace, L. A. Petitto, R. J. Sanders, and T. G. Bever. 1981. "Ape Language." *Science,* 86–88.

Bingham, Garrett, William Macke, and Risto Miikkulainen. 2020. "Evolutionary Optimization of Deep Learning Activation Functions." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Bingham, Garrett, and Risto Miikkulainen. 2022. "Discovering Parametric Activation Functions." *Neural Networks* 148:48–65.

Bingham, Garrett, and Risto Miikkulainen. 2023a. "AutoInit: Analytic Signal-Preserving Weight Initialization for Neural Networks." In *Proceedings of the AAAI Conference on Artificial Intelligence,* 6823–6833.

Bingham, Garrett, and Risto Miikkulainen. 2023b. "Efficient Activation Function Optimization through Surrogate Modeling." In *Proceedings of the 23rd Conference on Neural Information Processing Systems (NeurIPS 2023).*

Blount, Zachary D., Christina Z. Borland, and Richard E. Lenski. 2008. "Historical contingency and the evolution of a key innovation in an experimental population of Escherichia coli." *Proceedings of the National Academy of Sciences* 105 (23): 7899–7906.

Bongard, Josh. 2011. "Morphological change in machines accelerates the evolution of robust behavior." *Proceedings of the National Academy of Sciences* 108:1234–1239.

Bongard, Josh C, Rolf Pfeifer, et al. 2001. "Repeated structure and dissociation of genotypic and phenotypic complexity in artificial ontogeny." In *Proceedings of the genetic and evolutionary computation conference,* vol. 829836.

Bongard, Josh C. 2013. "Evolutionary Robotics." *Communications of the ACM* 56:74–83.

Bontrager, Philip, Aditi Roy, Julian Togelius, Nasir Memon, and Arun Ross. 2018. "Deepmasterprints: Generating masterprints for dictionary attacks via latent variable evolution." In *2018 IEEE 9th International Conference on Biometrics Theory, Applications and Systems (BTAS),* 1–9. IEEE.

Brant, Jonathan C, and Kenneth O Stanley. 2017. "Minimal criterion coevolution: a new approach to open-ended search." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 67–74.

Brock, Andrew, Theodore Lim, James M Ritchie, and Nick Weston. 2017. "Smash: one-shot model architecture search through hypernetworks." *arXiv preprint arXiv:1708.05344.*

Brockman, G., V. Cheung, L. Pettersson, J. Schneider, J. Schulman, J. Tang, and W. Zaremba. 2016. "OpenAI Gym." *Preprint arXiv:1606.01540,* https://arxiv.org/abs/1606.01540.

Brown, Tom, Benjamin Mann, Nick Ryder, Melanie Subbiah, Jared D Kaplan, Prafulla Dhariwal, Arvind Neelakantan, Pranav Shyam, Girish Sastry, Amanda Askell, et al. 2020. "Language models are few-shot learners." *Advances in neural information processing systems* 33:1877–1901.

Bruce, Joseph, and Risto Miikkulainen. 2001. "Evolving Populations of Expert Neural Networks." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 251–257.

Bryant, Bobby D., and Risto Miikkulainen. 2006. "Evolving Stochastic Controller Networks for Intelligent Game Agents." In *Proceedings of the 2006 Congress on Evolutionary Computation.* Piscataway, NJ: IEEE.

Bryant, Bobby D., and Risto Miikkulainen. 2007. "Acquiring Visibly Intelligent Behavior with Example-Guided Neuroevolution." In *Proceedings of the Twenty-Second National Conference on Artificial Intelligence.* Menlo Park, CA: AAAI Press.

Bryant, Bobby D., and Risto Miikkulainen. 2018. "A Neuroevolutionary Approach to Adaptive Multi-agent Teams." In *Foundations of Trusted Autonomy,* edited by H. A. Abbass, J. Scholz, and D. J. Reid, 87–114. New York: Springer.

Buccino, Alessio Paolo, Tanguy Damart, Julian Bartram, Darshan Mandge, Xiaohan Xue, Mickael Zbili, Tobias Gänswein, et al. 2024. "A Multimodal Fitting Approach to Construct Single-Neuron Models With Patch Clamp and High-Density Microelectrode Arrays." *Neural Computation* 36:1286–1331.

Buzsáki, György. 2006. *Rhythms of the Brain.* Oxford University Press.

Cangelosi, A. 1999. "Evolution of communication using symbol combination in populations of neural networks." In *Proceedings of the International Joint Conference on Neural Networks,* 4365–4368.

Cangelosi, Angelo, and Domenico Parisi. 1998. "The Emergence of a 'Language' in an Evolving Population of Neural Networks." *Connection Science* 10:83–97.

Cardamone, Luigi, Daniele Loiacono, and Pier Luca Lanzi. 2009. "On-line neuroevolution applied to the open racing car simulator." In *Proceedings of the Eleventh Conference on Congress on Evolutionary Computation,* 2622–2629.

Caruana, Rich. 1997. "Multitask Learning." *Machine Learning* 28:41–75.

Carvelli, Christian, Djordje Grbic, and Sebastian Risi. 2020. "Evolving hypernetworks for game-playing agents." In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference Companion,* 71–72.

Chao, Wang, Jiaxuan Zhao, Licheng Jiao, Lingling Li, Fang Liu, and Shuyuan Yang. 2024. "A match made in consistency heaven: when large language models meet evolutionary algorithms." *arXiv preprint arXiv:2401.10510.*

Chellapilla, Kumar, and David B. Fogel. 1999. "Evolution, Neural Networks, Games, and Intelligence." *Proceedings of the IEEE* 87:1471–1496.

Chemla, S., and F. Chavane. 2010. "Voltage-sensitive dye imaging: Technique review and models." *Journal of Physiology-Paris* 104:40–50.

Chen, Lili, Kevin Lu, Aravind Rajeswaran, Kimin Lee, Aditya Grover, Misha Laskin, Pieter Abbeel, Aravind Srinivas, and Igor Mordatch. 2021. "Decision transformer: Reinforcement learning via sequence modeling." *Advances in neural information processing systems* 34:15084–15097.

Cheney, Nick, Josh Bongard, Vytas SunSpiral, and Hod Lipson. 2018. "Scalable Co-Optimization of Morphology and Control in Embodied Machines." *Journal of the Royal Society Interface* 15 (21170937).

Cheney, Nick, Robert MacCurdy, Jeff Clune, and Hod Lipson. 2014. "Unshackling evolution: evolving soft robots with multiple materials and a powerful generative encoding." *ACM SIGEVOlution* 7 (1): 11–23.

Chiel, Hillel J., Randall D. c, and John C. Gallagher. 1999. "Evolution and Analysis of Model CPGs for Walking: I. Dynamical Modules." *Journal of Computational Neuroscience* 7:99–118.

Chomsky, Noam. 1986. *Knowledge of language: Its nature, origin, and use.* Greenwood Publishing Group.

Chung, Junyoung, Caglar Gulcehre, KyungHyun Cho, and Yoshua Bengio. 2014. "Empirical evaluation of gated recurrent neural networks on sequence modeling." *arXiv preprint arXiv:1412.3555.*

Cliff, Dave, Inman Harvey, and Phil Husbands. 1993. "Explorations in Evolutionary Robotics." *Adaptive Behavior* 2:73–110.

Clune, Jeff, Benjamin E Beckmann, Robert T Pennock, and Charles Ofria. 2011. "HybrID: A hybridization of indirect and direct encodings for evolutionary computation." In *Advances in Artificial Life. Darwin Meets von Neumann: 10th European Conference, ECAL 2009, Budapest, Hungary, September 13-16, 2009, Revised Selected Papers, Part II 10,* 134–141. Springer.

Clune, Jeff, and Hod Lipson. 2011. "Evolving three-dimensional objects with a generative encoding inspired by developmental biology (full article)." In *Artificial Life Conference Proceedings 23,* 24. MIT Press One Broadway, 12th Floor, Cambridge, Massachusetts 02142, USA …

Clune, Jeff, Jean-Baptiste Mouret, and Hod Lipson. 2013. "The evolutionary origins of modularity." *Proceedings of the Royal Society B: Biological Sciences* 280:20122863.

Clune, Jeff, Kenneth O Stanley, Robert T Pennock, and Charles Ofria. 2011. "On the performance of indirect encoding across the continuum of regularity." *IEEE Transactions on Evolutionary Computation* 15 (3): 346–367.

Coello Coello, Carlos A., David A. Van Veldhuizen, and Gary B. Lamont. 2007. *Evolutionary Algorithms for Solving Multi-Objective Problems.* Berlin; New York: Springer.

Cognizant AI Labs. 2023. *Pandemic Response Challenge: Technical Setup, Assessment, and Results.* Https://evolution.ml/xprize/, accessed 3/25/2023.

Colas, Cédric, Vashisht Madhavan, Joost Huizinga, and Jeff Clune. 2020. "Scaling map-elites to deep neuroevolution." In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference,* 67–75.

Coleman, K. 2019. "Lophius piscatorius, Animal Diversity Web." Retrieved 11/26/2022. https://animaldiversity.org/accounts/Lophius%5C_piscatorius/.

Collins, Francis S, Mark S Guyer, and Aravinda Chakravarti. 1997. "Variations on a theme: cataloging human DNA sequence variation." *Science* 278 (5343): 1580–1581.

Combes, D., P. Meyrand, and J. Simmers. 1999. "Motor pattern specification by dual descending pathways to a lobster rhythm-generating network." *Journal of Neuroscience* 19:2610–2619.

Confavreux, Basile, Friedemann Zenke, Everton Agnes, Timothy Lillicrap, and Tim Vogels. 2020. "A meta-learning approach to (re)discover plasticity rules that carve a desired function into a neural network." In *Advances in Neural Information Processing Systems,* 16398–16408.

Corballis, M. C. 2011. *The recursive mind: The origins of human language, thought, and civilization.* Princeton, NJ: Princeton University Press.

Cruau, F. 1994. "Neural network synthesis using cellular encoding and the genetic algorithm." *PhD thesis, Laboratoire do PInformatique du Parallilisme, Ecole Normale Supirieure de Lyon, France.*

Cully, A., Jeff Clune, D. Tarapore, and J. B. Mouret. 2015. "Robots that can adapt like animals." *Nature* 521:503–507.

Cybenko, G. 1989. "Approximation by Superpositions of a Sigmoidal Function." *Mathematics of Control, Signals, and Systems* 2:303–314.

Dai, Zihang, Hanxiao Liu, Quoc V Le, and Mingxing Tan. 2021. "CoAtNet: Marrying convolution and attention for all data sizes." *Advances in Neural Information Processing Systems* 34:3965–3977.

Davies, Mike, Narayan Srinivasa, Tsung-Han Lin, Gautham Chinya, Yongqiang Cao, Sri Harsha Choday, Georgios Dimou, et al. 2018. "Loihi: A Neuromorphic Manycore Processor with On-Chip Learning." *IEEE Micro* 38:82–99.

de Jong, Edwin D., and Jordan B. Pollack. 2004. "Ideal Evaluation from Coevolution." *Evolutionary Computation* 12:159–192.

De Jong, Kenneth A. 1975. "An Analysis of the Behavior of a Class of Genetic Adaptive Systems." PhD diss., The University of Michigan.

Deb, Kalyanmoy, and Himanshu Jain. 2014. "An Evolutionary Many-Objective Optimization Algorithm Using Reference-Point-Based Nondominated Sorting Approach, Part I: Solving Problems With Box Constraints." *IEEE Transactions on Evolutionary Computation* 18:577–601.

Deb, Kalyanmoy, and Christie Myburgh. 2017. "A population-based fast algorithm for a billion-dimensional resource allocation problem with integer variables." *European Journal of Operational Research* 261:460–474.

Deb, Kalyanmoy, Amrit Pratap, Sameer Agarwal, and TAMT Meyarivan. 2002. "A fast and elitist multiobjective genetic algorithm: NSGA-II." *IEEE transactions on evolutionary computation* 6 (2): 182–197.

Dellaert, F., and R. D. Beer. 1994. "Toward an Evolvable Model of Development for Autonomous Agent Synthesis." In *Proceedings of the Fourth International Workshop on the Synthesis and Simulation of Living Systems (Artificial Life IV).* Cambridge, MA: MIT Press.

Department of Energy. 2019. "Detecting Radiological Threats in Urban Areas." Retrieved 11/04/2023. https://www.topcoder.com/challenges/30085346.

Devlin, Jacob, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. 2018. "Bert: Pre-training of deep bidirectional transformers for language understanding." *arXiv preprint arXiv:1810.04805.*

DiCaprio, R. A. 1990. "An interneurone mediating motor programme switching in the ventilatory system of the crab." *Journal of Experimental Biology* 154:517–535.

Dietterich, Thomas G, et al. 2002. "Ensemble learning." *The handbook of brain theory and neural networks* 2 (1): 110–125.

Disease Control, Center for, and Prevention. 2023. *COVID-19 Data Sources.* Https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covid-19-data-sources.html, accessed 3/25/2023.

Doncieux, Stephane, Nicolas Bredeche, Jean-Baptiste Mouret, and Agoston E. (Gusz) Eiben. 2015. "Evolutionary Robotics: What, Why, and Where to." *Frontiers in Robotics and AI* 2.

Dong, Xuanyi, and Yi Yang. 2020. "NAS-Bench-201: Extending the Scope of Reproducible Neural Architecture Search." In *8th International Conference on Learning Representations (ICLR 2020).*

Dorigo, Marco, Guy Theraulaz, and Vito Trianni. 2021. "Swarm Robotics: Past, Present, and Future [Point of View]." *Proceedings of the IEEE* 109 (7): 1152–1165.

Doursat, René, Hiroki Sayama, and Olivier Michel. 2013. "A review of morphogenetic engineering." *Natural Computing* 12:517–535.

Druckmann, S., Y. Banitt, A. Gidon, F. Schürmann, H. Markram, and I. Segev. 2007. "A novel multiple objective optimization framework for constraining conductance-based neuron models by experimental data." *Frontiers of Neuroscience* 1 (1): 7–18.

Earle, Sam, Justin Snider, Matthew C Fontaine, Stefanos Nikolaidis, and Julian Togelius. 2022. "Illuminating diverse neural cellular automata for level generation." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 68–76.

Edwards, D. H., W. J. Heitler, and F. B. Krasne. 1999. "Fifty years of command neurons: The neurobiology of escape behavior in the crayfish." *Trends in Neuroscience* 22:153–161.

Eiben, A.E., and S.K. Smit. 2011. "Parameter tuning for configuring and analyzing evolutionary algorithms." *Swarm and Evolutionary Computation* 1 (1): 19–31.

Ellefsen, Kai Olav, Jean-Baptiste Mouret, and Jeff Clune. 2015. "Neural modularity helps organisms evolve to learn new skills without forgetting old skills." *PLoS computational biology* 11 (4): e1004128.

Elman, Jeffrey L., Elizabeth A. Bates, Mark H. Johnson, Annette Karmiloff-Smith, Domenico Parisi, and Kim Plunkett. 1996a. *Rethinking Innateness: A Connectionist Perspective on Development.* Cambridge, MA: MIT Press.

Elman, Jeffrey L., Elizabeth A. Bates, Mark H. Johnson, Annette Karmiloff-Smith, Domenico Parisi, and Kim Plunkett. 1996b. *Rethinking Innateness: A Connectionist Perspective on Development.* Cambridge, MA: MIT Press.

ElSaid, AbdElRahman, Karl Ricanek, Zimeng Lyu, Alexander Ororbia, and Travis Desell. 2023. "Backpropagation-free 4D continuous ant-based neural topology search." *Applied Soft Computing* 147:110737.

Elsken, Thomas, Jan Hendrik Metzen, and Frank Hutter. 2019. "Neural Architecture Search: A Survey." *Journal of Machine Learning Research* 20:1–21.

Ermentrout, G Bard, and Leah Edelstein-Keshet. 1993. "Cellular automata approaches to biological modeling." *Journal of theoretical Biology* 160 (1): 97–133.

Fairey, Jason, and Terence Soule. 2014. "Evolution of Communication and Cooperation." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 169–176.

Fan, James, Raymond Lau, and Risto Miikkulainen. 2003. "Utilizing Domain Knowledge in Neuroevolution." In *Machine Learning: Proceedings of the 20th Annual Conference.*

Fernando, Chrisantha, Dylan Banarse, Charles Blundell, Yori Zwols, David Hay, Andrei A. Rusu, Alexander Pritzel, and Daan Wierstra. 2017. "PathNet: Evolution Channels Gradient Descent in Super Neural Networks." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Fernando, Chrisantha, Dylan Banarse, Henryk Michalewski, Simon Osindero, and Tim Rocktäschel. 2023. "Promptbreeder: Self-referential self-improvement via prompt evolution." *arXiv preprint arXiv:2309.16797.*

Fernando, Chrisantha, Dylan Banarse, Malcolm Reynolds, Frederic Besse, David Pfau, Max Jaderberg, Marc Lanctot, and Daan Wierstra. 2016. "Convolution by evolution: Differentiable pattern producing networks." In *Proceedings of the Genetic and Evolutionary Computation Conference 2016,* 109–116.

Fernando, Chrisantha, Jakub Sygnowski, Simon Osindero, Jane Wang, Tom Schaul, Denis Teplyashin, Pablo Sprechmann, Alexander Pritzel, and Andrei Rusu. 2018. "Meta-learning by the baldwin effect." In *Proceedings of the Genetic and Evolutionary Computation Conference Companion,* 1313–1320.

Ficici, Sevan G., and Jordan B. Pollack. 2001. "Pareto Optimality in Coevolutionary Learning." In *Sixth European Conference on Artificial Life,* edited by Jozef Kelemen. Springer.

Finn, Chelsea, Pieter Abbeel, and Sergey Levine. 2017. "Model-agnostic meta-learning for fast adaptation of deep networks." In *International conference on machine learning,* 1126–1135. PMLR.

Floreano, D., and J. Urzelai. 2000. "Evolutionary Robots with On-Line Self-Organization and Behavioral Fitness." *Neural Networks* 13:431–4434.

Floreano, Dario, Peter Dürr, and Claudio Mattiussi. 2008. "Neuroevolution: From Architectures to Learning." *Evolutionary Intelligence* 1:47–62.

Floreano, Dario, Sara Mitri, Stéphane Magnenat, and Laurent Keller. 2007. "Evolutionary Conditions for the Emergence of Communication in Robots." *Current Biology* 17 (6): 514–519.

Floreano, Dario, and Francesco Mondada. 1996a. "Evolution of homing navigation in a real mobile robot." *IEEE Transactions on Systems, Man, and Cybernetics* 26:396–407.

Floreano, Dario, and Francesco Mondada. 1996b. "Evolution of plastic neurocontrollers for situated agents." In *Proc. of The Fourth International Conference on Simulation of Adaptive Behavior (SAB), From Animals to Animats.* ETH Zürich.

Floreano, Dario, and Joseba Urzelai. 1999. "Evolution of Neural Controllers with Adaptive Synapses and Compact Genetic Encoding." In *Advances in Artificial Life,* edited by Dario Floreano, Jean-Daniel Nicoud, and Francesco Mondada, 183–194. Berlin, Heidelberg: Springer.

Fogel, David B. 2001. *Blondie24: Playing at the Edge of AI.* San Francisco: Kaufmann.

Fogel, David B., T. J. Hays, S. L. Hahn, and J. Quon. 2004. "A Self-Learning Evolutionary Chess Program." *Proceedings of the IEEE* 92:1947–1954.

Fontaine, Matthew, and Stefanos Nikolaidis. 2021. "Differentiable Quality Diversity." In *Advances in Neural Information Processing Systems,* edited by M. Ranzato, A. Beygelzimer, Y. Dauphin, P.S. Liang, and J. Wortman Vaughan, 34:10040–10052. Curran Associates, Inc. https://proceedings.neurips.cc/paper_files/paper/2021/file/532923f11ac97d3e7cb0130315b067dc-Paper.pdf.

Fontaine, Matthew, and Stefanos Nikolaidis. 2023. "Covariance matrix adaptation map-annealing." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 456–465.

Fontaine, Matthew C, Julian Togelius, Stefanos Nikolaidis, and Amy K Hoover. 2020. "Covariance matrix adaptation for the rapid illumination of behavior space." In *Proceedings of the 2020 genetic and evolutionary computation conference,* 94–102.

Fox, Spencer J., Michael Lachmann, Mauricio Tec, Remy Pasco, Spencer Woody, Zhanwei Du, Xutong Wang, et al. 2022. "Real-time pandemic surveillance using hospital admissions and mobility data." *Proceedings of the National Academy of Sciences* 119:e2111870119.

Francon, Olivier, Santiago Gonzalez, Babak Hodjat, Elliot Meyerson, Risto Miikkulainen, Xin Qiu, and Hormoz Shahrzad. 2020. "Effective Reinforcement Learning through Evolutionary Surrogate-Assisted Prescription." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO-2020),* 814–822.

Friedlingstein, P., M. O'Sullivan, M. W. Jones, R. M. Andrew, D. C. E. Bakker, J. Hauck, P. Landschützer, et al. 2023. "Global Carbon Budget 2023." *Earth System Science Data* 15 (12): 5301–5369.

Friedmann, Naama, and Dana Rusou. 2015. "Critical period for first language: the crucial role of language input during the first year of life." *Current Opinion in Neurobiology* 35:27–34.

Fullmer, Brad, and Risto Miikkulainen. 1992. "Using Marker-Based Genetic Encoding of Neural Networks to Evolve Finite-State Behaviour." In *Toward a Practice of Autonomous Systems: Proceedings of the First European Conference on Artificial Life,* edited by Francisco J. Varela and Paul Bourgine, 255–262. Cambridge, MA: MIT Press.

Gad, Ahmed G. 2022. "Particle Swarm Optimization Algorithm and Its Applications: A Systematic Review." *Archives of Computational Methods in Engineering* 29:2531–2561.

Gaier, Adam, Alexander Asteroth, and Jean-Baptiste Mouret. 2020. "Discovering representations for black-box optimization." In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference,* 103–111.

Gaier, Adam, and David Ha. 2019. "Weight agnostic neural networks." *Advances in neural information processing systems* 32.

Galke, Lukas, Yoav Ram, and Limor Raviv. 2022. *Emergent Communication for Understanding Human Language Evolution: What's Missing?*

Ganon, Zohar, Alon Keinan, and Eytan Ruppin. 2003. "Evolutionary Network Minimization: Adaptive Implicit Pruning of Successful Agents." In *Advances in Artificial Life,* edited by Wolfgang Banzhaf, Jens Ziegler, Thomas Christaller, Peter Dittrich, and Jan T. Kim, 319–327. Berlin, Heidelberg: Springer Berlin Heidelberg.

Gao, Boyan, Henry Gouk, and Timothy M. Hospedales. 2021. "Searching for Robustness: Loss Learning for Noisy Classification Tasks." *2021 IEEE/CVF International Conference on Computer Vision,* 6650–6659.

García, N., César Hervás-Martínez, and D. Ortiz-Boyer. 2005. "Cooperative coevolution of artificial neural network ensembles for pattern classification." *IEEE Transactions on Evolutionary Computation* 9:271–302.

Gauci, Jason, Kenneth O Stanley, et al. 2008. "A case study on the critical role of geometric regularity in machine learning." In *AAAI,* 628–633.

Gauci, Jason, and Kenneth O Stanley. 2010. "Autonomous evolution of topographic regularities in artificial neural networks." *Neural computation* 22 (7): 1860–1898.

Ghawaly, James, Aaron Young, Dan Archer, Nick Prins, Brett Witherspoon, and Catherine Schuman. 2022. "A Neuromorphic Algorithm for Radiation Anomaly Detection." In *Proceedings of the International Conference on Neuromorphic Systems 2022.*

Ghawaly, James, Aaron Young, Andrew Nicholson, Brett Witherspoon, Nick Prins, Mathew Swinney, Cihangir Celik, Catherine Schuman, and Karan Patel. 2023. "Performance Optimization Study of the Neuromorphic Radiation Anomaly Detector." In *Proceedings of the 2023 International Conference on Neuromorphic Systems,* 1–7.

Giles, C. F., C. B. Miller, D. Chen, G. Z. Sun, H. H. Chen, and Y. C. Lee. 1991. "Extracting and Learning an Unknown Grammar with Recurrent Neural Networks." In *Advances in Neural Information Processing Systems,* 317–324.

Gilpin, William. 2019. "Cellular automata as convolutional neural networks." *Physical Review E* 100 (3): 032402.

Glorot, Xavier, and Yoshua Bengio. 2010. "Understanding the difficulty of training deep feedforward neural networks." In *Proceedings of the Thirteenth International Conference on Artificial Intelligence and Statistics,* 249–256.

Goldberg, David E., and J. Richardson. 1987. "Genetic Algorithms with Sharing for Multimodal Function Optimization." In *Proceedings of the Second International Conference on Genetic Algorithms,* 148–154. Kaufmann.

Gomes, Jorge, Paulo Urbano, and Anders Lyhne Christensen. 2013. "Evolution of swarm robotics systems with novelty search." *Swarm Intelligence* 7:115–144.

Gomez, Faustino, and Risto Miikkulainen. 1997. "Incremental Evolution of Complex General Behavior." *Adaptive Behavior* 5:317–342.

Gomez, Faustino, and Risto Miikkulainen. 2003. "Active Guidance for a Finless Rocket Using Neuroevolution." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 2084–2095.

Gomez, Faustino, and Risto Miikkulainen. 2004. "Transfer of Neuroevolved Controllers in Unstable Domains." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Gomez, Faustino, Jürgen Schmidhuber, and Risto Miikkulainen. 2008. "Accelerated Neural Evolution Through Cooperatively Coevolved Synapses." *Journal of Machine Learning Research* 9:937–965.

Gomez, Faustino J. 2003. "Robust Non-Linear Control through Neuroevolution." PhD diss., Department of Computer Sciences, The University of Texas at Austin.

Gonzalez, Santiago, Mohak Kant, and Risto Miikkulainen. 2021. "Evolving GAN Formulations for Higher Quality Image Synthesis." *arXiv:2102.08578.*

Gonzalez, Santiago, Joshua Landgraf, and Risto Miikkulainen. 2019. "Faster Training by Selecting Samples Using Embeddings." In *Proceedings of the 2019 International Joint Conference on Neural Networks.*

Gonzalez, Santiago, and Risto Miikkulainen. 2020. "Improved Training Speed, Accuracy, and Data Utilization Through Loss Function Optimization." In *Proceedings of the 2020 IEEE Congress on Evolutionary Computation (CEC).*

Gonzalez, Santiago, and Risto Miikkulainen. 2021a. "Effective Regularization Through Loss-Function Metalearning." *arXiv:2010.00788.*

Gonzalez, Santiago, and Risto Miikkulainen. 2021b. "Optimizing Loss Functions Through Multivariate Taylor Polynomial Parameterization." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Goodfellow, Ian, Jean Pouget-Abadie, Mehdi Mirza, Bing Xu, David Warde-Farley, Sherjil Ozair, Aaron Courville, and Yoshua Bengio. 2014. "Generative Adversarial Nets." In *Advances in Neural Information Processing Systems 27,* edited by Z. Ghahramani, M. Welling, C. Cortes, N. D. Lawrence, and K. Q. Weinberger, 2672–2680.

Goodman, Erik. 2023. "Annual Humies Awards For Human-Competitive Results." Retrieved 12/12/2023. https://human-competitive.org.

Graves, Alex, Greg Wayne, and Ivo Danihelka. 2014. "Neural turing machines." *arXiv preprint arXiv:1410.5401.*

Grefenstette, John J. 1986. "Optimization of Control Parameters for Genetic Algorithms." *IEEE Transactions on Systems, Man, and Cybernetics* 16 (1): 122–128.

Greff, Klaus, Rupesh K Srivastava, Jan Koutník, Bas R Steunebrink, and Jürgen Schmidhuber. 2016. "LSTM: A search space odyssey." *IEEE transactions on neural networks and learning systems* 28 (10): 2222–2232.

Greff, Klaus, Rupesh K. Srivastava, Jan Koutník, Bas R. Steunebrink, and Jürgen Schmidhuber. 2017. "LSTM: A Search Space Odyssey." *IEEE Transactions on Neural Networks and Learning Systems* 28:222–2232.

Greve, Rasmus Boll, Emil Juul Jacobsen, and Sebastian Risi. 2016. "Evolving neural turing machines for reward-based learning." In *Proceedings of the genetic and evolutionary computation conference 2016,* 117–124.

Grillotti, Luca, and Antoine Cully. 2022. "Unsupervised Behavior Discovery With Quality-Diversity Optimization." *IEEE Transactions on Evolutionary Computation* 26 (6): 1539–1552.

Gruau, Frederic. 1994. "Automatic definition of modular neural networks." *Adaptive behavior* 3 (2): 151–183.

Gruau, Frederic, and Darrell Whitley. 1993. "Adding Learning to the Cellular Development of Neural Networks: Evolution and the Baldwin Effect." *Evolutionary Computation* 1:213–233.

Gruau, Frederic, Darrell Whitley, and Larry Pyeatt. 1996. "A Comparison Between Cellular Encoding and Direct Encoding for Genetic Neural Networks." In *Genetic Programming 1996: Proceedings of the First Annual Conference,* edited by John R. Koza, David E. Goldberg, David B. Fogel, and Rick L. Riolo, 81–89. Cambridge, MA: MIT Press.

Guo, Qingyan, Rui Wang, Junliang Guo, Bei Li, Kaitao Song, Xu Tan, Guoqing Liu, Jiang Bian, and Yujiu Yang. 2023. "Connecting large language models with evolutionary algorithms yields powerful prompt optimizers." *arXiv preprint arXiv:2309.08532.*

Gupta, Agrim, Silvio Savarese, Surya Ganguli, and Li Fei-Fei. 2021. "Embodied intelligence via learning and evolution." *Nature communications* 12 (1): 5721.

Ha, David, Andrew Dai, and Quoc V Le. 2016. "Hypernetworks." *arXiv preprint arXiv:1609.09106.*

Ha, David, and Jürgen Schmidhuber. 2018. "Recurrent World Models Facilitate Policy Evolution." In *Advances in Neural Information Processing Systems 31,* 2451–2463. Https://worldmodels.github.io. Curran Associates, Inc. https://papers.nips.cc/paper/7512-recurrent-world-models-facilitate-policy-evolution.

Hadi, Muhammad Usman, Qasem Al-Tashi, Rizwan Qureshi, Abbas Shah, Amgad Muneer, Muhammad Irfan, Anas Zafar, et al. 2023. "Large Language Models: A Comprehensive Survey of its Applications, Challenges, Limitations, and Future Prospects." *TechRxiv, November 16,* https://doi.org/10.36227/techrxiv.23589741.v4.

Hadjiivanov, Alexander, and Alan Blair. 2021. "Epigenetic evolution of deep convolutional models." *arXiv:2104.05411.*

Hale, Thomas, Sam Webster, Anna Petherick, Toby Phillips, and Beatriz Kira. 2020. *Oxford COVID-19 Government Response Tracker.* Blavatnik School of Government. Https://www.bsg.ox.ac.uk/research/research–projects/crbinavirus–government-response-tracker, accessed 3/23/2023.

Hansen, N., and A. Ostermeier. 2001. "Completely Derandomized Self-Adaptation in Evolution Strategies." *Evolutionary Computation* 9:159–195.

Hansen, Nikolaus. 2016. "The CMA evolution strategy: A tutorial." *arXiv preprint arXiv:1604.00772.*

Hansen, Nikolaus, Anne Auger, Steffen Finck, and Raymond Ros. 2010. "Real-parameter black-box optimization benchmarking 2010: Experimental setup." PhD diss., INRIA.

Hansen, Nikolaus, and Andreas Ostermeier. 1996. "Adapting arbitrary normal mutation distributions in evolution strategies: The covariance matrix adaptation." In *Proceedings of IEEE international conference on evolutionary computation,* 312–317.

Hansis, Eberhard, Steven J. Davis, and Julia Pongratz. 2015. "Relevance of methodological choices for accounting of land use change carbon fluxes." *Global Biogeochemical Cycles* 29 (8): 1230–1246.

Hanson, Stephen José, and Lorien Y. Pratt. 1988. "Comparing Biases for Minimal Network Construction with Back-Propagation." In *Proceedings of the 1st International Conference on Neural Information Processing Systems,* 177–185. Cambridge, MA, USA: MIT Press.

Hardison, Ross C. 2003. "Comparative genomics." *PLoS biology* 1 (2): e58.

Harp, S. A., T. Samad, and A. Guha. 1989. "Towards the genetic synthesis of neural networks." In *Proceedings of the Third International Conference on Genetic Algorithms,* 391–396. San Francisco: Kaufmann.

Hastings, Erin Jonathan, Ratan K Guha, and Kenneth O Stanley. 2009. "Automatic content generation in the galactic arms race video game." *IEEE Transactions on Computational Intelligence and AI in Games* 1 (4): 245–263.

Hausknecht, Matthew, Joel Lehman, Risto Miikkulainen, and Peter Stone. 2014. "A neuroevolution approach to general atari game playing." *IEEE Transactions on Computational Intelligence and AI in Games* 6 (4): 355–366.

Hawkins, Jeff, and Subutai Ahmad. 2016. “Why Neurons Have Thousands of Synapses, a Theory of Sequence Memory in Neocortex.” *Frontiers in Neural Circuits* 10.

Hawkins, Jeff, and Sandra Blakeslee. 2004. *On Intelligence.* Times Books.

He, Kaiming, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. 2016a. “Deep residual learning for image recognition.” In *IEEE Conference on Computer Vision and Pattern Recognition,* 770–778.

He, Kaiming, Xiangyu Zhang, Shaoqing Ren, and Jian Sun. 2016b. “Deep residual learning for image recognition.” In *Proceedings of the IEEE conference on computer vision and pattern recognition,* 770–778.

He, Xin, Kaiyong Zhao, and Xiaowen Chu. 2021. “AutoML: A survey of the state-of-the-art.” *Knowledge-Based Systems* 212:106622.

Hebb, Donald Olding. 2005. *The organization of behavior: A neuropsychological theory.* Psychology press.

Herzing, Denise L., and Christine M. Johnson. 2015. *Dolphin communication and cognition : past, present, and future.* Cambridge, MA: MIT Press.

Hingston, Phil, ed. 2012. *Believable Bots.* New York: Springer.

Hinton, Geoffrey E., and Steven J. Nowlan. 1987. “How Learning Can Guide Evolution.” *Complex Systems* 1:495–502.

Hochreiter, Sepp, and Jürgen Schmidhuber. 1997. “Long short-term memory.” *Neural computation* 9 (8): 1735–1780.

Holland, John H., and J. S. Reitman. 1978. “Cognitive Systems Based on Adaptive Algorithms.” In *Pattern-Directed Inference Systems,* edited by D. A. Waterman and F. Hayes-Roth. San Diego, CA: Academic Press.

Hoover, Amy K, Paul A Szerlip, and Kenneth O Stanley. 2014. “Functional scaffolding for composing additional musical voices.” *Computer Music Journal* 38 (4): 80–99.

Horibe, Kazuya, Kathryn Walker, Rasmus Berg Palm, Shyam Sudhakaran, and Sebastian Risi. 2022. “Severe damage recovery in evolving soft robots through differentiable programming.” *Genetic Programming and Evolvable Machines* 23 (3): 405–426.

Horibe, Kazuya, Kathryn Walker, and Sebastian Risi. 2021. “Regenerating soft robots through neural cellular automata.” In *Genetic Programming: 24th European Conference, EuroGP 2021, Held as Part of EvoStar 2021, Virtual Event, April 7–9, 2021, Proceedings 24,* 36–50. Springer.

Hornby, Gregory S, and Jordan B Pollack. 2001. “The advantages of generative grammatical encodings for physical design.” In *Proceedings of the 2001 congress on evolutionary computation (ieee cat. no. 01th8546),* 1:600–607. IEEE.

Hornby, Gregory S, and Jordan B Pollack. 2002. “Creating high-level components with a generative representation for body-brain evolution.” *Artificial life* 8 (3): 223–246.

Hornik, K., M. Stinchcombe, and H. White. 1989. “Multilayer Feedforward Networks are Universal Approximators.” *Neural Networks* 2:359–366. http://1cj3301.ucsd.edu/hwcv-028.pdf.

Horvát, Szabolcs, R□zvan G□m□nu□, Mária Ercsey-Ravasz, Loïc Magrou, Bianca G□m□nu□, David C. Van Essen, Andreas Burkhalterand Kenneth Knoblauch, Zoltán Toroczkai, and Henry Kennedy. 2016. “Spatial Embedding and Wiring Cost Constrain the Functional Layout of the Cortical Network of Rodents and Primates.” *PLOS Biology* 14:e1002512. https://doi.org/10.1371/journal.pbio.1002512.

Howard, Andrew G, Menglong Zhu, Bo Chen, Dmitry Kalenichenko, Weijun Wang, Tobias Weyand, Marco Andreetto, and Hartwig Adam. 2017. “Mobilenets: Efficient convolutional neural networks for mobile vision applications.” *arXiv preprint arXiv:1704.04861.*

Huang, Pei-Chi, Luis Sentis, Joel Lehman, Chien-Liang Fok, Aloysius K. Mok, and Risto Miikkulainen. 2019. “Tradeoffs in Neuroevolutionary Learning-Based Real-Time Robotic Task Design in the Imprecise Computation Framework.” *ACM Transactions on Cyber-Physical Systems* 3.

Hubel, David H., and Torsten N. Wiesel. 1968. “Receptive Fields and Functional Architecture of Monkey Striate Cortex.” *The Journal of Physiology* 195:215–243.

Huizinga, Joost, Kenneth O Stanley, and Jeff Clune. 2018. “The emergence of canalization and evolvability in an open-ended, interactive evolutionary system.” *Artificial life* 24 (3): 157–181.

Hurtt, G. C., L. Chini, R. Sahajpal, S. Frolking, B. L. Bodirsky, K. Calvin, J. C. Doelman, et al. 2020. *Harmonization of Global Land-Use Change and Management for the Period 850-2100 (LUH2) for CMIP6.* Geoscientifc Model Development Discussions. Https://doi.org/10.5194/gmd-2019-360.

Husbands, P., and F. Mill. 1991. "Simulated co-evolution as the mechanism for emergent planning and scheduling." In *Proceedings of the Fourth International Conference on Genetic Algorithms,* edited by R. K. Belew and L. B. Booker, 264–270.

Iba, Hitoshi, and Nasimul Noman, eds. 2016. *Evolutionary Computation in Gene Regulatory Network Research.* Wiley.

Ijspeert, Auke J. 2008. "Central pattern generators for locomotion control in animals and robots: A review." *Neural Networks* 21:642–653.

Ijspeert, Auke Jan, Alessandro Crespi, Dimitri Ryczko, and Jean-Marie Cabelguen. 2007. "From Swimming to Walking with a Salamander Robot Driven by a Spinal Cord Model." *Science* 315:1416–1420.

International Human Genome Sequencing Consortium. 2004. "Finishing the euchromatic sequence of the human genome." *Nature* (London) 431:931–945.

Iranmehr, Ensieh, Saeed Bagher Shouraki, Mohammad Mahdi Faraji, Nassim Bagheri, and Bernabé Linares-Barranco. 2019. "Bio-Inspired Evolutionary Model of Spiking Neural Networks in Ionic Liquid Space." *Frontiers in Neuroscience* 13:1085.

Ishibuchi, Hisao, Noritaka Tsukamoto, and Yusuke Nojima. 2008. "Evolutionary many-objective optimization: A short review." In *2008 IEEE Congress on Evolutionary Computation (IEEE World Congress on Computational Intelligence),* 2419–2426.

Ishida Lab. 2018. "The N700 Series Shinkansen (Bullet Train)." Retrieved 9/29/2018. https://www.sys.cs.tut.ac.jp/en/research-activities/research%5C%20-introduction/what-is-a-genetic-algorithm/2/.

Islam, Md. Monirul, and Xin Yao. 2008. "Evolving Artificial Neural Network Ensembles." In *Computational Intelligence: A Compendium,* edited by John Fulcher and L. C. Jain, 851–880. Berlin, Heidelberg: Springer.

ITU. 2023. *Project Resilience.* Https://www.itu.int/en/ITU-T/extcoop/ai-data-commons/Pages/project-resilience.aspx, accessed 3/25/2023.

Jacob, François. 1977. "Evolution and Tinkering." *Science* 196 (4295): 1161–1166.

Jahns, James, and Arend Hintze. 2018. "How the integration of group and individual level selection affects the evolution of cooperation." In *The 2018 Conference on Artificial Life,* 530–535.

Jain, Ashish, Anand Subramoney, and Risto Miikkulainen. 2012. "Task decomposition with neuroevolution in extended predator-prey domain." In *Proceedings of Thirteenth International Conference on the Synthesis and Simulation of Living Systems.* East Lansing, MI, USA.

James, Conrad D., James B. Aimone, Nadine E. Miner, Craig M. Vineyard, Fredrick H. Rothganger, Kristofor D. Carlson, Samuel A. Mulder, et al. 2017. "A historical survey of algorithms and hardware architectures for neural-inspired and neuromorphic computing applications." *Biologically Inspired Cognitive Architectures* 19:49–64.

Jastrzebski, Stanislaw, Devansh Arpit, Oliver Astrand, Giancarlo B Kerg, Huan Wang, Caiming Xiong, Richard Socher, Kyunghyun Cho, and Krzysztof J Geras. 2021. "Catastrophic Fisher explosion: Early phase Fisher matrix impacts generalization." In *International Conference on Machine Learning,* 4772–4784.

Jiang, Shen, Zipeng Ji, Guanghui Zhu, Chunfeng Yuan, and Yihua Huang. 2023. "Operation-Level Early Stopping for Robustifying Differentiable NAS." In *Advances in Neural Information Processing Systems,* edited by A. Oh, T. Naumann, A. Globerson, K. Saenko, M. Hardt, and S. Levine, 70983–71007.

Jordan, Jacob, Maximilian Schmidt, Walter Senn, and Mihai A. Petrovici. 2021. "Evolving interpretable plasticity for spiking networks." *eLife* 10:e66273.

Kang, Hongwei, Fengfan Bei, Yong Shen, Xingping Sun, and Qingyi Chen. 2021. "A Diversity Model Based on Dimension Entropy and Its Application to Swarm Intelligence Algorithm." *Entropy* 23:397.

Kaplan, Jared, Sam McCandlish, Tom Henighan, Tom B Brown, Benjamin Chess, Rewon Child, Scott Gray, Alec Radford, Jeffrey Wu, and Dario Amodei. 2020. "Scaling laws for neural language models." *arXiv preprint arXiv:2001.08361.*

Karakida, Ryo, Shotaro Akaho, and Shun-ichi Amari. 2019. "Universal statistics of fisher information in deep neural networks: Mean field approach." In *The 22nd International Conference on Artificial Intelligence and Statistics,* 1032–1041.

Karpov, Igor, Leif Johnson, Vinod Valsalam, and Risto Miikkulainen. 2012. "Evaluation Methods for Human-Guided Neuroevolution in Games." In *2012 AAAI Fall Symposium on Robots that Learn Interactively from Human Teachers.* Menlo Park, CA: AAAI.

Karpov, Igor V., Leif M. Johnson, and Risto Miikkulainen. 2015. "Evaluating team behaviors constructed with human-guided machine learning." In *Proceedings of the IEEE Conference on Computational Intelligence in Games.* http://nn.cs.utexas.edu/?karpov:cig15.

Karpov, Igor V., Jacob Schrum, and Risto Miikkulainen. 2012. "Believable Bot Navigation via Playback of Human Traces." In *Believable Bots,* edited by Philip F. Hingston, 151–170. Springer Berlin Heidelberg. http://nn.cs.utexas.edu/?karpov:believablebots12.

Karpov, Igor V., Vinod K. Valsalam, and Risto Miikkulainen. 2011. "Human-Assisted Neuroevolution Through Shaping, Advice and Examples." In *Proceedings of the 13th Annual Genetic and Evolutionary Computation Conference (GECCO 2011).* Dublin, Ireland.

Kashtan, N., and Uri Alon. 2005. "Spontaneous evolution of modularity and network motifs." *Proceedings of the National Academy of Sciences* 102:13773–13778.

Kashtan, N., S. Itzkovitz, R. Milo, and U. Alon. 2004. "Efficient sampling algorithm for estimating subgraph concentrations and detecting network motifs." *Bioinformatics* 20 (11): 1746–1758.

Kay, Tomas, Laurent Keller, and Laurent Lehmann. 2020. "The evolution of altruism and the serial rediscovery of the role of relatedness." *Proceedings of the National Academy of Sciences - PNAS* 117 (46): 28894–28898.

Keinan, Alon, Ben Sandbank, Claus C. Hilgetag, Isaac Meilijson, and Eytan Ruppin. 2006. "Axiomatic Scalable Neurocontroller Analysis via the Shapley Value." *Artificial Life* 12:333–352.

Kempka, Michael, Marek Wydmuch, Grzegorz Runc, Jakub Toczek, and Wojciech Jaskowski. 2016. "ViZDoom: A Doom-based AI Research Platform for Visual Reinforcement Learning." In *IEEE Conference on Computational Intelligence and Games,* 341–348. The best paper award. Santorini, Greece: IEEE. http://arxiv.org/abs/1605.02097.

Kennedy, J., and R. C. Eberhart. 2001. *Swarm Intelligence.* San Francisco: Kaufmann.

Kermack, William Ogilvy, and Anderson G McKendrick. 1927. "A contribution to the mathematical theory of epidemics." *Proceedings of the Royal Society of London Series A* 115 (772): 700–721.

Khadka, Shauharda, Jen Jen Chung, and Kagan Tumer. 2019. "Neuroevolution of a Modular Memory-Augmented Neural Network for Deep Memory Problems." *Evolutionary Computation* 27:639–664.

Khadka, Shauharda, and Kagan Tumer. 2018. "Evolution-guided policy gradient in reinforcement learning." *Advances in Neural Information Processing Systems* 31.

Kingma, D., and M. Welling. 2013. "Auto-Encoding Variational Bayes." *ArXiv preprint,* https://arxiv.org/abs/1312.6114.

Kirby, Simon, Tom Griffiths, and Kenny Smith. 2014. "Iterated learning and the evolution of language." *Current Opinion in Neurobiology* 28:108–114.

Kirschner, Marc, and John Gerhart. 1998. "Evolvability." *Proceedings of the National Academy of Sciences* 95:8420–8427.

Kitano, Hiroaki. 1990. "Designing Neural Networks Using Genetic Algorithms with Graph Generation System." *Complex Systems* 4:461–476.

Klimov, Oleg. 2016. "CarRacing-v0." Accessed November 1, 2017. https://gym.openai.com/envs/CarRacing-v0/.

Knight, Chris, and Camilla Power. 2012. "Social conditions for the evolutionary emergence of language." In *The Oxford handbook of language evolution,* edited by Maggie Tallerman and Kathleen R. Gibson, 346–349. Oxford: Oxford University Press.

Kohl, Nate, and Risto Miikkulainen. 2011. "An Integrated Neuroevolutionary Approach to Reactive Control and High-level Strategy." *IEEE Transactions on Evolutionary Computation,* http://nn.cs.utexas.edu/?kohl:ieeetec11.

Koppejan, Rogier, and Shimon Whiteson. 2011. "Neuroevolutionary reinforcement learning for generalized control of simulated helicopters." *Evolutionary Intelligence* 4:219–241.

Koutnik, Jan, Faustino Gomez, and Jürgen Schmidhuber. 2010. "Evolving neural networks in compressed weight space." In *Proceedings of the 12th annual conference on Genetic and evolutionary computation,* 619–626.

Koutnik, Jan, Giuseppe Cuccu, Jürgen Schmidhuber, and Faustino Gomez. 2013. "Evolving large-scale neural networks for vision-based reinforcement learning." In *Proceedings of the 15th annual conference on Genetic and evolutionary computation,* 1061–1068.

Koza, J. R. 1992. *Genetic Programming: On the Programming of Computers by Means of Natural Selection.* Cambridge, MA: MIT Press.

Koza, John R. 1994. "Genetic programming as a means for programming computers by natural selection." *Statistics and computing* 4:87–112.

Kramer, Oliver. 2010. "Evolutionary self-adaptation: A survey of operators and strategy parameters." *Evolutionary Intelligence* 3:51–65.

Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E Hinton. 2012. "Imagenet classification with deep convolutional neural networks." *Advances in neural information processing systems* 25.

Kuhn, Thomas S. 1962. *The Structure of Scientific Revolutions.* (2nd, enlarged edition 1970). Chicago: The University of Chicago Press.

Kumar, Akarsh, Bo Liu, Risto Miikkulainen, and Peter Stone. 2022. "Effective Mutation Rate Adaptation through Group Elite Selection." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Kwon, Jaerock, and Yoonsuck Choe. 2009. "Facilitating neural dynamics for delay compensation: A road to predictive neural dynamics?" *Neural Networks* 22:267–276.

Lacal, Irene, and Rossella Ventura. 2018. "Epigenetic Inheritance: Concepts, Mechanisms and Perspectives." *Frontiers of Molecular Neuroscience* 11:00292.

Lake, Brenden M., Ruslan Salakhutdinov, and Joshua B. Tenenbaum. 2015. "Human-level concept learning through probabilistic program induction." *Science* 350:1332–1338.

Lamarck, J. B. 1809/1984. *Zoological Philosophy: An Exposition with Regard to the Natural History of Animals.* Translated from the French *Philosophie Zoologique* by Hugh Elliot, 1914. Chicago: University of Chicago Press.

Lange, Robert, Yingtao Tian, and Yujin Tang. 2024a. "Evolution transformer: In-context evolutionary optimization." In *Proceedings of the Genetic and Evolutionary Computation Conference Companion,* 575–578.

Lange, Robert, Yingtao Tian, and Yujin Tang. 2024b. "Large language models as evolution strategies." In *Proceedings of the Genetic and Evolutionary Computation Conference Companion,* 579–582.

Lange, Robert Tjarko. 2023. "evosax: Jax-based evolution strategies." In *Proceedings of the Companion Conference on Genetic and Evolutionary Computation,* 659–662.

Larranaga, Pedro, and Jose Lozano, eds. 2002. *Estimation of Distribution Algorithms: A New Tool for Evolutionary Computation.* Dordrecht, The Netherlands: Kluwer.

LeCun, Yann, Yoshua Bengio, and Geoffrey Hinton. 2015. "Deep Learning." *Nature* 521:436–444.

Lehman, Joel, Jeff Clune, Dusan Misevic, Christoph Adami, Julie Beaulieu, Peter J. Bentley, Samuel Bernard, et al. 2020. "The Surprising Creativity of Digital Evolution: A Collection of Anecdotes from the Evolutionary Computation and Artificial Life Research Communities." *Artificial Life* 26:274–306.

Lehman, Joel, Jonathan Gordon, Shawn Jain, Kamal Ndousse, Cathy Yeh, and Kenneth O Stanley. 2023. "Evolution through large models." In *Handbook of Evolutionary Machine Learning,* 331–366. Springer.

Lehman, Joel, Jonathan Gordon, Shawn Jain, Kamal Ndousse, Cathy Yeh, and Kenneth O. Stanley. 2022. "Evolution through Large Models." *arXiv:2207.04857.*

Lehman, Joel, and Risto Miikkulainen. 2013. "Boosting Interactive Evolution using Human Computation Markets." In *Proceedings of the 2nd International Conference on the Theory and Practice of Natural Computation.* Springer.

Lehman, Joel, and Risto Miikkulainen. 2014. "Overcoming Deception in Evolution of Cognitive Behaviors." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO 2014).* Vancouver, BC, Canada. http://nn.cs.utexas.edu/?lehman:gecco14.

Lehman, Joel, and Risto Miikkulainen. 2015. "Extinction Events Can Accelerate Evolution." *PLoS ONE* 10:e0132886.

Lehman, Joel, and Kenneth O Stanley. 2011. "Evolving a diversity of virtual creatures through novelty search and local competition." In *Proceedings of the 13th annual conference on Genetic and evolutionary computation,* 211–218.

Lehman, Joel, and Kenneth O. Stanley. 2010. "Abandoning Objectives: Evolution Through the Search for Novelty Alone." *Evolutionary Computation* 19:189–223.

Lehman, Joel, and Kenneth O. Stanley. 2012. "Beyond Open-endedness: Quantifying Impressiveness." In *ALIFE 2012: The Thirteenth International Conference on the Synthesis and Simulation of Living Systems,* 75–82.

Lehmann, Kenna D.S., Tracy M. Montgomery, Sarah M. MacLachlan, Jenna M. Parker, Olivia S. Spagnuolo, Kelsey J. VandeWetering, Patrick S. Bills, and Kay E. Holekamp. 2016. "Lions, hyenas and mobs (oh my!)" *Current Zoology* 63:313–322.

Lenartowicz, A., and R.A. Poldrack. 2010. "Brain Imaging." In *Encyclopedia of Behavioral Neuroscience,* edited by George F. Koob, Michel Le Moal, and Richard F. Thompson, 187–193. Oxford: Academic Press.

Lessin, Dan, Don Fussell, and Risto Miikkulainen. 2014. "Adapting Morphology to Multiple Tasks in Evolved Virtual Creatures." In *Proceedings of The Fourteenth International Conference on the Synthesis and Simulation of Living Systems (ALIFE 14) 2014.* http://nn.cs.utexas.edu/?lessin:alife14.

Lessin, Daniel, Donald Fussell, and Risto Miikkulainen. 2013. "Open-Ended Behavioral Complexity for Evolved Virtual Creatures." In *Proceedings of the Genetic and Evolutionary Computation Conference.* http://nn.cs.utexas.edu/?lessin:gecco13.

Lettvin, J. Y., H. R. Maturana, Warren S. McCulloch, and Walter H. Pitts. 1940. "What the Frog's Eye Tells the Frog's Brain." In *Proceedings of the IRE.*

Li, Hui, Xuesong Wang, and Shifei Ding. 2018. "Research and Development of Neural Network Ensembles: A Survey." *Artificial Intelligence Review* 49:455–479.

Li, Liam, and Ameet Talwalkar. 2020. "Random search and reproducibility for neural architecture search." In *Uncertainty in artificial intelligence,* 367–377. PMLR.

Li, Xun, and Risto Miikkulainen. 2016. "Evolving Artificial Language Through Evolutionary Reinforcement Learning." In *Proceedings of the Fifteenth International Conference on the Synthesis and Simulation of Living Systems.* Cambridge, MA: MIT Press.

Li, Xun, and Risto Miikkulainen. 2018. "Opponent Modeling and Exploitation in Poker Using Evolved Recurrent Neural Networks." In *Proceedings of The Genetic and Evolutionary Computation Conference (GECCO 2018).* Kyoto, Japan: ACM.

Liang, J., E. Meyerson, and R. Miikkulainen. 2018. "Evolutionary Architecture Search for Deep Multitask Networks." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 466–473.

Liang, Jason, Santiago Gonzalez, Hormoz Shahrzad, and Risto Miikkulainen. 2021. "Regularized Evolutionary Population-Based Training." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Liang, Jason, Elliot Meyerson, Babak Hodjat, Dan Fink, Karl Mutch, and Risto Miikkulainen. 2019. "Evolutionary Neural AutoML for Deep Learning." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO-2019).* http://nn.cs.utexas.edu/?liang:gecco19.

Liang, Jason, Hormoz Shahrzad, and Risto Miikkulainen. 2023. "Asynchronous Evolution of Deep Neural Network Architectures." *Applied Soft Computing.*

Liang, Jason Zhi, and Risto Miikkulainen. 2015. "Evolutionary Bilevel Optimization for Complex Control Tasks." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO 2015).* Madrid, Spain.

Liang, Tengyuan, Tomaso Poggio, Alexander Rakhlin, and James Stokes. 2019. "Fisher-Rao metric, geometry, and complexity of neural networks." In *The 22nd International Conference on Artificial Intelligence and Statistics,* 888–896.

Liao, Zhibin, Tom Drummond, Ian Reid, and Gustavo Carneiro. 2018. "Approximate Fisher information matrix to characterize the training of deep neural networks." *IEEE transactions on pattern analysis and machine intelligence* 42:15–26.

Light, Will. 1992. "Ridge Functions, Sigmoidal Functions and Neural Networks." In *Approximation Theory VII,* edited by E. W. Cheney, C. K. Cui, and L. L. Schumaker, 158–201. Boston: Academic Press.

Lim, Heejin, and Yoonsuck Choe. 2006. "Facilitating neural dynamics for delay compensation and prediction in evolutionary neural networks." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 167–174. Seattle, WA.

Lindenmayer, Aristid. 1968. "Mathematical Models for Cellular Interaction in Development Parts I and II." *Journal of Theoretical Biology* 18:280–299 and 300–315.

Lipson, Hod, and Jordan B. Pollack. 2000. "Automatic Design and Manufacture of Robotic Lifeforms." *Nature* 406:974–978.

Liu, Hanxiao, Karen Simonyan, and Yiming Yang. 2018. "Darts: Differentiable architecture search." *arXiv preprint arXiv:1806.09055.*

Liu, Yuqiao, Yanan Sun, Bing Xue, Mengjie Zhang, Gary G. Yen, and Kay Chen Tan. 2021. "A Survey on Evolutionary Neural Architecture Search." *IEEE Transactions on Neural Networks and Learning Systems,* 1–21.

Liu, Zhenhua, Xinfeng Zhang, Shanshe Wang, Siwei Ma, and Wen Gao. 2021. "Evolutionary Quantization of Neural Networks with Mixed-Precision." In *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP),* 2785–2789.

Lockett, Alan, and Risto Miikkulainen. 2013. “Neuroannealing: Martingale-driven Learning for Neural Network.” In *Proceedings of the Genetic and Evolutionary Computation Conference.* http://nn.cs.utexas.edu/?lockett:gecco 13.

Lorenzo, Pablo Ribalta, and Jakub Nalepa. 2018. “Memetic evolution of deep neural networks.” In *Proceedings of the Genetic and Evolutionary Computation Conference,* 505–512.

Lorenzo, Pablo Ribalta, Jakub Nalepa, Michal Kawulok, Luciano Sanchez Ramos, and José Ranilla Pastor. 2017. “Particle swarm optimization for hyper-parameter selection in deep neural networks.” In *Proceedings of the Genetic and Evolutionary Computation Conference,* 481–488.

Lozano, Jose A., Pedro Larrañaga, Iñaki Inza, and Endika Bengoetxea. 2006. *Towards a New Evolutionary Computation: Advances on Estimation of Distribution Algorithms (Studies in Fuzziness and Soft Computing).* Berlin, Heidelberg: Springer-Verlag.

Lu, Sen, and Abhronil Sengupta. 2022. “Neuroevolution Guided Hybrid Spiking Neural Network Training.” *Frontiers in Neuroscience* 16:838523.

Lu, Zhichao, Kalyanmoy Deb, Erik Goodman, Wolfgang Banzhaf, and Vishnu Naresh Boddeti. 2020. “NSGANetV2: Evolutionary multi-objective surrogate-assisted neural architecture search.” In *European Conference on Computer Vision ECCV-2020,* 12346:35–51.

Lüders, Benno, Mikkel Schläger, and Sebastian Risi. 2016. “Continual learning through evolvable neural turing machines.”

Luke, Sean, and Lee Spector. 1996. “Evolving Graphs and Networks with Edge Encoding: Preliminary Report.” In *Late=Breaking Papers of the Genetic Programming COnference,* edited by John R. Koza, 117–124.

Luo, Calvin. 2022. “Understanding Diffusion Models: A Unified Perspective.” *arXiv:2208.11970.*

Lynch, M. 2007. “The frailty of adaptive hypotheses for the origins of organismal complexity.” *Proceedings of the National Acadademy of Sciences* 104:8597–8604.

MacNeilage, Peter F. 1998. “The Frame/Content Theory of Evolution of Speech Production.” *Behavioral and Brain Sciences* 21:499–511.

Maheri, Alireza, Shahin Jalili, Yousef Hosseinzadeh, Reza Khani, and Mirreza Miryahyavi. 2021. “A comprehensive survey on cultural algorithms.” *Swarm and Evolutionary Computation* 62:100846.

Mao, Xudong, Qing Li, Haoran Xie, Raymond Y.K. Lau, Zhen Wang, and Stephen Paul Smolley. 2017. “Least Squares Generative Adversarial Networks.” In *Proceedings of the IEEE International Conference on Computer Vision (ICCV).*

Markram, Henry, Yun Wang, and Michail Tsodyks. 1998. “Differential Signaling via the Same Axon of Neocortical Pyramidal Neurons.” *Proceedings of the National Academy of Sciences of the United States of America* 95:5323–5328.

Masoudnia, Saeed, and Reza Ebrahimpour. 2014. “Mixture of experts: A literature survey.” *Artificial Intelligence Review* 42:275.

Mattiussi, Claudio, and Dario Floreano. 2007. “Analog Genetic Encoding for the Evolution of Circuits and Networks.” *IEEE Transactions on Evolutionary Computation* 11 (5): 596–607.

Maynard Smith, J., and E. Szathmary. 1997. *The Major Transitions in Evolution.* Oxford University Press.

McQuesten, Paul. 2002. “Cultural Enhancement of Neuroevolution.” PhD diss., Department of Computer Sciences, The University of Texas at Austin.

McQuesten, Paul, and Risto Miikkulainen. 1997. “Culling and Teaching in Neuro-Evolution.” In *Seventh International Conference on Genetic Algorithms,* 760–767.

Meoded, A., A. Poretti, S. Mori, and J. Zhang. 2017. “Diffusion Tensor Imaging (DTI).” In *Reference Module in Neuroscience and Biobehavioral Psychology.* Elsevier.

Meredith, Robert W., Jan E. Jane□ka, John Gatesy, Oliver A. Ryder, Colleen A. Fisher, Emma C. Teeling, Alisha Goodbla, et al. 2011. “Impacts of the Cretaceous Terrestrial Revolution and KPg Extinction on Mammal Diversification.” *Science* 334:521–524.

Metzen, Jan Hendrik, Frank Kirchner, Mark Edgington, and Yohannes Kassahun. 2008. “Towards efficient online reinforcement learning using neuroevolution.” In *Proceedings of the 10th Annual Conference on Genetic and Evolutionary Computation,* 1425–1426.

Meyerson, Elliot, Olivier Francon, Darren Sargent, Babak Hodjat, and Risto Miikkulainen. 2024. “Unlocking the Potential of Global Human Expertise.” In *Proceedings of the 38th Conference on Neural Information Processing Systems (NeurIPS 2024).*

Meyerson, Elliot, Joel Lehman, and Risto Miikkulainen. 2016a. "Learning Behavior Characterizations for Novelty Search." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO 2016).* Denver, CO: ACM.

Meyerson, Elliot, Joel Lehman, and Risto Miikkulainen. 2016b. "Learning behavior characterizations for novelty search." In *Proceedings of the Genetic and Evolutionary Computation Conference 2016,* 149–156.

Meyerson, Elliot, and Risto Miikkulainen. 2017. "Discovering Evolutionary Stepping Stones through Behavior Domination." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO 2017),* 139–146. Berlin, Germany.

Meyerson, Elliot, and Risto Miikkulainen. 2018a. "Beyond Shared Hierarchies: Deep Multitask Learning through Soft Layer Ordering." In *Proceedings of the International Conference on Learning Representations.*

Meyerson, Elliot, and Risto Miikkulainen. 2018b. "Pseudo-task Augmentation: From Deep Multitask Learning to Intratask Sharing—and Back." In *Proceedings of the 35th International Conference on Machine Learning,* 739–748.

Meyerson, Elliot, and Risto Miikkulainen. 2019. "Modular Universal Reparameterization: Deep Multi-task Learning Across Diverse Domains." In *Advances in Neural Information Processing Systems 32,* edited by H. Wallach, H. Larochelle, A. Beygelzimer, F. d Alche-Buc, E. Fox, and R. Garnett.

Meyerson, Elliot, and Risto Miikkulainen. 2021. "The Traveling Observer Model: Multi-task Learning Through Spatial Variable Embeddings." In *International Conference on Learning Representations.*

Meyerson, Elliot, Xin Qiu, and Risto Miikkulainen. 2022. "Simple Genetic Operators are Universal Approximators of Probability Distributions (and other Advantages of Expressive Encodings)." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Miconi, Thomas, Kenneth Stanley, and Jeff Clune. 2018. "Differentiable plasticity: training plastic neural networks with backpropagation." In *International Conference on Machine Learning,* 3559–3568. PMLR.

Miikkulainen, Risto. 2021. "Creative AI through Evolutionary Computation: Principles and Examples." *SN Computer Science* 2:163.

Miikkulainen, Risto. 2024. "Generative AI: An AI Paradigm Shift in the Making?" *AI Magazine.*

Miikkulainen, Risto, James A. Bednar, Yoonsuck Choe, and Joseph Sirosh. 2005. *Computational Maps in the Visual Cortex.* Berlin, Heidelberg, New York: Springer.

Miikkulainen, Risto, Myles Brundage, Jonathan Epstein, Tyler Foster, Babak Hodjat, Neil Iscoe, Jingbo Jiang, et al. 2020. "Ascend by Evolv: AI-Based Massively Multivariate Conversion Rate Optimization." *AI Magazine* 42:44–60.

Miikkulainen, Risto, and Stephanie Forrest. 2021. "A Biological Perspective on Evolutionary Computation." *Nature Machine Intelligence* 3:9–15.

Miikkulainen, Risto, Olivier Francon, Elliot Meyerson, Xin Qiu, Darren Sargent, Elisa Canzani, and Babak Hodjat. 2021. "From Prediction to Prescription: Evolutionary Optimization of Non-Pharmaceutical Interventions in the COVID-19 Pandemic." *IEEE Transactions on Evolutionary Computation* 25:386–401.

Miikkulainen, Risto, Olivier Francon, Daniel Young, Elliot Meyerson, and Babak Hodjat. 2023. "Discovering Effective Policies for Land-Use Planning." *arxiv:2311.12304.*

Miikkulainen, Risto, Jason Liang, Elliot Meyerson, Aditya Rawal, Dan Fink, Olivier Francon, Bala Raju, et al. 2023. "Evolving Deep Neural Networks." In *Artificial Intelligence in the Age of Neural Networks and Brain Computing (second edition),* edited by R. Kozma, C. Alippi, Y. Choe, and F. Morabito, 269–287. New York: Elsevier. http://nn.cs.utexas.edu/?miikkulainen:chapter23.

Miikkulainen, Risto, Elliot Meyerson, Xin Qiu, Ujjayant Sinha, Raghav Kumar, Karen Hofmann, Yiyang Matt Yan, et al. 2021. "Evaluating Medical Aesthetics Treatments through Evolved Age-Estimation Models." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Miller, G., P. Todd, and S. Hedge. 1989. "Designing neural networks using genetic algorithm." In *Proceedings of the Third International Conference on Genetic Algorithms,* 391–396. San Francisco: Kaufmann.

Miller, Julian, and Andrew Turner. 2015. "Cartesian genetic programming." In *Proceedings of the Companion Publication of the 2015 Annual Conference on Genetic and Evolutionary Computation,* 179–198.

Miller, Julian F. 2003. "Evolving developmental programs for adaptation, morphogenesis, and self-repair." In *European Conference on Artificial Life,* 256–265. Springer.

Miller, Julian F., ed. 2011. *Cartesian Genetic Programming.* Berlin, Heidelberg: Springer.

Miller, Julian Francis. 2004. “Evolving a self-repairing, self-regulating, french flag organism.” In *Genetic and Evolutionary Computation Conference,* 129–139. Springer.

Mirchandani, Suvir, Fei Xia, Pete Florence, brian ichter, Danny Driess, Montserrat Gonzalez Arenas, Kanishka Rao, Dorsa Sadigh, and Andy Zeng. 2023. “Large Language Models as General Pattern Machines.” In *7th Annual Conference on Robot Learning.* https://openreview.net/forum?id=RcZMI8MSyE.

Mitchell, Melanie, et al. 2005. “Computation in Cellular Automata: A Selected Review.” *Non-standard computation,* 95–140.

Mitchell, Melanie. 2006. “Coevolutionary Learning with Spatially Distributed Populations.” In *Computational Intelligence: Principles and Practice,* edited by Gary Y. Yen and David B. Fogel. Piscataway, NJ: IEEE Computational Intelligence Society.

Mitchell, Melanie, James P Crutchfield, Rajarshi Das, et al. 1996. “Evolving cellular automata with genetic algorithms: A review of recent work.” In *Proceedings of the First international conference on evolutionary computation and its applications (EvCA’96),* vol. 8. Moscow.

Mitchell, Melanie, Peter Hraber, and James P Crutchfield. 1993. “Revisiting the edge of chaos: Evolving cellular automata to perform computations.” *arXiv preprint adap-org/9303003.*

Mjolsness, Eric, David H. Sharp, and Bradley K. Alpert. 1989. “Scaling, Machine Learning, and Genetic Neural Nets.” *Advances in Applied Mathematics* 10:137–163.

Mnih, Volodymyr, Koray Kavukcuoglu, David Silver, Andrei A. Rusu, Joel Veness, Marc G. Bellemare, Alex Graves, et al. 2015. “Human-level control through deep reinforcement learning.” *Nature* 518:529–533.

Montana, David J., and Lawrence Davis. 1989. “Training Feedforward Neural Networks Using Genetic Algorithms.” In *Proceedings of the 11th International Joint Conference on Artificial Intelligence,* 762–767.

Mordvintsev, Alexander, Ettore Randazzo, Eyvind Niklasson, and Michael Levin. 2020. “Growing neural cellular automata.” *Distill* 5 (2): e23.

Morgan, Nelson, and Herve Bourlard. 1989. *Generalization and Parameter Estimation in Feedforward Nets: Some Experiments.* Technical report TR-89-017. Berkeley, CA: International Computer Science Institute.

Moriarty, David E., and Risto Miikkulainen. 1996. “Evolving Obstacle Avoidance Behavior In A Robot Arm.” In *From Animals to Animats 4: Proceedings of the Fourth International Conference on Simulation of Adaptive Behavior,* edited by Pattie Maes, Maja J. Mataric, Jean-Arcady Meyer, Jordan Pollack, and Stewart W. Wilson, 468–475. Cambridge, MA: MIT Press.

Moriarty, David E., and Risto Miikkulainen. 1997. “Forming Neural Networks Through Efficient And Adaptive Coevolution.” *Evolutionary Computation* 5:373–399. http://nn.cs.utexas.edu/?moriarty:ec97.

Morris, Clint, Michael Jurado, and Jason Zutty. 2024. “LLM Guided Evolution-The Automation of Models Advancing Models.” In *Proceedings of the Genetic and Evolutionary Computation Conference,* 377–384.

Mouret, Jean-Baptiste, and Jeff Clune. 2015. “Illuminating search spaces by mapping elites.” *arXiv preprint arXiv:1504.04909.*

Mouret, Jean-Baptiste, and Stéphane Doncieux. 2012. “Encouraging behavioral diversity in evolutionary robotics: An empirical study.” *Evolutionary Computation* 20:91–133.

Mouret, Jean-Baptiste, and Stephane Doncieux. 2009. “Overcoming the bootstrap problem in evolutionary robotics using behavioral diversity.” In *IEEE Congress on Evolutionary Computation,* 1161–1168.

Mühlenbein, Heinz, and J. Kindermann. 1989. “The dynamics of evolution and learning: Towards genetic neural networks.” In *Connectionism in Perspective,* edited by R. Pfeifer, Z. Schreter, F. Fogelman Soulié, and L. Steels, 301–308. Amsterdam: Elsevier.

Müller, Gerd B. 2014. “EvoDevo Shapes the Extended Synthesis.” *Biological Theory* 9 (2): 119–121.

Nair, Vinod, and Geoffrey E Hinton. 2010. “Rectified linear units improve restricted boltzmann machines.” In *Proceedings of the 27th international conference on machine learning (ICML-10),* 807–814.

Najarro, Elias, and Sebastian Risi. 2020a. “Meta-Learning through Hebbian Plasticity in Random Networks.” In *Advances in Neural Information Processing Systems,* 20719–20731.

Najarro, Elias, and Sebastian Risi. 2020b. “Meta-learning through hebbian plasticity in random networks.” *Advances in Neural Information Processing Systems* 33:20719–20731.

Najarro, Elias, Shyam Sudhakaran, Claire Glanois, and Sebastian Risi. 2022. “HyperNCA: Growing Developmental Networks with Neural Cellular Automata.” *arXiv preprint arXiv:2204.11674.*

Najarro, Elias, Shyam Sudhakaran, and Sebastian Risi. 2023. "Towards Self-Assembling Artificial Neural Networks through Neural Developmental Programs." In *Artificial Life Conference Proceedings 35,* 80. MIT Press One Rogers Street, Cambridge, MA 02142-1209, USA journals-info …

Newman, M. E. 2006. "Modularity and community structure in networks." *Proceedings of the National Academy of Sciences* 103:8577–8582.

Newman, Mark EJ. 2002. "Spread of epidemic disease on networks." *Physical Review E* 66:016128.

Nichele, Stefano, Mathias Berild Ose, Sebastian Risi, and Gunnar Tufte. 2017. "Ca-neat: evolved compositional pattern producing networks for cellular automata morphogenesis and replication." *IEEE Transactions on Cognitive and Developmental Systems* 10 (3): 687–700.

Nisioti, Eleni, Erwan Plantec, Milton Montero, Joachim Pedersen, and Sebastian Risi. 2024. "Growing artificial neural networks for control: the role of neuronal diversity." In *Proceedings of the Genetic and Evolutionary Computation Conference Companion,* 175–178.

Nolfi, Stefano, Jeffery L. Elman, and Domenico Parisi. 1994. "Learning and Evolution in Neural Networks." *Adaptive Behavior* 2:5–28.

Nolfi, Stefano, and Dario Floreano. 2000. *Evolutionary robotics: The biology, intelligence, and technology of self-organizing machines.* MIT press.

Nolfi, Stefano, and Dario Floreano. 2004. *Evolutionary Robotics: The Biology, Intelligence, and Technology of Self-Organizing Machines.* Cambridge, MA: MIT Press.

Nolfi, Stefano, and Domenico Parisi. 1994a. "Desired Answers Do Not Correspond to Good Teaching Inputs in Ecological Neural Networks." *Neural Processing Letters* 1:1–5.

Nolfi, Stefano, and Domenico Parisi. 1994b. "Growing Neural Networks." In *Proceedings of the Workshop on Artificial Life (ALIFE '92),* edited by Christopher G. Langton. Reading, MA: Addison-Wesley.

Nordin, Peter, and Wolfgang Banzhaf. 1995. "Complexity Compression and Evolution." In *Proceedings of the Sixth International Conference on Genetic Algorithms,* 310–317. San Francisco: Kaufmann.

Nowak, Martin A., and David C. Krakauer. 1999. "The evolution of language." *Proceedings of the National Acadeny of Sciences* 96:8028–8033.

Ollion, Charles, Tony Pinville, and Stéphane Doncieux. 2012. "With a little help from selection pressures: evolution of memory in robot controllers." In *The Thirteenth International Conference on the Synthesis and Simulation of Living Systems,* 407–414.

OpenAI. 2023. "GPT-4 Technical Report." *ArXiv* abs/2303.08774. https://arxiv.org/abs/2303.08774.

Ororbia, Alexander, AbdElRahman ElSaid, and Travis Desell. 2019. "Investigating recurrent neural network memory structures using neuro-evolution." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 446–455.

Ouyang, Long, Jeff Wu, Xu Jiang, Diogo Almeida, Carroll L. Wainwright, Pamela Mishkin, Chong Zhang, et al. 2022. "Training language models to follow instructions with human feedback." *arXiv:2203.02155.*

Oymak, Samet. 2018. "Learning Compact Neural Networks with Regularization." In *International Conference on Machine Learning,* 3963–3972.

Papavasileiou, Evgenia, Jan Cornelis, and Bart Jansen. 2021. "A Systematic Literature Review of the Successors of "NeuroEvolution of Augmenting Topologies"." *Evolutionary Computation* 29:1–73.

Pardoe, David, Michael Ryoo, and Risto Miikkulainen. 2005. "Evolving Neural Network Ensembles for Control Problems." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Park, J., and I. W. Sandberg. 1991. "Universal Approximation Using Radial-Basis-Function Networks." *Neural Computation* 3:246–257.

Park, Joon Sung, Joseph O'Brien, Carrie Jun Cai, Meredith Ringel Morris, Percy Liang, and Michael S Bernstein. 2023. "Generative agents: Interactive simulacra of human behavior." In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology,* 1–22.

Pedersen, Joachim Winther, and Sebastian Risi. 2021. "Evolving and merging hebbian learning rules: increasing generalization by decreasing the number of rules." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 892–900.

Pelikan, Martin, David E. Goldberg, and Erick Cantú-Paz. 1999. "BOA: The Bayesian Optimization Algorithm." In *Proceedings of the 1st Annual Conference on Genetic and Evolutionary Computation,* 525–532. San Francisco: Kaufmann.

Pham, Hieu, Melody Guan, Barret Zoph, Quoc Le, and Jeff Dean. 2018. "Efficient neural architecture search via parameters sharing." In *International conference on machine learning,* 4095–4104. PMLR.

Plantec, Erwan, Joachim W Pedersen, Milton L Montero, Eleni Nisioti, and Sebastian Risi. 2024. "Evolving Self-Assembling Neural Networks: From Spontaneous Activity to Experience-Dependent Learning." In *ALIFE 2024: Proceedings of the 2024 Artificial Life Conference.* MIT Press.

Polani, Daniel, and Risto Miikkulainen. 2000. "Eugenic Neuro-Evolution for Reinforcement Learning." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO-2000),* 1041–1046. San Francisco: Kaufmann.

Pollack, Jordan B. 1987. "Cascaded Back-Propagation on Dynamic Connectionist Networks." In *Proceedings of the 10th Annual Conference of the Cognitive Science Society,* 391–404.

Popovici, Elena, Anthony Bucci, R. Paul Wiegand, and Edwin D. De Jong. 2012. "Coevolutionary Principles." In *Handbook of Natural Computing,* edited by Grzegorz Rozenberg, Thomas Bäck, and Joost N. Kok, 987–1033. Berlin, Heidelberg: Springer Berlin Heidelberg.

Potter, Mitchell A., and Kenneth A. De Jong. 2000. "Cooperative Coevolution: An Architecture for Evolving Coadapted Subcomponents." *Evolutionary Computation* 8:1–29.

Prellberg, Jonas, and Oliver Kramer. 2018. "Lamarckian Evolution of Convolutional Neural Networks." In *Parallel Problem Solving from Nature,* edited by Anne Auger, Carlos M. Fonseca, Nuno Lourenço, Penousal Machado, Luís Paquete, and Darrell Whitley, 424–435. Cham: Springer.

Prior, John. 1998. "Eugenic Evolution for Combinatorial Optimization." Master's thesis, Department of Computer Sciences, The University of Texas at Austin.

Prusinkiewicz, Przemyslaw, Mikolaj Cieslak, Pascal Ferraro, and Jim Hanan. 2018. "Modeling plant development with L-systems." *Mathematical modelling in plant biology,* 139–169.

Pugh, Justin K, Lisa B Soros, and Kenneth O Stanley. 2016. "Quality diversity: A new frontier for evolutionary computation." *Frontiers in Robotics and AI* 3:40.

Qiu, Xin, Elliot Meyerson, and Risto Miikkulainen. 2020. "Quantifying Point-Prediction Uncertainty in Neural Networks via Residual Estimation with an I/O Kernel." In *Proceedings of the International Conference on Learning Representations.*

Qiu, Xin, and Risto Miikkulainen. 2023. "Shortest Edit Path Crossover: A Theory-driven Solution to the Permutation Problem in Evolutionary Neural Architecture Search." In *Proceedings of the International Conference on Machine Learning (ICML-2023).*

Rajagopalan, Padmini, Kay E. Holekamp, and Risto Miikkulainen. 2014. "The Evolution of General Intelligence." In *Proceedings of The Fourteenth International Conference on the Synthesis and Simulation of Living Systems (ALIFE 14).* New York, NY. http://nn.cs.utexas.edu/?rajagopalan:alife14.

Rajagopalan, Padmini, Kay E. Holekamp, and Risto Miikkulainen. 2019. "Factors that Affect the Evolution of Complex Cooperative Behavior." In *The 2019 Conference on Artificial Life (ALIFE 2019),* 333–340.

Rajagopalan, Padmini, Kay E. Holekamp, and Risto Miikkulainen. 2020. "Evolution of Complex Coordinated Behavior." In *2020 IEEE Congress on Evolutionary Computation (CEC).*

Rajagopalan, Padmini, Aditya Rawal, Risto Miikkulainen, Marc A. Wiseman, and Kay E. Holekamp. 2011. "The Role of Reward Structure, Coordination Mechanism and Net Return in the Evolution of Cooperation." In *Proceedings of the IEEE Conference on Computational Intelligence and Games (CIG 2011).* Seoul, South Korea. http://nn.cs.utexas.edu/?rajagopalan:cig11.

Ramachandran, Prajit, Barret Zoph, and Quoc V. Le. 2017. "Searching for Activation Functions." *arXiv:1710.05941.*

Raup, David M. 1986. "Biological Extinction in Earth History." *Science* 231:1528–1533.

Rawal, Aditya, Janette Boughman, and Risto Miikkulainen. 2014. "Evolution of Communication in Mate Selection." In *Proceedings of The Fourteenth International Conference on the Synthesis and Simulation of Living Systems (ALIFE 14).*

Rawal, Aditya, and Risto Miikkulainen. 2020. "Discovering Gated Recurrent Neural Network Architectures." In *Deep Neural Evolution – Deep Learning with Evolutionary Computation,* edited by Hitoshi Iba and Nasimul Noman, 233–251. Springer.

Rawal, Aditya, Padmini Rajagopalan, and Risto Miikkulainen. 2010. "Constructing Competitive and Cooperative Agent Behavior Using Coevolution." In *IEEE Conference on Computational Intelligence and Games (CIG 2010).* Copenhagen, Denmark.

Real, Esteban, Alok Aggarwal, Yanping Huang, and Quoc V. Le. 2019. "Regularized Evolution for Image Classifier Architecture Search." In *Proceedings of the AAAI Conference on Artificial Intelligence,* 4780–4789.

Real, Esteban, Chen Liang, David So, and Quoc Le. 2020. "AutoML-Zero: Evolving Machine Learning Algorithms From Scratch." In *Proceedings of the 37th International Conference on Machine Learning,* edited by Hal Daumé III and Aarti Singh, 119:8007–8019.

Real, Esteban, Sherry Moore, Andrew Selle, Saurabh Saxena, Yutaka Leon Suematsu, Jie Tan, Quoc V Le, and Alexey Kurakin. 2017. "Large-scale evolution of image classifiers." In *International conference on machine learning,* 2902–2911. PMLR.

Rechenberg, Ingo. 1989. "Evolution strategy: Nature's way of optimization." In *Optimization: Methods and Applications, Possibilities and Limitations: Proceedings of an International Seminar Organized by Deutsche Forschungsanstalt für Luft-und Raumfahrt (DLR), Bonn, June 1989,* 106–126. Springer.

reddit. 2017. "Investing in ICO's. Results may vary." Retrieved 10/29/2017. https://blog.otoro.net/2017/10/29/visual-evolution-strategies/.

Reed, R. 1993. "Pruning algorithms-a survey." *IEEE Transactions on Neural Networks* 4:740–747.

Reisinger, Joseph, and Risto Miikkulainen. 2006. "Selecting for Evolvable Representations." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Reisinger, Joseph, and Risto Miikkulainen. 2007. "Acquiring Evolvability through Adaptive Representations." In *Proceeedings of the Genetic and Evolutionary Computation Conference,* 1045–1052.

Reynolds, John, James Plank, and Catherine Schuman. 2019. "Intelligent Reservoir Generation for Liquid State Machines using Evolutionary Optimization." In *Proceedings of the 2019 International Joint Conference on Neural Networks.*

Reynolds, R. G., Z. Michalewicz, and M. J. Cavaretta. 1995. "Using cultural algorithms for constraint handling in GENOCOP." In *Proceedings of the Fourth Annual Conference on Evolutionary Programming,* edited by J. R. McDonnell, R. G. Reynolds, and D. B. Fogel, 289–305. Cambridge, MA: MIT Press.

Risi, Sebastian, Charles E Hughes, and Kenneth O Stanley. 2010. "Evolving plastic neural networks with novelty search." *Adaptive Behavior* 18:470–491.

Risi, Sebastian, Joel Lehman, David B. D'Ambrosio, Ryan Hall, and Kenneth O. Stanley. 2016. "Petalz: Search-Based Procedural Content Generation for the Casual Gamer." *IEEE Transactions on Computational Intelligencde and AI in Games* 8:244–255.

Risi, Sebastian, and Kenneth O Stanley. 2010. "Indirectly encoding neural plasticity as a pattern of local rules." In *International conference on simulation of adaptive behavior,* 533–543. Springer.

Risi, Sebastian, and Kenneth O Stanley. 2012a. "A unified approach to evolving plasticity and neural geometry." In *The 2012 International Joint Conference on Neural Networks (IJCNN),* 1–8. IEEE.

Risi, Sebastian, and Kenneth O Stanley. 2012b. "An enhanced hypercube-based encoding for evolving the placement, density, and connectivity of neurons." *Artificial life* (Cambridge, MA) 18:331–363.

Robson, Ann L. 2023. "Critical/Sensitive Periods." In *Child Development.* Retrieved 2/22/2023. encyclopedia.com. https://www.encyclopedia.com/children/applied-and-social-sciences-magazines/criticalsensitive-periods.

Rock, David, and Heidi Grant. 2016. "Why diverse teams are smarter." Nov 4, 2016, *Harward Business Review.*

Routley, Nick. 2017. "Visualizing the Trillion-Fold Increase in Computing Power." Retrieved 11/17/2022. https://www.visualcapitalist.com/visualizing-trillion-fold-in%5C%20crease-computing-power/.

Rumelhart, David E., Geoffrey E. Hinton, and Ronald J. Williams. 1986. "Learning Internal Representations by Error Propagation." In *Parallel Distributed Processing: Explorations in the Microstructure of Cognition, Vol. 1: Foundations,* 318–362. Cambridge, MA: MIT Press.

Ruppin, Eytan. 2002. "Evolutionary autonomous agents: A neuroscience perspective." *Nature Reviews Neuroscience* 3:132–141.

Ryan Ruggiero, Vincent. 2012. *Beyond feelings: A guide to critical thinking.* McGraw Hill.

Salge, Christoph, Cornelius Glackin, and Daniel Polani. 2014a. "Empowerment–An Introduction." In *Guided Self-Organization: Inception,* edited by Mikhail Prokopenko, 67–114. Berlin, Heidelberg: Springer.

Salge, Christoph, Cornelius Glackin, and Daniel Polani. 2014b. "Empowerment–An Introduction." In *Guided Self-Organization: Inception,* edited by Mikhail Prokopenko, 67–114. Berlin, Heidelberg: Springer.

Salimans, Tim, Jonathan Ho, Xi Chen, Szymon Sidor, and Ilya Sutskever. 2017. "Evolution strategies as a scalable alternative to reinforcement learning." *arXiv preprint arXiv:1703.03864.*

Samuel, A. 1963. "Some Studies in Machine Learning Using the Game of Checkers." In *Computers and Thought,* edited by Edward A. Feigenbaum and Jerome A. Feldman. McGraw-Hill.

Saunders, Gregory M., and Jordan B. Pollack. 1996. "The Evolution of Communication Schemes Over Continuous Channels." In *Proceedings of the Fourth International Conference on Simulation of Adaptive Behavior,* edited by Pattie Maes, Maja J. Mataric, Jean-Arcady Meyer, Jordan Pollack, and S. W. Wilson, 580–589. MIT Press.

Schaffer, J. D., R. A. Caruana, and L. Eshelman. 1990. "Using genetic search to exploit the emergent behavior of neural networks." In *Emergent Computataion,* edited by S. Forrest, 244–248. North Holland.

Schaffer, J. D., D. Whitley, and L. J. Eshelman. 1992. "Combinations of Genetic Algorithms and Neural Networks: A Survey of the State of the Art." In *Proceedings of the International Workshop on Combinations of Genetic Algorithms and Neural Networks,* edited by Darrell Whitley and Jonathan Schaffer, 1–37. Los Alamitos, CA: IEEE Computer Society Press.

Schmidhuber, Jürgen. 1992. "Learning to control fast-weight memories: An alternative to dynamic recurrent networks." *Neural Computation* 4 (1): 131–139.

Schmidhuber, Jürgen, Daan Wierstra, Matteo Gagliolo, and Faustino Gomez. 2007. "Training recurrent networks by evolino." *Neural computation* 19 (3): 757–779.

Schrum, Jacob, Igor Karpov, and Risto Miikkulainen. 2012. "Humanlike Combat Behavior via Multiobjective Neuroevolution." In *Believable Bots,* edited by P. Hingston. New York: Springer. http://nn.cs.utexas.edu/?schrum:believablebots11.

Schrum, Jacob, Igor V. Karpov, and Risto Miikkulainen. 2011. "UT2: Human-like Behavior via Neuroevolution of Combat Behavior and Replay of Human Traces." In *Proceedings of the IEEE Conference on Computational Intelligence and Games (CIG 2011),* 329–336. Seoul, South Korea: IEEE.

Schrum, Jacob, and Risto Miikkulainen. 2016. "Solving Multiple Isolated, Interleaved, and Blended Tasks through Modular Neuroevolution." *Evolutionary Computation* 24:459–490.

Schultz, Wolfram. 2024. "A dopamine mechanism for reward maximization." *Proceedings of the National Academy of Sciences* 121 (20): e2316658121.

Schuman, C. D., J. P. Mitchell, R. M. Patton, T. E. Potok, and J. S. Plank. 2020. "Evolutionary Optimization for Neuromorphic Systems." In *NICE: Neuro-Inspired Computational Elements Workshop.*

Schuman, Catherine, Robert Patton, Shruti Kulkarni, Maryam Parsa, Christopher Stahl, N Quentin Haas, J Parker Mitchell, et al. 2022. "Evolutionary vs. imitation learning for neuromorphic control at the edge*." *Neuromorphic Computing and Engineering* 2:014002.

Schuman, Catherine D., Thomas E. Potok, Robert M. Patton, J. Douglas Birdwell, Mark E. Dean, Garrett S. Rose, and James S. Plank. 2017. "A Survey of Neuromorphic Computing and Neural Networks in Hardware." *arXiv:1705.06963.*

Secretan, Jimmy, Nicholas Beato, David B D'Ambrosio, Adelein Rodriguez, Adam Campbell, Jeremiah T Folsom-Kovarik, and Kenneth O Stanley. 2011a. "Picbreeder: A case study in collaborative evolutionary exploration of design space." *Evolutionary computation* 19 (3): 373–403.

Secretan, Jimmy, Nicholas Beato, David B. D'Ambrosio, Adelein Rodriguez, Adam Campbell, J. T. Folsom-Kovarik, and Kenneth O. Stanley. 2011b. "Picbreeder: A Case Study in Collaborative Evolutionary Exploration of Design Space." *Evolutionary Computation* 19:345–371.

Sehnke, Frank, Christian Osendorfer, Thomas Rückstieß, Alex Graves, Jan Peters, and Jürgen Schmidhuber. 2010. "Parameter-exploring policy gradients." *Neural Networks* 23 (4): 551–559.

Shahrzad, Hormoz, Babak Hodjat, and Risto Miikkulainen. 2024. "EVOTER: Evolution of Transparent Explainable Rule-sets." *arXiv:2204.10438.*

Sharma, Shubham, Jette Henderson, and Joydeep Ghosh. 2020. "CERTIFAI: A Common Framework to Provide Explanations and Analyse the Fairness and Robustness of Black-Box Models." In *Proceedings of the AAAI/ACM Conference on AI, Ethics, and Society,* 166–172. New York, NY, USA: Association for Computing Machinery.

Shayani, H., P. J. Bentley, and Andy Tyrrell. 2008. "An FPGA-based Model suitable for Evolution and Development of Spiking Neural Networks." In *Proceedings of the European Symposium on Artificial Neural Networks,* 197–202.

Silva, F., P. Urbano, L. C. Correia, and A. Christensen. 2015. "odNEAT: An algorithm for decentralised online evolution of robotic controllers." *Evolutionary Computation* 23 (3): 421–449.

Silver, David, Thomas Hubert, Julian Schrittwieser, Ioannis Antonoglou, Matthew Lai, Arthur Guez, Marc Lanctot, et al. 2018. "A general reinforcement learning algorithm that masters chess, shogi, and Go through self-play." *Science* 362:1140–1144.

Simon, Herbert A. 1969. *The Sciences of the Artificial.* Cambridge, MA: MIT Press.

Simonyan, Karen, and Andrew Zisserman. 2014. "Very deep convolutional networks for large-scale image recognition." *arXiv preprint arXiv:1409.1556.*

Sims, Karl. 1991. "Artificial Evolution for Computer Graphics." In *Proceedings of the 18th Annual Conference on Computer Graphics and Interactive Techniques (SIGGRAPH '91),* 319–328.

Sims, Karl. 1994. "Evolving 3D Morphology and Behavior by Competition." In *Proceedings of the Fourth International Workshop on the Synth esis and Simulation of Living Systems (Artificial Life IV),* edited by Rodney A. Brooks and Pattie Maes, 28–39. Cambridge, MA: MIT Press.

Singleton, Jenny L., and Elissa L. Newport. 2004. "When learners surpass their models: The acquisition of American Sign Language from inconsistent input." *Cognitive Psychology* 49:370–407.

Sinha, Ankur, Pekka Malo, Peng Xu, and Kalyanmoy Deb. 2014. "A bilevel optimization approach to automated parameter tuning." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO 2014).* Vancouver, BC, Canada.

Sipper, Moshe, Jason H. Moore, and Ryan J. Urbanowicz. 2019. "Solution and Fitness Evolution (SAFE): Coevolving Solutions and Their Objective Functions." In *Genetic Programming,* edited by Lukas Sekanina, Ting Hu, Nuno Lourenço, Hendrik Richter, and Pablo García-Sánchez, 146–161. Cham: Springer International Publishing.

Sit, Yiu Fai, and Risto Miikkulainen. 2005. "Learning Basic Navigation for Personal Satellite Assistant Using Neuroevolution." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Smith, J. E., K. D. S. Lehmann, T. M. Montgomery, E. D. Strauss, and K. E. Holekamp. 2017. "Insights from long-term field studies of mammalian carnivores." *Journal of Mammalogy* 98:631–641.

So, David, Quoc Le, and Chen Liang. 2019. "The evolved transformer." In *International conference on machine learning,* 5877–5886. PMLR.

Sohl-Dickstein, Jascha, Eric Weiss, Niru Maheswaranathan, and Surya Ganguli. 2015. "Deep Unsupervised Learning using Nonequilibrium Thermodynamics." In *Proceedings of the 32nd International Conference on Machine Learning,* 37:2256–2265.

Solomon, M., T. Soule, and R. B. Heckendorn. 2012. "A comparison of a communication strategies in cooperative learning." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 153–160.

Soltoggio, Andrea, John A Bullinaria, Claudio Mattiussi, Peter Dürr, and Dario Floreano. 2008. "Evolutionary advantages of neuromodulated plasticity in dynamic, reward-based scenarios." In *Proceedings of the 11th international conference on artificial life (Alife XI),* 569–576. MIT Press.

Soltoggio, Andrea, Peter Durr, Claudio Mattiussi, and Dario Floreano. 2007. "Evolving neuromodulatory topologies for reinforcement learning-like problems." In *2007 IEEE Congress on Evolutionary Computation,* 2471–2478.

Soltoggio, Andrea, Kenneth O Stanley, and Sebastian Risi. 2018. "Born to learn: the inspiration, progress, and future of evolved plastic artificial neural networks." *Neural Networks* 108:48–67.

Song, Sen, Kenneth D. Miller, and L. F. Abbott. 2000. "Competitive Hebbian Learning Through Spike-Timing-Dependent Synaptic Plasticity." *Nature Neuroscience* 3:919–926.

Song, Xingyou, Wenbo Gao, Yuxiang Yang, Krzysztof Choromanski, Aldo Pacchiano, and Yunhao Tang. 2019. "Es-maml: Simple hessian-free meta learning." *arXiv preprint arXiv:1910.01215.*

Song, Xingyou, Yuxiang Yang, Krzysztof Choromanski, Ken Caluwaerts, Wenbo Gao, Chelsea Finn, and Jie Tan. 2020. "Rapidly adaptable legged robots via evolutionary meta-learning." In *2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS),* 3769–3776. IEEE.

Spector, L., and S. Luke. 1996. "Cultural transmission of information in genetic programming." In *Genetic Programming 1996,* edited by J. R. Koza, D. E. Goldberg, D. B. Fogel, and L. R. Riolo, 209–214. Cambridge, MA: MIT Press.

Sporns, Olaf, and Richard F. Betzel. 2016. "Modular Brain Networks." *Annual Reviews of Psychology* 67:613–640.

Srivastava, Nitish, Geoffrey Hinton, Alex Krizhevsky, Ilya Sutskever, and Ruslan Salakhutdinov. 2014. "Dropout: A Simple Way to Prevent Neural Networks from Overfitting." *Journal of Machine Learning Research* 15 (56): 1929–1958.

Srivastava, Rupesh Kumar, Klaus Greff, and Jürgen Schmidhuber. 2015. "Highway networks." *arXiv preprint arXiv:1505.00387.*

Stanley, Kenneth, Nate Kohl, Rini Sherony, and Risto Miikkulainen. 2005. "Neuroevolution of an Automobile Crash Warning System." In *Proceedings of the Genetic and Evolutionary Computation Conference.*

Stanley, Kenneth O. 2007. "Compositional pattern producing networks: A novel abstraction of development." *Genetic programming and evolvable machines* 8:131–162.

Stanley, Kenneth O, Jeff Clune, Joel Lehman, and Risto Miikkulainen. 2019a. "Designing neural networks through neuroevolution." *Nature Machine Intelligence* 1 (1): 24–35.

Stanley, Kenneth O, David B D'Ambrosio, and Jason Gauci. 2009. "A hypercube-based encoding for evolving large-scale neural networks." *Artificial life* 15 (2): 185–212.

Stanley, Kenneth O. 2003. "Efficient Evolution of Neural Networks Through Complexification." PhD diss., Department of Computer Sciences, The University of Texas at Austin.

Stanley, Kenneth O., Bobby D. Bryant, and Risto Miikkulainen. 2003. "Evolving Adaptive Neural Networks with and Without Adaptive Synapses." In *Proceedings of the 2003 Congress on Evolutionary Computation.* Piscataway, NJ: IEEE.

Stanley, Kenneth O., Bobby D. Bryant, and Risto Miikkulainen. 2005. "Real-Time Neuroevolution in the NERO Video Game." *IEEE Transactions on Evolutionary Computation* 9:653–668.

Stanley, Kenneth O., Jeff Clune, Joel Lehman, and Risto Miikkulainen. 2019b. "Designing Neural Networks through Evolutionary Algorithms." *Nature Machine Intelligence* 1:24–35. http : //nn.cs.utexas.edu/?stanley : naturemi19.

Stanley, Kenneth O., and Joel Lehman. 2015. *Why Greatness Cannot Be Planned: The Myth of the Objective.* New York: Springer.

Stanley, Kenneth O., and Risto Miikkulainen. 2002. "Evolving Neural Networks Through Augmenting Topologies." *Evolutionary Computation* 10:99–127.

Stanley, Kenneth O., and Risto Miikkulainen. 2003. "A Taxonomy for Artificial Embryogeny." *Artificial Life* 9:93–130.

Stanley, Kenneth O., and Risto Miikkulainen. 2004. "Competitive Coevolution through Evolutionary Complexification." *Journal of Artificial Intelligence Research* 21:63–100.

Steels, Luc L. 2016. "Agent-based models for the emergence and evolution of grammar." *Philosophical Transactions of the Royal Society B: Biological Sciences* 371:20150447.

Steuer, I., and P. A. Guertin. 2019. "Central pattern generators in the brainstem and spinal cord: an overview of basic principles, similarities and differences." *Reviews in the Neurosciences* 30:107–164.

Such, Felipe Petroski, Vashisht Madhavan, Edoardo Conti, Joel Lehman, Kenneth O. Stanley, and Jeff Clune. 2017. "Deep Neuroevolution: Genetic Algorithms Are a Competitive Alternative for Training Deep Neural Networks for Reinforcement Learning." *arXiv:1712.06567.*

Sudhakaran, Shyam, Djordje Grbic, Siyan Li, Adam Katona, Elias Najarro, Claire Glanois, and Sebastian Risi. 2021. "Growing 3d artefacts and functional machines with neural cellular automata." In *Artificial Life Conference Proceedings 33,* 2021:108. 1. MIT Press One Rogers Street, Cambridge, MA 02142-1209, USA journals-info …

Sun, Yanan, Bing Xue, Mengjie Zhang, and Gary G. Yen. 2020. "Evolving Deep Convolutional Neural Networks for Image Classification." *IEEE Transactions on Evolutionary Computation* 24:394–407. https://doi.org/10.1109/TEVC.2019.2916183.

Szathmáry, Eörs. 2015. "Toward major evolutionary transitions theory 2.0." *Proceedings of the National Academy of Sciences* 112 (33): 10104–10111.

Szegedy, Christian, Wei Liu, Yangqing Jia, Pierre Sermanet, Scott Reed, Dragomir Anguelov, Dumitru Erhan, Vincent Vanhoucke, and Andrew Rabinovich. 2015. "Going deeper with convolutions." In *2015 IEEE Conference on Computer Vision and Pattern Recognition (CVPR),* 1–9.

Szegedy, Christian, Vincent Vanhoucke, Sergey Ioffe, Jon Shlens, and Zbigniew Wojna. 2016. "Rethinking the Inception Architecture for Computer Vision." In *2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR),* 2818–2826.

Takagi, Hideyuki. 2001. "Interactive evolutionary computation: Fusion of the capabilities of EC optimization and human evaluation." *Proceedings of the IEEE* 89 (9): 1275–1296.

Tang, Yujin, Duong Nguyen, and David Ha. 2020. "Neuroevolution of self-interpretable agents." In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference,* 414–424.

Tang, Yujin, Jie Tan, and Tatsuya Harada. 2020. "Learning agile locomotion via adversarial training." In *2020 IEEE/RSJ International Conference On Intelligent Robots And Systems (IROS),* 6098–6105. IEEE.

Tang, Yujin, Yingtao Tian, and David Ha. 2022. "Evojax: Hardware-accelerated neuroevolution." In *Proceedings of the Genetic and Evolutionary Computation Conference Companion,* 308–311.

Tanneberg, Daniel, Elmar Rueckert, and Jan Peters. 2020. "Evolutionary training and abstraction yields algorithmic generalization of neural computers." *Nature machine intelligence* 2 (12): 753–763.

Tansey, Wesley, Eliana Feasley, and Risto Miikkulainen. 2012. "Accelerating Evolution via Egalitarian Social Learning." In *Proceedings of the 14th Annual Genetic and Evolutionary Computation Conference (GECCO 2012).*

Teyke, T., K. Weiss, and I. Kupfermann. 1990. "An identified neuron (CPR) evokes neuronal responses reflecting food arousal in Aplysia." *Science* 247:85–87.

Tonelli, Paul, and Jean-Baptiste Mouret. 2013. "On the relationships between generative encodings, regularity, and learning abilities when evolving plastic artificial neural networks." *PloS one* 8 (11): e79138.

Touvron, Hugo, Louis Martin, Kevin Stone, Peter Albert, Amjad Almahairi, Yasmine Babaei, Nikolay Bashlykov, Soumya Batra, Prajjwal Bhargava, Shruti Bhosale, et al. 2023. "Llama 2: Open foundation and fine-tuned chat models." *arXiv preprint arXiv:2307.09288.*

Towell, Geoffrey G., and Jude W. Shavlik. 1994. "Knowledge-Based Artificial Neural Networks." *Artificial Intelligence* 70:119–165.

Trianni, V., E. Tuci, C. Ampatzis, and M. Dorigo. 2014. "Evolutionary Swarm Robotics: A Theoretical and Methodological Itinerary from Individual Neuro-Controllers to Collective Behaviour." In *Evolutionary Swarm Robotics: A Theoretical and Methodological Itinerary from Individual Neuro-Controllers to Collective Behaviour,* edited by P. A. Vargas, E. Di Paolo, I. Harvey, and P. Husbands. Cambridge, MA: MIT Press.

Turing, Alan. 1952. "The chemical basis of morphogenesis." *Philosophical Transactions of the Royal Society B* 237:37–72.

Turney, Peter D. 2020. "Symbiosis Promotes Fitness Improvements in the Game of Life." *Artificial Life* 26 (3): 338–365.

Tutum, Cem C, Suhaib Abdulquddos, and Risto Miikkulainen. 2021. "Generalization of Agent Behavior through Explicit Representation of Context." In *Proceedings of the 3rd IEEE Conference on Games (COG-2021).*

Tyulmankov, Danil, Guangyu Robert Yang, and L F Abbott. 2022. "Meta-learning synaptic plasticity and memory addressing for continual familiarity detection." *Neuron* 110:544–557.e8.

Ulyanov, Dmitry, Andrea Vedaldi, and Victor Lempitsky. 2018. "Deep image prior." In *Proceedings of the IEEE conference on computer vision and pattern recognition,* 9446–9454.

Valsalam, V., J. Hiller, R. MacCurdy, H. Lipson, and R. Miikkulainen. 2013. "Constructing Controllers for Physical Multilegged Robots using the ENSO Neuroevolution Approach." *Evolutionary Intelligence* 14:303–331.

Valsalam, Vinod, and Risto Miikkulainen. 2011. "Evolving Symmetry for Modular System Design." *IEEE Transactions on Evolutionary Computation* 15:368–386.

Valsalam, Vinod K., James A. Bednar, and Risto Miikkulainen. 2005. "Constructing Good Learners Using Evolved Pattern Generators." In *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO-2005,* 11–18.

Valsalam, Vinod K., James A. Bednar, and Risto Miikkulainen. 2007. "Developing Complex Systems Using Evolved Pattern Generators." *IEEE Transactions on Evolutionary Computation* 11:181–198.

van Eck Conradie, Alex, Risto Miikkulainen, and C. Aldrich. 2002a. "Adaptive Control Utilising Neural Swarming." In *Proceedings of the Genetic and Evolutionary Computation Conference (GECCO-2002),* 60–67.

van Eck Conradie, Alex, Risto Miikkulainen, and C. Aldrich. 2002b. "Intelligent Process Control Utilizing Symbiotic Memetic Neuro-Evolution." In *Proceedings of the 2002 Congress on Evolutionary Computation,* 623–628.

Vargas, Patricia A., Ezequiel Di Paolo, Inman Harvey, and Phil Husbands, eds. 2014. *The horizons of evolutionary robotics.* Cambridge, MA: MIT Press.

Vassiliades, Vassilis, Konstantinos Chatzilygeroudis, and Jean-Baptiste Mouret. 2017. "Using centroidal voronoi tessellations to scale up the multidimensional archive of phenotypic elites algorithm." *IEEE Transactions on Evolutionary Computation* 22 (4): 623–630.

Vaswani, Ashish, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N Gomez, Łukasz Kaiser, and Illia Polosukhin. 2017. "Attention is All you Need." In *Advances in Neural Information Processing Systems,* edited by I. Guyon, U. Von Luxburg, S. Bengio, H. Wallach, R. Fergus, S. Vishwanathan, and R. Garnett, vol. 30. Curran Associates, Inc.

Velez, Roby, and Jeff Clune. 2017. "Diffusion-based neuromodulation can eliminate catastrophic forgetting in simple neural networks." *PloS one* 12 (11): e0187736.

Venkadesh, S., A. O. Komendantov, S. Listopad, E. O. Scott, K. De Jong, J. L. Krichmar, and G. A. Ascoli. 2018. "Evolving Simple Models of Diverse Intrinsic Dynamics in Hippocampal Neuron Types." *Frontiers of Neuroinformatics* 12 (8).

Venkatramanan, Srinivasan, Bryan Lewis, Jiangzhuo Chen, Dave Higdon, Anil Vullikanti, and Madhav Marathe. 2018. "Using data-driven agent-based models for forecasting emerging infectious diseases." *Epidemics* 22:43–49.

Verbancsics, Phillip, and Kenneth O Stanley. 2011. "Constraining connectivity to encourage modularity in HyperNEAT." In *Proceedings of the 13th annual conference on Genetic and evolutionary computation,* 1483–1490.

Versace, Elisabetta, Antone Martinho-Truswell, Alex Kacelnik, and Giorgio Vallortigara. 2018. "Priors in animal and artificial intelligence: where does learning begin?" *Trends in cognitive sciences* 22 (11): 963–965.

Vinyals, O., A. Toshev, S. Bengio, and D. Erhan. 2015. "Show and tell: A neural image caption generator." In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition,* 3156–3164.

Volz, Vanessa, Jacob Schrum, Jialin Liu, Simon M Lucas, Adam Smith, and Sebastian Risi. 2018. "Evolving Mario levels in the latent space of a deep convolutional generative adversarial network." In *Proceedings of the genetic and evolutionary computation conference,* 221–228.

Wagner, Andreas. 2005. *Robustness and evolvability in living systems.* Princeton, New Jersey: Princeton University Press.

Wagner, Kyle, James A. Reggia, Juan Uriagereka, and Gerald S. Wilkinson. 2003. "Progress in the Simulation of Emergent Communication and Language." *Adaptive Behavior* 11:37–69.

Wang, Jane X, Zeb Kurth-Nelson, Dhruva Tirumala, Hubert Soyer, Joel Z Leibo, Remi Munos, Charles Blundell, Dharshan Kumaran, and Matt Botvinick. 2016. "Learning to reinforcement learn." *arXiv preprint arXiv:1611.05763.*

Wang, Rui, Joel Lehman, Jeff Clune, and Kenneth O Stanley. 2019a. "Poet: open-ended coevolution of environments and their optimized solutions." In *Proceedings of the Genetic and Evolutionary Computation Conference,* 142–151.

Wang, Rui, Joel Lehman, Jeff Clune, and Kenneth O. Stanley. 2019b. "POET: open-ended coevolution of environments and their optimized solutions." In *Proceedings of the Genetic and Evolutionary Computation Conference, GECCO 2019, Prague, Czech Republic, July 13-17, 2019,* 142–151.

Wang, Rui, Joel Lehman, Aditya Rawal, Jiale Zhi, Yulun Li, Jeffrey Clune, and Kenneth Stanley. 2020. "Enhanced POET: Open-ended reinforcement learning through unbounded invention of learning challenges and their solutions." In *International Conference on Machine Learning,* 9940–9951. PMLR.

Wang, Yong. 2013. "Gene Regulatory Networks." In *Encyclopedia of Systems Biology,* edited by Werner Dubitzky, Olaf Wolkenhauer, Kwang-Hyun Cho, and Hiroki Yokota, 801–805. New York: Springer.

Warner, Jamieson, Ashwin Devaraj, and Risto Miikkulainen. 2024. "Using context to adapt to sensor drift." In *Proceedings of the International Conference on Development and Learning (ICDL 2024).*

Watson, R. A., N. Palmius, R. Mills, S. T. Powers, and A. Penn. 2011. "Can selfish symbioses effect higher-level selection?" In *Advances in Artificial Life,* 27–36. Berlin, Heidelberg: Springer.

Watson, R. A., and J. B. Pollack. 2003. "A computational model of symbiotic composition in evolutionary transitions." *Biosystems* 69:187–209.

Werner, Gregory M., and Michael G. Dyer. 1992. "Evolution of Communication in Artificial Organisms." In *Proceedings of the Workshop on Artificial Life (ALIFE'90),* edited by Christopher G. Langton, Charles Taylor, J. Doyne Farmer, and Steen Rasmussen, 659–687. Reading, MA: Addison-Wesley.

White, Colin, Mahmoud Safari, Rhea Sukthanker, Binxin Ru, Thomas Elsken, Arber Zela, Debadeepta Dey, and Frank Hutter. 2023. "Neural architecture search: Insights from 1000 papers." *arXiv preprint arXiv:2301.08727.*

Whiteson, Shimon. 2006. "Evolutionary function approximation for reinforcement learning." *Journal of Machine Learning Research* 7.

Whitley, Darrell, Stephen Dominic, and Rajarshi Das. 1991. "Genetic Reinforcement Learning with Multilayer Neural Networks." In *Proceedings of the Fourth International Conference on Genetic Algorithms,* 562–569. San Francisco: Kaufmann.

Whitley, Darrell, and Thomas Hanson. 1989. "Optimizing neural networks using faster, more accurate genetic search." In *Proceedings of the Third International Conference on Genetic Algorithms,* 391–396. San Francisco: Kaufmann.

Widrow, Bernard, Youngsik Kim, Dookun Park, and Jose Krause Perin. 2023. "Nature's Learning Rule: The Hebbian-LMS Algorithm." In *Artificial Intelligence in the Age of Neural Networks and Brain Computing (second edition),* edited by R. Kozma, C. Alippi, Y. Choe, and F. Morabito, 11–40. New York: Elsevier.

Wiegand, R. Paul. 2003. "An Analysis of Cooperative Coevolutionary Algorithms." PhD diss., George Mason University.

Wierstra, D., T. Schaul, J. Peters, and J. Schmidhuber. 2008. "Natural Evolution Strategies." In *2008 IEEE Congress on Evolutionary Computation (IEEE World Congress on Computational Intelligence).*

Williams, Ronald J. 1992a. "Simple statistical gradient-following algorithms for connectionist reinforcement learning." *Reinforcement learning,* 5–32.

Williams, Ronald J. 1992b. "Simple statistical gradient-following algorithms for connectionist reinforcement learning." *Machine Learning* 8:229–256.

Wissner-Gross, A. D., and C. E. Freer. 2013. "Causal Entropic Forces." *Physical Review Letters* 110 (16): 168702.

Wolpert, Lewis, Cheryll Tickle, and Alfonso Martinez Arias. 2015. *Principles of development.* Oxford University Press, USA.

Woolley, Brian G., and Kenneth O. Stanley. 2011. "On the Deleterious Effects of A Priori Objectives on Evolution and Representation." In *Proceedings of the 13th Annual Genetic and Evolutionary Computation Conference (GECCO 2011).* Dublin, Ireland.

Wu, Xingyu, Sheng-hao Wu, Jibin Wu, Liang Feng, and Kay Chen Tan. 2024. "Evolutionary computation in the era of large language model: Survey and roadmap." *arXiv preprint arXiv:2401.10034.*

Wulff, N., and J A Hertz. 1992. "Learning Cellular Automaton Dynamics with Neural Networks." In *Advances in Neural Information Processing Systems,* edited by S. Hanson, J. Cowan, and C. Giles, vol. 5. Morgan-Kaufmann. https://proceedings.neurips.cc/paper_files/paper/1992/file/d6c651ddcd97183b2e40bc464231c962-Paper.pdf.

Wurman, Peter R., Samuel Barrett, Kenta Kawamoto, James MacGlashan, Kaushik Subramanian, Thomas J. Walsh, Roberto Capobianco, et al. 2022. "Outracing Champion Gran Turismo Drivers with Deep Reinforcement Learning." *Nature* 62:223–228.

XKCD. 2021. *Types of Computer Vision Paper.* Https://twitter.com/jbhuang0604/status/1388577506253475849.

XPRIZE. 2023. *Pandemic Response Challenge.* Https://www.xprize.org/challenge/pandemicresponse, accessed 3/25/2023.

Yamauchi, Brian M., and Randall D. Beer. 1993. "Sequential Behavior and Learning in Evolved Dynamical Neural Networks." *Adaptive Behavior* 2:219–246.

Yao, Xin. 1999. "Evolving Artificial Neural Networks." *Proceedings of the IEEE* 87 (9): 1423–1447.

Ying, Chris, Aaron Klein, Eric Christiansen, Esteban Real, Kevin Murphy, and Frank Hutter. 2019. "NAS-Bench-101: Towards Reproducible Neural Architecture Search." In *Proceedings of the 36th International Conference on Machine Learning,* 97:7105–7114.

Yong, Chern Han, and Risto Miikkulainen. 2010. "Coevolution of Role-Based Cooperation in Multi-Agent Systems." *IEEE Transactions on Autonomous Mental Development* 1:170–186.

Yong, Chern Han, Kenneth O. Stanley, Risto Miikkulainen, and Igor Karpov. 2006. "Incorporating Advice into Neuroevolution of Adaptive Agents." In *Proceedings of the Second Artificial Intelligence and Interactive Digital Entertainment Conference,* 98–104. Menlo Park, CA: AAAI Press.

Zador, Anthony M. 2019. "A critique of pure learning and what artificial neural networks can learn from animal brains." *Nature communications* 10 (1): 3770.

Zela, Arber, Julien Niklas Siems, Lucas Zimmer, Jovita Lukasik, Margret Keuper, and Frank Hutter. 2022. "Surrogate NAS Benchmarks: Going Beyond the Limited Search Spaces of Tabular NAS Benchmarks." In *International Conference on Learning Representations (ICLR 2022).*

Zhang, Q., and H. Li. 2007. "MOEA/D: a multiobjective evolutionary algorithm based on decomposition." *IEEE Transactions on Evolutionary Computation* 11:712–731.

Zoph, Barret, and Quoc Le. 2017. "Neural Architecture Search with Reinforcement Learning." In *International Conference on Learning Representations.* https://openreview.net/forum?id=r1Ue8Hcxg.

Zoph, Barret, Vijay Vasudevan, Jonathon Shlens, and Quoc V Le. 2018. "Learning transferable architectures for scalable image recognition." In *Proceedings of the IEEE conference on computer vision and pattern recognition,* 8697–8710.

Zuidema, Willem, and Paulien Hogeweg. 2000. "Social patterns guide evolving grammars." In *Proceedings of the Evolution of Language Conference.*

Index