

# Stephanie Forrest

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## EDUCATION

Ph.D. Computer and Communication Sciences, The University of Michigan, Ann Arbor, MI, 1985.

M.S. Computer and Communication Sciences, The University of Michigan, Ann Arbor, MI, 1982.

B.A. St. John's College, Annapolis, MD and Santa Fe, NM, 1977.

## RESEARCH INTERESTS

Biology and computation, including computational immunology, genetic algorithms, computational modeling of biological systems, automated software repair, and biologically inspired approaches to computer security.

## EMPLOYMENT

1990–present. Department of Computer Science, The University of New Mexico, Albuquerque, NM. Department Chairman, 2006–2011; Professor, 1999–present; Associate Professor, 1994–1999; Assistant Professor, 1990–1994. Secondary appointment in Dept. of Biology, 2001–present.

2003–2006. Santa Fe Institute, Santa Fe, NM. Research Professor (part-time sabbatical leave).

1999–2000. Santa Fe Institute, Santa Fe, NM. Interim Vice President for Academic Affairs.

1996–1997. Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA. Visiting Associate Professor (sabbatical leave).

1988–1990. Center for Nonlinear Studies and Computing Division, Los Alamos National Laboratory, Los Alamos, NM. Director's Postdoctoral Research Fellow.

1985–1988. Teknowledge, Inc., Palo Alto, CA. Scientist and Senior Scientist, Research and Advanced Development. Project leader responsible for projects in real-time knowledge-based systems and parallel/distributed software architectures for symbolic computing.

## SELECTED PROFESSIONAL ACTIVITIES

Santa Fe Institute, Santa Fe, NM. Science Board Co-Chair (2010 - present), Science Board Member 1991–1997, 1998–2001, 2003–2008, 2009–present; SSC Steering Committee, 1993–1999; External Faculty, 1990–2003; Resident Faculty, 2003–2006.

Editing: Journal of Machine Learning Research (Action Editor, 2005–2010); Evolutionary Intelligence (Editorial Board, 2007-present); Evolutionary Computation (Associate Editor, 1995–2002; Action Editor, 1994-95); Journal of Artificial Intelligence Research (Editorial Board, 1998–2002); Journal of Experimental and Theoretical Artificial Intelligence (Editorial Board, 1989–1996); Artificial Life (Editorial Board, 1994–present).

Program Chair: Ninth Annual CNLS Conference, Emergent Computation (1989), Fifth International Conference on Genetic Algorithms (1993), Workshop on “Forging an effective immune response” held at Institute for Mathematics and its Applications, Univ. of Minnesota (1998) (Co-chair with one other), Festschrift in honor of John Holland (1999) (Co-organizer with three others), SFI Workshop on Software Evolvability (2005) (Co-chair with two others).

Program Committees: ACM Conference on Computer and Communications Security (2005), New Security Paradigms Workshop (2008), Hot Topics in Operating Systems (2005), International Conference on Artificial Immune Systems (2002,2003, 2004, 2005, 2006, 2007, 2008, 2011), International Conference on Genetic Algorithms (1991, 1993, 1995, 1997, 1999), Genetic and Evolutionary Computation Conference (2000, 2001, 2004, 2011) Workshop on Foundations of Genetic Algorithms (1992, 1994), Second European Conference on Artificial Life (1993), International Conference on Intelligent Systems for Molecular Biology (1994), Parallel Problem Solving from Nature (1994), IEEE Conference on Evolutionary Computation (1995), International Joint Conference on Artificial Intelligence (1995). Scientific Advisory Board for the ALife 7 Conference (2000, 2001).

Computing Community Consortium (CCC) Council (2009-2012). NSF GENI/NetSE Council (2007-2009). NSF Advisory Committee for the Directorate for Computer and Information Science and Engineering (2006-2008).

DIMACS Advisory Committee for special focus on epidemiology 2001-2004. Co-organizer of DIMACS working group on “analogies between computer viruses and immune systems and biological viruses and immune systems.”

DARPA Information Science and Technology (ISAT) advisory group (2001-2004). Conducts studies on emerging technologies of interest to the Defense Department and advises DARPA on promising directions for new research programs.

Senior Member, IEEE.

## **HONORS AND AWARDS**

University of New Mexico Research Lectureship (2012).

Association for Computing Machinery/AAAI Allen Newell Award. For innovations in computing technology that have made significant contributions enabling computer science to solve real-world challenges (2012)

New Mexico Council on Technology, Women in Technology Award (2009).

ACM SIGEVO GECCO Impact Award for highest impact paper published in the 1999 Genetic and Evolutionary Computation Conference (awarded in 2009 and shared with one other paper).

“Humies” \$5000 Gold Medal Award for human-competitive results produced by genetic and evolutionary computation (2009), shared with 3 others..

IFIP TC2 Manfred Paul Award for Excellence in Software: Theory and Practice (2009), shared with 3 others.

Senior Fellow of the International Society for Genetic and Evolutionary Computation (2003).

St. John’s College Alumni Award of Merit, 2002.

UNM General Library Faculty Acknowledgment Award, 1999. UNM Regents Lecturer, 1994-97, UNM College of Engineering Outstanding Research Award (Junior Faculty award, 1993; Senior Faculty award, 2000).

NSF Presidential Young Investigator Award, 1991-96.

Association of Western Universities Faculty Fellowship, 1991.

GE Foundation Young Faculty Award, 1990.

## FUNDED RESEARCH (since 1990)

- Defense Advanced Research Projects Agency (\$3,200,625) “Scalable RADAR for Co-evolutionary Adversarial Environments” S. Forrest (PI), J. Crandall, M. Moses, W. Weimer (Co-PIs). 2010-2014.
- National Science Foundation (UNM share \$ 500,000) “Collaborative Research: Search, Signals and Information Exchange in Distributed Biological Systems.” M. Moses (PI); S. Forrest, D. Gordon (Co-PIs). 2010-2013.
- Air Force Office of Scientific Research DURIP-10-054 (\$58,189) “Helix Project Testbed: Towards the Self-Regenerative Incorruptible Enterprise.” 2010.
- Department of Energy (UNM share \$600,000) ”ASIM: An integrated agent-based model of a complex network” S. Hofmeyr (PI), S. Forrest (Co-PI). 2009-2012.
- National Science Foundation (\$ 600,000) “Fixing real bugs in real programs using evolutionary algorithms.” W. Weimer (PI), S. Forrest (Co-PI). 2009-2012.
- National Science Foundation (\$69,930) “Safe Computing Workshop: Introspective Hardware Architectures for Information Assurance.” S. Forrest (PI). 2007-2008.
- Air Force Office of Scientific Research (UNM Share \$750,000) “Helix: A Self-Regenerative Architecture for the Incorruptible Enterprise.” J. C. Knight (PI), J. Davidson, D. Evans, W. Weimer, A. Nguyen-Tuong, H. Chen, K. Levitt, J. Rowe, Z. Su, F. Wu, F. Chong, S. Forrest, J. Saia (Co-PI). 2007-2012.
- National Institutes of Health (UNM Share \$144,046) “Modeling Early Influenza Virus Replication in Primary Human Lung Cells.” F. Koster (PI), S. Forrest (Co-PI). 2007-2009.
- National Science Foundation (\$230,921) “Collaborative Research: A Biologically Motivated Scaling Theory for Computing” S. Forrest (PI), J. Brown, A. Davis (Co-PIs). 2006-2009.
- Howard Hughes Medical Institute (\$1,000,000) “Program in Interdisciplinary Biomedical Science (PIBS)” J. Brown (PI), S. Forrest, N. Kenkre and F. Smith (Co-PIs). 2006-2011.
- Motorola (\$150,000) “Biological design for computer security.” 2005-2008.
- SFI International Program (\$17,500) “Instruction set diversification” G. Barrantes, J. Vargas, and S. Forrest. Project activities located at Universidad de Costa Rica. 2005-2006.
- UNM/LANL Joint Science and Technology Laboratory (\$131,750) “Realistic modeling of the immune response in tissue” S. Forrest and A. S. Perelson. 2005-2007.
- National Institutes of Health (\$10,141,000) “COBRE Center for Evolutionary and Theoretical Immunology” 2003-2008. E. S. Loker (PI), S. Forrest, R. D. Miller, A. S. Perelson (Co-PIs). CS share: \$2,123,085.
- National Science Foundation CCR Large ITR Grant (\$12,500,000) “Sensitive Information in a Wired World” 2003-2008. D. Boneh (PI), J. Feigenbaum, S. Forrest, H. Garcia-Molina, R. Kanan, H. Nissenbaum, A. Silberschatz, R. Wright (Co-PIs). UNM share: \$625,000.

National Science Foundation SGER (\$100,000) “Reconstructing Information from Database Fragments Via Negative Partial Match Detection” 2003-2004. S. Forrest (PI), P. Helman (Co-PI).

National Science Foundation (\$1,200,000) “Collaborative Grant: Automated and Adaptive Diversity for Improving Computer Systems Security” 2003-2007. D. Song (PI), M. Reiter, S. Forrest (Co-PIs). Unm Share: \$250,000.

Defense Advanced Research Projects Agency (\$280,000) “Automated Diversity in Computer Systems UNM Component” 2002-2003. Seedling project.

NIH P20 Center for the Spatiotemporal Modeling of Cell Signaling (\$988,815). Planning grant. J. Oliver (PI), S. Steinberg, S. Forrest, and G. Heffelfinger (Co-PIs). 2002-2005.

Intel Corp. (\$154,000) “Information Immune Systems.” 2001-03.

National Science Foundation (\$871,478). Understanding and surviving computation in the wild. S. Forrest (PI), D. Ackley (Co-PI) 2000-2005.

Defense Advanced Research Projects Agency. (\$1,100,000). Computation in the Wild: Moving Beyond the Metaphor. S. Forrest (PI), D. Ackley (Co-PI). 2000-2005.

Office of Naval Research (\$18,600). Dynamics Days Conference. Co-PI with David Egolf. 2000.

National Science Foundation (\$ 321,622). Pilot Program for NSF Physics Graduate Student Fellowships at the Santa Fe Institute. E. Jen (PI), D. Campbell, J. Crutchfield, and S. Forrest (Co-PIs). 1999-2002.

Department of Energy (\$ 606,000). A Broad Program in the Sciences of Complexity. Co-PI with Ellen Goldberg, Erica Jen, and Marc Feldman. 2001-2003.

Office of Naval Research (\$420,072). Emergent Computation. 1999-2003.

Intel Corporation (\$252,000) Information Immune Systems, 2001-2004; Biologically Inspired Approaches to Computer Security (\$169,398), 1998-2000.

National Science Foundation (\$292,350). Computer Immunology. 1997-2000.

IBM Partnership Award (\$20,000). 1998.

Defense Advanced Research Projects Agency (\$755,728). Research on a Simple Definition of Normal Behavior for Unix Processes. 1996-98.

NSF Research Training Grant (\$562,500). A BIO Research Training Group in Ecological Complexity, 1995-2000. CO-PI with five others.

Office of Naval Research N00014-95-1-0364 (\$400,000). Research in Computational Immunology, 1995-98.

NSF Presidential Young Investigator Award IRI-9157644 (\$500,000). Computational Aspects of the Immune System, 1991-96.

Sandia National Laboratories AN-4184 (\$26,039). Genetic programming for automatic learning and image classification. Graduate student support, 1995-96.

Santa Fe Institute (\$131,208). Graduate student support, 1991-95. Project 2050 (\$34,970), 1992-4.

Alfred P. Sloan Foundation (\$30,000). Foundations of Genetic Algorithms (administered through Santa Fe Institute). Principal Investigator with Melanie Mitchell, 1992-94.

Sandia University Research Program (SURP) grant AE-1679 (\$60,000). Inappropriate Convergence in Genetic Algorithms, 1991-93.

Association of Western Universities (AWU) Faculty Fellowship (\$10,000), 1991.

Los Alamos National Laboratory (CNLS) Contract (\$20,382). Genetic Algorithms and Classifier Systems. Release time, 1990-91.

University of California Institutional Collaborative Research (INCOR) grants (\$42,000), 1989-93.

## Ph.D. STUDENTS GRADUATED

- Terry Jones (1995) “Evolutionary algorithms, fitness landscapes and search.” Fluidinfo Ltd.
- Ron Hightower (1996) “Computational aspects of antibody gene families.” Self-employed.
- Derek Smith (1997) “The cross-reactive immune response.” (Nominated for ACM Best Dissertation award). Prof. of Zoology, Cambridge Univ. UK.
- Mihaela Oprea Zavalon (1999) “Optimizing the antibody repertoire for pathogen recognition.” Prof. of Bioinformatics, Univ. of Basel, Switzerland.
- Steven Hofmeyr (1999) “An immunological model of distributed detection and its application to network security.” Lawrence Berkeley Laboratory.
- Wim Hordijk (1999) “Dynamics, emergent computation, and evolution in cellular automata.” Self-employed.
- Patrik D’haeseleer (2000) “Reconstructing gene networks from large scale gene expression data.” Lawrence Livermore National Laboratory
- Anil Somayaji (2002) “Operating system stability and security through process homeostasis.” Assoc. Prof. of Computer Science, Carleton University, Ottawa.
- Dennis L. Chao (2004) “Modeling the cytotoxic T cell response.” Fred Hutchinson Cancer Research Center.
- Christina Warrender (2004) “ Modeling intercellular interactions in the peripheral immune system.” Sandia National Laboratory.
- Gabriela Barrantes (2005) “Automated methods for creating diversity in computer systems.” Prof. and Chair of Computer Science, Universidad de Costa Rica.
- Hajime Inoue (2005) “Anomaly detection in dynamic execution environments.” Principle Scientist, Architecture Technology Corporation.
- Fernando Esponda (2006) “Protecting Data Privacy through Hard-to-Reverse Negative Databases” Assoc. Prof. Instituto Tecnologico Autonomo de Mexico.
- Robert Abbott (2007) “Automated tactics modeling: Techniques and Applications” Principal Member of the Technical Staff, Sandia National Laboratory.
- Todd Kaplan (2008) “Detecting community structure in financial markets” Plektos.
- Eric Trias (2008) “Leveraging positive and negative representations of information” U.S.A.F.
- Josh Karlin (2009) “Distributed Internet security and measurement.” Google.
- George Bezerra (2012) “Energy Consumption in Networks on Chip: Efficiency and Scaling” MIT.
- Michael Groat (2012) “Energy Conserving Privacy Enhancing Algorithms in Resource-Constrained Devices”

## **POST-DOCTORAL SUPERVISION**

Dipankar Dasgupta (Univ. of Memphis, TN), Andrew Kosoresow (deceased), Derek Smith (Cambridge Univ. UK), Carlo Maley (UCSF), Steven Hofmeyr (LBL), Matt Glickman (Sandia National Labs.), Catherine Beauchemin (Ryerson Univ. CAN), Petter Holme (Royal Institute of Technology, Stockholm), Melanie Moses (Univ. of New Mexico), Hugh Mitchell (Pacific Northwest National Lab.), Terri Oda (current).



## PUBLICATIONS AND PATENTS (Reverse chronological order)

### PATENTS

- L. Allen, S. Forrest, and A. S. Perelson “A method of detecting changes to a collection of digital signals.” U.S. patent 5448668 (Sept. 5, 1995).

### BOOKS AND CONFERENCE PROCEEDINGS

- L. Booker, S. Forrest, M. Mitchell, and R. Riolo (Ed.) *Perspectives on Adaptation in Natural and Artificial Systems*, Oxford University Press (2005).
- S. Forrest (Ed.) *Proceedings of the Fifth International Conference on Genetic Algorithms*. Morgan Kaufmann, Los Altos, CA (1993).
- S. Forrest *Parallelism in Classifier Systems*. In monograph series “Research Notes in Artificial Intelligence.” Pitman Publishing, London and Morgan Kaufmann, Los Altos, CA (1991). Revised version of Ph.D. thesis.
- S. Forrest (Ed.) *Emergent Computation*. MIT Press, Cambridge, MA (1991). Also published as *Physica D* special issue Vol. 42, Nos. 1-3 (1990).

### CHAPTERS OF BOOKS

- C. Le Goues, A. Nguyen-Tuong, H. Chen, J. W. Davidson, S. Forrest, J. D. Hiser, J. C. Knight and M. Van Gundy. “Moving Target Defenses in the Helix Self-Regenerative Architecture.” In S. Jajodia, A. K. Ghosh, V. S. Subrahmanian, V. Swarup, C. Wang, and X. S. Wang Eds. *Moving Target Defense II: Application of Game Theory and Adversarial Modeling*. pp. 115–146 (2012).
- M. Moses and S. Forrest “Beyond Biology,” in *Metabolic Ecology: A Scaling Approach*, Wiley-Blackwell (2012).
- K. Ingham and S. Forrest “Network firewalls.” In V. Rao Vemuri and V. Sreeharirao Eds. *Enhancing Computer security with Smart Technology*, pp. 9-35. CRC Press (2005).
- S. Forrest, J. Balthrop, M. Glickman, and D. Ackley “Computation in the Wild.” E. Jen Ed. *Robust Design: A Repertoire of Biological, Ecological, and Engineering Case Studies*, pp. 207-230. Oxford University Press (2004). Reprinted in K. Park and W. Willinger Eds. *The Internet as a Large-Scale Complex System*, pp. 227-250. Oxford University Press (2005).
- D. J. Smith, A. S. Lapedes, S. Forrest, J. C. deJong, A. D. M. E. Osterhaus, R. A. M. Fouchier, N. J. Cox, and A. S. Perelson, “Modeling the effects of updating the influenza vaccine on the efficacy of repeated vaccination.” In *Options for the control of influenza virus IV*, eds. A.D.M.E. Osterhaus, N. Cox, and A. Hampson, Excerpta Medica, International Congress Series 1219, Amsterdam, 655-660 (2001).

- S. Forrest and S. A. Hofmeyr, Immunology as information processing. In *Design Principles for the Immune System and Other Distributed Autonomous Systems*, edited by L. A. Segel and I. Cohen. Santa Fe Institute Studies in the Sciences of Complexity. New York: Oxford University Press (2001).
- J.H. Holland, L.B. Booker, M. Colombetti, M. Dorigo, S. Forrest, D.G. Goldberg, R.L. Riolo, R.E. Smith, P.L. Lanzi, W. Stolzmann, and S.W. Wilson “What is a Learning Classifier System?” In P.L. Lanzi, W. Stolzmann, S.W. Wilson Eds. *Learning Classifier Systems: An Introduction to Contemporary Research* Springer Verlag, pp. 3–32 (2000).
- D. J. Smith, S. Forrest, D. H. Ackley, and A. S. Perelson “Modeling the effects of prior infection on vaccine efficacy.” In D. Dasgupta (Ed.) *Artificial Immune Systems and Their Applications*, Springer-Verlag, Berlin Germany (1998).
- D. J. Smith, S. Forrest, and A. S. Perelson “Immunological memory is associative.” In D. Dasgupta (Ed.) *Artificial Immune Systems and Their Applications*, Springer-Verlag, Berlin Germany (1998).
- S. Forrest “Genetic algorithms.” In A. B. Tucker (Ed.) *CRC Handbook of Computer Science and Engineering*, CRC Press, Boca Raton, FL (1996).
- M. Mitchell and S. Forrest “Fitness Landscapes: Royal Road Functions.” In Back, Fogel, and Michalewicz (Eds.) *Handbook of Evolutionary Computation*. Institute of Physics Publishing, Philadelphia and Bristol UK, B2.7:1-25 (1997).
- R. Hightower, S. Forrest and A. S. Perelson “The Baldwin effect in the immune system: learning by somatic hypermutation.” In R. K. Belew and M. Mitchell (Eds.) *Adaptive Individuals in Evolving Populations*, Addison-Wesley, Reading, MA, pp. 159-167 (1996).
- C. Burks, M.L. Engle, S. Forrest, R.J. Parsons, C.A. Soderlund, and P.E. Stolorz “Stochastic optimization tools for genomic sequence assembly.” In J.C. Venter (Ed.) *Automated DNA Sequencing and Analysis Techniques* Academic Press, London (1993).
- S. Forrest and G. Mayer-Kress “Genetic algorithms, nonlinear dynamical systems, and global Stability Models.” In L. Davis (ed.) *The Handbook of Genetic Algorithms*. Van Nostrand Reinhold, New York (1991).
- S. Forrest “Knowledge-based approaches for real-time process management.” In M.G. Singh (Ed.) *Systems and Control Encyclopedia, First Supplement*. Pergamon Books, Oxford (1990).

## REFEREED JOURNAL PUBLICATIONS

- E. Schulte, Z. P. Fry, E. Fast, W. Weimer, S. Forrest “Software mutational robustness” *Genetic Programming and Evolvable Machines* (submitted Nov. 2012).
- D. Levin, S. Forrest, S. Banerjee, C. Clay, M. Mitchell, and F. Koster “Spatially explicit model of the lymphocyte diaspora in influenza-infected lung quantifies constraints of chemokine directed migration.” *PLoS Computational Biology* (submitted Sept. 2012).

- M. Groat, B. Edwards, J. Horey, W. He, S. Forrest “Enhancing privacy in participatory sensing applications with multidimensional data” *Pervasive and Mobile Computing* (in revision).
- F. Esponda, E. Trias, E. Ackley, S. Forrest “Operations over negative databases: A relational algebra” *Natural Computing* (in press).
- C. Le Goues, T. Nguyen, S. Forrest, W. Weimer “GenProg: Automatic Bug Correction in Real Programs.” *ACM Transactions on Software Engineering* 38:1 pp. (2012).
- H. Mitchell, D. Levin, S. Forrest, C. Beauchemin, J. Tipper, J. Knight, N. Donart, C. Layton, J. Pyles, P. Gao, K. Harrod, A. Perelson, and F. Koster “Higher replication efficiency of 2009 (H1N1) pandemic influenza than seasonal and avian strains: Kinetics from epithelial cell culture and computational modeling.” *J. Virology* 85:2 pp. 11251135 (2011). doi:10.1128/JVI.01722-10.
- W. Weimer, S. Forrest, C. Le Goues, T. Nguyen “Automatic program repair with evolutionary computation.” *Communications of the ACM Research Highlight* 53:5 pp. 109-116 (2010).
- F. Esponda, S. Forrest, and P. Helman “Negative representations of information.” *International Journal of Information Security* 8:5 pp. 331 (2009). doi:10.1007/s10207-009-0078-1.
- J. Karlin, J. Rexford, and S. Forrest “Autonomous security for autonomous systems” *Computer Networks* 52:29082923 (2008).
- P. Holme, J. Karlin, and S. Forrest “An integrated model of traffic, geography and economy in the Internet.” *ACM SIGCOMM Computer Communication Review* 38:3, pp. 7-15 (2008).
- M. Moses, S. Forrest, A. L. Davis, M. Lodder, and J. H. Brown “Scaling theory for information networks.” *Journal of the Royal Society Interface* 5:29, pp. 1391-1510 (2008).
- F. Esponda, E. S. Ackley, P. Helman, H. Jia, and S. Forrest “Protecting Data Privacy through Hard-to-Reverse Negative Databases.” *Int. Journal of Information Security* 6:6 (2007).
- S. Forrest and C. Beauchemin “Computer Immunology.” *Immunological Reviews* 216:176-197 (2007).
- P. Holme, J. Karlin, and S. Forrest “Radial structure of the Internet.” *Proc. Royal Society A* 463:1231-1246 (2007).
- K. Ingham, A. Somayaji, S. Forrest, and J. Burge “Learning DFA representations of HTTP for protecting web applications.” *Journal of Computer Networks* 51:5, pp. 1239-1255 (2007).
- R. Gerety, S. Spencer, K. Pienta, and S. Forrest “Modeling somatic evolution in tumorigenesis.” *PLoS Computational Biology* 2:8 e108 (2006).
- R. G. Abbott, S. Forrest, and K. J. Pienta “Simulating the hallmarks of cancer.” *Journal of Artificial Life* Vol. 12, No. 4: 617-634 (2006).
- H. Inoue, D. Stefanovic, and S. Forrest. “On the prediction of Java object lifetimes.” *IEEE Transactions on Computers* 55:7, pp. 880- 892 (2006).
- C. Warrender, S. Forrest, and F. Koster “Modeling intercellular interactions in early Mycobacterium infection.” *Bulletin of Mathematical Biology* 66:6, pp. 1493 - 1514 (2006).

- D. L. Chao, M. P. Davenport, S. Forrest, A. S. Perelson “The effects of thymic selection on the range of T cell cross-reactivity” *European Journal of Immunology* 35:3452-3459 (2005).
- G. Barrantes, D. Ackley, S. Forrest, and D. Stefanovic “Randomized instruction set emulation” *ACM Transactions on Information Systems Security (TISSEC)* 8:1, pp. 3-40 (2005).
- M. Glickman, J. Balthrop, and S. Forrest. “A machine learning evaluation of an artificial immune system.” *Evolutionary Computation Journal* Vol. 13:2, pp. 179-212 (2005).
- F. Esponda, E. S. Ackley, S. Forrest, and P. Helman “On-line negative databases.” *Journal of Unconventional Computing* 1:3, pp. 201-220 (2005).
- C. Warrender, S. Forrest, and L. Segel. “Homeostasis of peripheral immune effectors.” *Bulletin of Mathematical Biology* 66:6, pp. 1493-1514 (2004).
- D. L. Chao, M. P. Davenport, S. Forrest, and A. S. Perelson. “A stochastic model of cytotoxic T cell responses.” *Journal of Theoretical Biology* Vol. 228:227-240 (2004).
- D. L. Chao, M. P. Davenport, S. Forrest, and A. S. Perelson “Modeling the impact of antigen kinetics on T cell activation and response.” *Immunology and Cell Biology* 82:1 (2004).
- J. Balthrop, S. Forrest, M. Newman, and M. Williamson. “Technological networks and the spread of computer viruses.” *Science* 304:527-529 (2004).
- C. C. Maley, B. J. Reid, and S. Forrest. “Cancer prevention strategies that address the evolutionary dynamics of neoplastic cells: Simulating benign cell boosters and selection for chemosensitivity.” *Cancer Epidemiology, Biomarkers and Prevention* 13(8):1375-84 (2004).
- F. Esponda, S. Forrest, and P. Helman. “A formal framework for positive and negative detection.” *IEEE Transactions on Systems, Man, and Cybernetics* 34:1 pp. 357-373 (2004).
- D. L. Chao and S. Forrest. “Information immune systems.” *Genetic Programming and Evolvable Machines* Vol 4:4, pp. 311-331 (2003).
- M. Newman, S. Forrest, and J. Balthrop. “Email networks and the spread of computer viruses.” *Physical Review E* 66, 035101 (2002).
- M. Moses and S. Forrest. Book review of *The Computational Beauty of Nature* by G. Flake. *Artificial Intelligence* 128:239-242 (2001).
- S. Forrest and S. Hofmeyr, “Engineering an immune system.” *Graft* Vol. 4:5 pp. 5-9 (2001).
- C. C. Maley and S. Forrest. Exploring the relationship between neutral and selective mutations in cancer. *Artificial Life* 6: 325-345 (2000).
- S. Hofmeyr and S. Forrest. “Architecture for an artificial immune system.” *Evolutionary Computation Journal* Vol. 8:4 pp. 443-473 (2000).
- D. J. Smith, S. Forrest, D. H. Ackley, and A. S. Perelson “Variable efficacy of repeated annual influenza vaccination.” *Proceedings of the National Academy of Sciences* 96:14001-14006 (1999).

- D. J. Smith, S. Forrest, D. H. Ackley, and A. S. Perelson "Using lazy evaluation to simulate realistic-size repertoires in models of the immune system." *Bulletin of Mathematical Biology* Vol. 60, pp. 647-658 (1998).
- S. Hofmeyr, S. Forrest, and A. Somayaji "Intrusion detection using sequences of system calls." *Journal of Computer Security* Vol. 6, pp. 151-180 (1998).
- D. J. Smith, S. Forrest, R. R. Hightower, and A. S. Perelson "Deriving shape-space parameters from immunological data for a model of cross-reactive memory." *Journal of Theoretical Biology* Vol. 189: 141-150 (1997).
- S. Forrest, S. Hofmeyr, and A. Somayaji "Computer immunology" *Communications of the ACM* Vol. 40, No. 10, pp. 88-96 (1997).
- P. Hraber, T. Jones, and S. Forrest "The ecology of Echo." *Artificial Life* Vol. 3, No. 3, pp. 165-190 (1997).
- A. Perelson, R. Hightower, and S. Forrest "Evolution (and learning) of v-region genes." *Research in Immunology* Vol. 147, pp. 202-208 (1996).
- S. Forrest "Genetic Algorithms." *ACM Computing Surveys* Vol. 28:1, pp. 77-80 (1996).
- R. Parsons, S. Forrest, and C. Burks "Genetic operators for the DNA fragment assembly problem" *Machine Learning* Vol. 21:1/2, pp. 11-33 (1995).
- M. Mitchell and S. Forrest "Genetic algorithms and artificial life." *Artificial Life* 1:3, pp. 267-289 (1994). Reprinted in C. G. Langton (Ed.) *Artificial Life: An Overview*, MIT Press, Cambridge, MA (1995).
- S. Forrest "Genetic algorithms: principles of natural selection applied to computation." *Science* Vol. 261, pp. 872-878 (Aug. 13, 1993).
- S. Forrest, B. Javornik, R. E. Smith and A. S. Perelson "Using genetic algorithms to explore pattern recognition in the immune system." *Evolutionary Computation* 1:3, pp. 191-211 (1993).
- R. E. Smith, S. Forrest, and A. S. Perelson "Searching for diverse, cooperative populations with genetic algorithms." *Evolutionary Computation* 1:2, pp. 127-149 (1993).
- S. Forrest and M. Mitchell "What makes a problem hard for a genetic algorithm? Some anomalous results and their explanation." *Machine Learning* 13:2/3, pp. 129-163 (1993).
- S. Forrest "Introduction to the Proceedings of the Ninth Annual CNLS Conference." *Physica D* Vol. 42:1-3, pp. 1-11 (1990).
- S. Forrest and J. H. Miller "Emergent behaviors of classifier systems." *Physica D* Vol. 42:1-3, pp. 213-227 (1990).
- J. Lark, L. Erman, S. Forrest, K. Gostelow, F. Hayes-Roth, J. Lark, and D. Smith "Concepts, methods, and languages for building timely intelligent systems." *Real-time Systems* 2:1 (1990).
- R. Belew and S. Forrest "Learning and programming in classifier systems." *Machine Learning* 3: 193-223 (1988).

- B. D'Ambrosio, M. Fehling, S. Forrest, P. Raulefs, and M. Wilber "Real-time process management for materials composition in chemical manufacturing." *IEEE Expert* pp. 80-93 (Summer, 1987).

## REFEREED CONFERENCE PUBLICATIONS

- E. Schulte, J. DiLorenzo, W. Weimer, S. Forrest "Automated repair of binary and assembly programs for cooperating embedded devices." Eighteenth International Conference on Architectural Support for Programming Languages and Operating (ASPLOS'13), accepted for publication.
- B. Edwards, T. Moore, G. Stelle, S. Hofmeyr and S. Forrest. "Beyond the Blacklist: Modeling Malware Spread and the Effect of Interventions." New Security Paradigms Workshop (2012).
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### **RECENT INVITED TALKS (PAST FOUR YEARS)**

- Plenary talk, International Conference on Artificial Immune Systems (ICARIS), Taormina IT “The biology of software” (2012)
- Sandia National Laboratories ”Evolutionary software repair” (2012)
- World Economic Forum, Davos, Switzerland “Biological models for software security” (2012)
- Morrison Lecture, Stanford Univ. “Evolvable software” (2011)
- Colorado State University, ISteC Distinguished Lecture “Evolutionary software repair”
- Keynote Address, University College, London, CREST Open Workshop ”Genetic programming for software engineering” (2011)
- Panel Presentation, In-Q-Tel CEO Summit, San Francisco CA ”Cyberattack and defense” (2010)
- AI Colloquium, UT Austin Dept. of Computer Science “Automatic program repair with evolutionary computation” (2010)
- JASON Advisory Group, San Diego summer meeting “Bridging CS and biology for cyberSecurity” (2010)
- Keynote Address, Conference on Object-Oriented Programming, Languages, Systems (OOP-SLA/SPLASH) “The case for evolvable software” (2010)
- Dept. Colloquium, Univ. of Massachusetts, Amherst “Evolutionary program repair” (2010)
- Nanyang Technological University, Singapore, “Evolving software to fix real bugs in real programs” (2009)
- Syracuse University, NY “Evolution of Software” (2009)
- UC Berkeley TRUST Seminar series “Anomaly detection and response” (2009)

Portland State University, OR "Evolution of software" (2009)

Univ. Pennsylvania, School of Medicine "Agent-based modeling of evolutionary diseases" (2008)

ITAM (Instituto Tecnológico Autónomo de México) "Technological Networks: From Empirical Laws to Theory", Mexico City; Mexico Conference on Artificial Intelligence, Tecnológico de Monterrey, Mexico City Plenary talk: "Computer Immunology" (2008)

Microsoft Research, Trento, Italy. Meeting on Biological Complexity. "Agent-based modeling of evolutionary multi-cellular systems" (2008)

NSF/NSA meeting, Oakland, CA "Biology is the Science of Security"