Larry S. Yaeger

Software Engineer, Google
Adjunct Professor, School of Informatics & Computing,
Indiana University, Bloomington Campus

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Core Areas of Expertise

Innovative problem solving, computer programming, neural networks, genetic / evolutionary algorithms, pattern / handwriting recognition, machine learning, artificial life, information theory, graph theory / network science, complex systems, computer graphics, scientific visualization, computational fluid dynamics, aerospace engineering.

Biographical Sketch

I have used computers to solve a wide variety of problems throughout my career. Having studied Aerospace Engineering, with a focus on computers, I carried out pioneering computational fluid dynamic flow studies over the space shuttle and submarines. As Director of Software Development at Digital Productions, I used a Cray X-MP supercomputer to generate the world's first photo-realistic computer graphics for a feature film, *The Last Starfighter*, in addition to special effects for the films *2010* and *Labyrinth*, and a number of Clio Award-winning television commercials. While with Alan Kay's Vivarium Program at Apple Computer, I designed and programmed a computer "voice" for Koko the gorilla, helped introduce computers into routine production on *Star Trek: The Next Generation*, and created a widely respected Artificial Life computational ecology ("Polyworld"), that evolves neural architectures resulting from the mutation and recombination of genetic codes, via behavior-based, sexual reproduction of artificial organisms. I also co-authored possibly the first book+CD-ROM title, the award-winning *Visualization of Natural Phenomena*. In the Apple Research Laboratories (nee Advanced Technology Group), I was Technical Lead in the development of the neural network-based hand-print recognition system that shipped in second generation Newton PDAs and was hailed as the "world's first usable" handwriting recognizer. I subsequently designed and implemented the system software to deploy this technology in Mac OS X under the name "Inkwell", and continued to extend the recognizer's neural network learning methods.

Entering academia as a Full Professor I returned to Artificial Life research using information-theoretic measures of neural complexity and graph theoretical measures of network topology to study the evolution of complexity and the relationship between network structure and function, in pursuit of the neural correlates of behavior most likely to yield Artificial Intelligence. During this period I developed and taught a course on these topics—"Artificial Life as an approach to Artificial Intelligence"—at Senior and graduate levels. I also taught introductory computer programming to undergraduates, in C and Python.

Deciding to return to industry and more hands-on programming, I joined Google's Ads group and have developed predictive models of customer behaviors and preferences using deep learning models (the Google Brain neural network platform) and logistic regression models. I developed novel techniques to apply information theory to the selection of optimal signals for machine learning and the discretization of continuous signals for logistic regression.

I consider myself a scientist and a programmer—a problem solver with strong math skills, capable of decomposing complex problems into their constituent parts, solving them from first principles, and designing and developing the software to embody those solutions. I have produced significant work in multiple fields of science in a variety of computer languages (octal code, various assemblers, FORTRAN, Basic, Pascal, Smalltalk, C, C++, and Python, among others) under a variety of operating systems (VMS, COS, unix/Linux, Mac OS 9 and X, and others).

Professional Experience

2012 to present   SOFTWARE ENGINEER, LEVEL 7, GOOGLE
• Developed Google Brain deep learning model of advertiser preferences
• Developed logistic regression models of various customer behaviors and preferences
• Developed an Entropy – Minimum Description Length algorithm for discretizing continuous signals
• Developed information theoretic tools for identifying useful signals for machine learning models, based on mutual information with desired outcome (class labels)
• Developed information theoretic tools for identifying similar and redundant signals using normalized mutual information and clustering
• Designed a novel automatic signal selection suite of algorithms to take arbitrary collections of data signals and yield an optimal, normalized subset for use in machine learning

2004 to 2012   **FULL PROFESSOR, SCHOOL OF INFORMATICS, INDIANA UNIVERSITY**
CORE FACULTY, COGNITIVE SCIENCE PROGRAM
• Released and maintain cross-platform implementation of Polyworld artificial life system on SourceForge.net
• Designed and taught Senior/Graduate-level class on "Artificial Life as an approach to Artificial Intelligence"
• Taught required core class to freshmen, I101 – Introduction to Informatics
• Designed and taught required core class to sophomores, I210 – Introduction to Programming
• Co-organized Artificial Life X conference at IU
• With PhD student released and maintained "bct-cpp", a C++ implementation of the Brain Connectivity Toolbox
• Organized and chaired the Guided Self-Organization 3 workshop at Indiana University
• Co-organized Guided Self-Organization 4 workshop at University of Hertfordshire, UK
• Advised Computer Science PhD graduate, Matt Whitehead
• Advised Informatics and Cognitive Science PhD student, Steven Williams
• Serving as adjunct advisor to Computer Science and Cognitive Science PhD student, Jason Yoder
• Served on PhD advisory committees for Paul Williams, Richard Hullinger, Giancarlo Schrementi, 10 others

1987 to 2006   **PRINCIPAL ENGINEER, SENIOR RESEARCH ENGINEER, SENIOR ENGINEER/SCIENTIST III,**
DISTINGUISHED SCIENTIST: APPLE COMPUTER

As Distinguished Scientist with International Text Group
• Technical Lead, principle designer and author of "Inkwell", the handwriting recognition solution for Mac OS X
  - Designed programming interface and neural net recognition to support "application gestures" in Motion app
  - Designed and implemented "Ink On Demand" support first for Motion app, then system-wide
  - Continued to innovate neural network training methods to improve gesture and handwriting recognition
    accuracy
  - Designed event-based mechanism for delivering multiple levels of ink and handwriting recognition support
  - Designed system gesture suite
  - Designed user interface for the "write anywhere" model of handwriting data entry and other UI elements
  - Worked across entire operating system, at kernel, IOKit, CoreGraphics, and application framework
    (Cocoa/AppKit and Carbon) levels
  - Redesigned the Mac's mouse event

With Perception Systems Group in Advanced Technology Group
• Technical Lead and principle designer and author of the "Print Recognizer" shipped in second generation
  Newton MessagePads
  - Main developer, debugger, and Technical Lead throughout life of project
  - Designed and implemented integrated recognition and segmentation scheme
  - Designed and wrote neural network library
  - Co-designed language/context model
  - Conceived, implemented, and tested novel (patented) neural network learning algorithms and training
    techniques to increase recognition accuracy
  - Chief designer and implementer of connected character recognition
  - Began work to extend to full cursive recognition
• Coauthored multiple-award-winning book + CD-ROM, *Visualization of Natural Phenomena*

With Alan Kay's Vivarium Program
• Conceived and implemented a landmark Artificial Life simulator, "Polyworld", that combines neural networks
  and genetic algorithms to achieve complex emergent behaviors in a rich computational ecology
• Designed and programmed a computer user interface for Koko the gorilla
• Designed and programmed an object-oriented C++ wrapper for Silicon Graphics' "gl" (Graphics Library)
• Modified a Macintosh video display to synchronize with film, shot a test at Panavision, and provided proof-of-
  concept results that convinced the Star Trek-TNG production team to employ Macintosh computer graphics as a
  routine element of the show
• Modeled a kelp forest ecology on an Evans & Southerland CT6 flight simulator
• Extended Sejnowski's "NETtalk" neural network speech synthesis work to include syllabic stress

1982 to 1987 **DIRECTOR OF SOFTWARE DEVELOPMENT: DIGITAL PRODUCTIONS**
VICE PRESIDENT, SOFTWARE SYSTEMS: OMNIBUS COMPUTER GRAPHICS, DIGITAL PRODUCTIONS, ROBERT ABEL & ASSOCIATES

• Principal author of DP3D computer graphics rendering environment used for films, including *The Last Starfighter*, and many award-winning commercials
• Managed many aspects of software development for the support of the computer graphics production system, including team of 18 top notch software engineers
• Provided technical guidance to Producers and Executive Producer in bidding and budgeting, and developed bids for new projects
• Technical Directed (and assisted in the Art Direction and design of) the award-winning flying owl opening title sequence for the film *Labyrinth*
• Conceived and led the implementation of the simulation of the planet Jupiter for the film *2010*, in one of the first combinations of physical simulation with computer graphics

Prior to 1982 **RESEARCH SCIENTIST: POSEIDON RESEARCH ('79-'82), ROCKETDYNE ('77-'78), AND GRUMMAN AEROSPACE ('72-'77)**

• Extensive background in computers, fluids, mathematics, and 3-D modeling
• Codesigned and implemented a 3-D geometry specification, modeling, and visualization package, QUICK, in 1972 which is still in use
• Simulated a complete 3-D hypersonic flow field over the Space Shuttle (possibly the first such)
• Analyzed fluid vibration problem in main oxidizer valve of Space Shuttle Main Engine
• Created the first simulation of the complete flow field over a submarine, including hull effects, lifting surfaces, and turbulent wake; demonstrated agreement with measured data

Education

| 1972-1974 | M.S., | Aerospace Engineering, PolyTechnic Institute of New York, Long Island Extension |
| 1968-1972 | B.S., | Aerospace Engineering, Purdue University, West Lafayette, Indiana |

Patents

US5515489	5/7/96	Collision detector utilizing collision contours
US5768422	6/16/98	Method for training an adaptive statistical classifier to discriminate against improper patterns
US5805730	9/8/98	Method for training an adaptive statistical classifier with improved learning of difficult samples
US5805731	9/8/98	Adaptive statistical classifier which provides reliable estimates of output classes having low probabilities
US5859925	1/12/99	Classifying system having a single neural network architecture for multiple input representations
US5917941	6/29/99	Character segmentation technique with integrated word search for handwriting recognition
WO067222	9/13/01	Method and apparatus for acquiring and organizing ink information in pen-aware computer systems
US7564995	7/21/09	Method and apparatus for acquiring and organizing ink information in pen-aware computer systems
US7894641	2/22/11	Method and apparatus for acquiring and organizing ink information in pen-aware computer systems

Honors, Awards, Etc.

Undergraduate Scholarship, Teamsters Union (1968)
Member Aerospace Engineering Honorary (1972)
Graduated B.S. with distinction (1972)
Masters Fellowship, Grumman Aerospace
Graduated M.S. with highest distinction (1974)
Grumman Project Sterling Award for New Technology (1976)
NASA New Technology Award (1976)
Rocketdyne President's Achievement Award (1978)

NCGA Best Computer Animation Award for *Labyrinth* opening title sequence (1986)
Clio Awards for various television commercials (1982 – 1987)
NCGA Computer Animation Awards for various commercials (1982 – 1987)
Best Digital World at Artificial Life III Conference, for Polyworld (1992)
Best Nonfiction Computer Book of 1993, Computer Press Association, for *Visualization of Natural Phenomena* (1994)
Honorable Mention (2nd Place) Best New Electronic Product of 1993, American Association of Publishers, Professional and Scholarly Publishing Division, for *Visualization of Natural Phenomena* (1994)
Distinguished Engineer, Scientist, or Technologist, Apple Computer (1998)
Senior Cognitive Scientist, Cognitive Science Dept., Indiana University (2003)
Featured in the CBS News production, NextWorld, on the Discovery Channel, in the "*Future Intelligence*" episode.
Indiana University Trustees Teaching Award (2010)
Invited to participate in NAKFI (National Academies / Keck Futures Initiative) invitation-only Conference on Complex Systems, Newport Beach, CA, Nov. 13-15 (2008)
Invited lecturer or keynote speaker at Randolph-Macon College, VA (Nov. 2006); Instituto de Física Corpuscular, University of Valencia, Spain (May 2008); First International Guided Self-Organization Workshop, CSIRO, Sydney, Australia (Nov. 2008); Second International Guided Self-Organization Workshop, Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany (Aug. 2009); Midwestern Undergraduate Cognitive Science Conference, Indiana University (April 2011); University of Hertfordshire, Hatfield, UK (Oct. 5, 2011); Keele University, Stoke-on-Trent, UK (Nov. 2, 2011); Gatsby Computational Neuroscience Unit, University College London, UK (Nov. 9, 2011)
Invited Distinguished Lecture Series speaker at St Andrews University, St Andrews, Scotland (March 12, 2012)

Publications

1. A Brief User's Guide for the QUICK Geometry System, Yaeger, L.S., Grumman Propulsion Doc. No. PXP--001-36 (1974)
2. Computation of High-Speed Inviscid Flows About Real Configurations, Marconi, F., Yaeger, L.S., and Hamilton, H., NASA SP-347 (1975)
3. QUICK Geometry—A Rapid Response Method for Mathematically Modeling Configuration Geometry, Vachris, A. and Yaeger, L.S., NASA-LRC Conference on Applications of Computer Graphics in Engineering, NASA SP-390 (1975)
4. Development of a Computer Code for Calculating the Steady Super/Hypersonic Inviscid Flow Around Real Configurations, Vol. I—Computational Technique, Marconi, F. and Yaeger, L.S., NASA CR-2675 (1976)
5. Development of a Computer Code for Calculating the Steady Super/Hypersonic Inviscid Flow Around Real Configurations, Vol. II—Code Documentation, Marconi, F. and Yaeger, L.S., NASA CR-2676 (1976)
6. Transonic Flow Over Afterbodies Including the Effects of Jet-Plume and Viscous Interactions with Separation, Yaeger, L.S., AIAA 15th Aerospace Sciences Meeting, AIAA 77-228 (1977)
7. A Numerical Technique for Analyzing Laser Cavity Acoustics, Yaeger, L.S., Acoustical Society of America Meeting (1978)
8. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
9. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
10. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
11. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
12. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
13. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
14. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
15. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
16. Secret/SH publication on signal processing & hydrodynamic modeling of submarine flow fields, 1980-1982
17. Digital Scene Simulation, Yaeger, L.S., (invited) Proceedings of the Cray User Group meeting, October, 1984
18. Combining Physical and Visual Simulation—Creation of the Planet Jupiter for the Film "2010", Yaeger, L.S., Upson, C., Myers, R., Computer Graphics, Vol. 19, Num. 4 (proceedings of SIGGRAPH 1985)
19. Digital Scene Simulation: An Application of Vector and Parallel Processing to Computer Graphics, Yaeger, L.S., (invited) Vector and Parallel Processors in Computational Science III Conference (1987)
20. The Vivarium Program, Yaeger, L.S., (invited) Proceedings of the Computer World '89 International Symposium in Osaka, Japan (1989)

21. Koko's Mac II: A Preliminary Report, Clark, M., Ferrara, T., Jones, D., Marion, A., Rose, K., and Yaeger, L., in *The Art of Human-Computer Interface Design*, ed. Brenda Laurel, p. 95-102, Addison-Wesley (1990)
22. Computational Genetics, Physiology, Metabolism, Neural Systems, Learning, Vision, and Behavior or PolyWorld: Life in a New Context, Yaeger, L., p. 263-298, Proceedings of the Artificial Life III Conference (in 1992), ed. Chris Langton, Addison-Wesley (1994)
23. *Visualization of Natural Phenomena*, Wolff, R.S. and Yaeger, L., Telos/Springer-Verlag (1993)
24. T2 and Technology, Supplementary Chapter for T2 Special Edition Laserdisc of *Terminator 2: Judgment Day*, Carolco/Pioneer (1993)
25. Neural networks provide robust character recognition for Newton PDAs, Yaeger, L., (invited) IEEE Expert, Vol. 11, Issue 4, p. 10-11 (1996)
26. On-Line Hand-Printing Recognition with Neural Networks, Lyon, R.F. and Yaeger, L.S., (invited) Proceedings of MicroNeuro '96 (1996)
27. Effective Training of a Neural Network Character Classifier for Word Recognition, Yaeger, L., Lyon, R., Webb, B., *Advances in Neural Information Processing 9* (1996 Conference Proceedings), p. 807-813, MIT Press (1997)
28. Combining Neural Networks and Context-Driven Search for On-Line, Printed Handwriting Recognition in the Newton, Yaeger, L. S., Webb, B. J., Lyon, R. F., AI Magazine, AAAI, 19:1 (Spring 1998) p73-89
29. Combining Neural Networks and Context-Driven Search for On-Line, Printed Handwriting Recognition in the Newton, Yaeger, L. S., Webb, B. J., Lyon, R. F., in *Neural Network Tricks of the Trade*, ed. G. Orr, K. Müller, p. 275-298, Springer-Verlag (1998)
30. T2 and Technology, Supplemental Chapter for T2 Ultimate Edition DVD of *Terminator 2: Judgment Day*, Carolco/Artisan Entertainment (2000)
31. Ink Markup Language, Yi-Min Chee, Jose-Antonio Magana, Katrin Franke, Max Froumentin, Gregory Russell, Sriganesh Madhvanath, Giovanni Seni, Christopher Tremblay, Larry Yaeger, W3C Working Draft (2004)
32. Ideal Free Distribution in Agents with Evolved Neural Architectures, Griffith, V. and Yaeger, L.S., in Rocha, L. et al eds. *Artificial Life X: Proceedings of the Tenth International Conference on the Simulation and Synthesis of Living Systems*, pp. 372–378, MIT Press, Cambridge, MA (2006)
33. Evolution of Neural Structure and Complexity in a Computational Ecology, Yaeger, L. S. and Sporns, O., in Rocha, L. et al eds. *Artificial Life X: Proceedings of the Tenth International Conference on the Simulation and Synthesis of Living Systems*, pp. 330–336, MIT Press, Cambridge, MA (2006)
34. Pen-Based User Interfaces—An Applications Overview, Giovanni Seni, Jayashree Subrahmonia, and Larry Yaeger, in *The Computer Engineering Handbook, 2nd Edition*, CRC Press (2008)
35. Artificial Life in Michael Crichton's *Prey*, Larry Yaeger, in *The Science of Michael Crichton: An Unauthorized Exploration into the Real Science Behind the Fictional Worlds of Michael Crichton*, BenBella Books (now Smart Pop) (2008)
36. Sentiment Mining Using Ensemble Classification Models, Whitehead, M. and Yaeger, L., In *Proceedings of the 2008 CISSE/SCSS International Conference on Systems, Computing Sciences and Software Engineering*. Springer (2008)
37. Passive and Driven Trends in the Evolution of Complexity, Yaeger, L. S., Griffith, V., and Sporns, O., in Bullock, S. et al eds. *Artificial Life XI: Proceedings of the Eleventh International Conference on the Simulation and Synthesis of Living Systems*, pp. 725-732, MIT Press, Cambridge, MA (2008)
38. Building a General Purpose Cross-Domain Sentiment Mining Model, Whitehead, M. and Yaeger, L., in *Proceedings of the 2009 CSIE World Congress on Computer Science and Information Engineering*, IEEE Computer Society. (2009)
39. Functional and structural topologies in evolved neural networks, Lizier, J.T., Piraveenan, M., Pradhana, D., Prokopenko, M., and Yaeger, L.S., in Advances in Artificial Life: Proceedings of the Tenth European Conference on Artificial Life (ECAL2009), pp. 140-147, Springer Verlag, Heidelberg (2009)
40. How evolution guides complexity, Yaeger, L. S., *HFSP J*. 3(5):328-339 (2009)
41. Evolutionary Selection of Network Structure and Function, Yaeger, L., Sporns, O., Williams, S., Shuai, X., Dougherty, S. *Artificial Life XII: Proceedings of the Twelfth International Conference on the Simulation and Synthesis of Living Systems*, pp. 313-320, MIT Press, Cambridge, MA (2010)
42. Genetic clustering for the identification of species, Murdock, J. and Yaeger, L.S., in *GECCO '11: Proceedings of the 13th annual conference companion on Genetic and evolutionary computation*, pp. 29-30, SIGEVO/ACM, New York, NY (2011)

43. Identifying Species by Genetic Clustering, Murdock, J. and Yaeger, L.S., in *Advances in Artificial Life, ECAL 2011*, pp. 565-572, MIT Press, Boston, MA (2011)
44. Multi-K Machine Learning Ensembles, Whitehead, M. and Yaeger, L.S., *MAICS 2012 Conference Proceedings* (2012)
45. Identifying Neural Network Topologies That Foster Dynamical Complexity, Yaeger, L.S., in *Advances in Complex Systems, special topical issue on Guided Self-Organization* 16.02n03 (2013)
46. Information and Self-Organization of Behavior, Polani, D., Prokopenko, M., and Yaeger, L., in *Advances in Complex Systems, special topical issue on Guided Self-Organization* 16.02n03 (2013)
47. Evolution of Complexity and Neural Topologies, Yaeger, L. in *Guided Self-Organization: Inception*, pp. 415-454, Springer Berlin Heidelberg (2014)