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Research Interests

My primary research interests are in the areas of Artificial Life, Artificial Intelligence, Information Theory, and Complexity, and technologies such as Neural Networks and Genetic Algorithms. I am especially interested in the evolution of machine intelligence based on scientific knowledge of natural intelligence and natural selection.

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.

Recently I have been engaged in Artificial Life research, employing genetic algorithms, neural networks, and information-theoretic measures of complexity in artificial worlds, for the purpose of understanding the neural correlates of behavior in the pursuit of Artificial Intelligence. I am currently investigating the relation between neural complexity and behavior and evolutionary fitness, and beginning to investigate the application of graph theory/network science to determine the relationship between dynamical neural complexity and the underlying structural motifs that give rise to it. I have also begun teaching these subjects and ideas in a course on "Artificial Life as an approach to Artificial Intelligence", at Senior and graduate levels. I also teach introductory computer programming to undergraduates.

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, Mac OS 9 and X, and others).

Professional Experience

2004 to Present **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 teach 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 teach required core class to sophomores, I210 – Introduction to Programming
- Co-organized Artificial Life X conference at IU
- With PhD student released and maintain "bct-cpp", a C++ implementation of the Brain Connectivity Toolbox
- Organized and chaired the Guided Self-Organization 3 workshop
- Co-organized Guided Self-Organization 4 workshop at University of Hertfordshire, UK
- Advised Computer Science PhD graduate, Matt Whitehead
- Advising Informatics and Cognitive Science PhD graduate, Steven Williams
- Served on thesis committees for PhD graduates, Paul Williams, Richard Hullinger, Giancarlo Schementi

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 IOKit, CoreGraphics, and application framework (Cocoa 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
 - Codesigned 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)

Publications

- A Brief User's Guide for the QUICK Geometry System, Yaeger, L.S., Grumman Propulsion Doc. No. PXP--001-36 (1974)
- Computation of High-Speed Inviscid Flows About Real Configurations, Marconi, F., Yaeger, L.S., and Hamilton, H., NASA SP-347 (1975)
- 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)
- 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)
- 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)
- 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)
- A Numerical Technique for Analyzing Laser Cavity Acoustics, Yaeger, L.S., Acoustical Society of America Meeting (1978)
- [Nine Secret publications on signal processing and hydrodynamic modeling of submarine flow fields, 1980-1982]
- Digital Scene Simulation, Yaeger, L.S., (invited) Proceedings of the Cray User Group meeting, October, 1984
- Combining Physical and Visual Simulation—Creation of the Planet Jupiter for the Film "2010", Yaeger, L.S., Upton, C., Myers, R., Computer Graphics, Vol. 19, Num. 4 (proceedings of SIGGRAPH 1985)
- 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)
- The Vivarium Program, Yaeger, L.S., (invited) Proceedings of the Computer World '89 International Symposium in Osaka, Japan (1989)
- 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)
- 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)
- Visualization of Natural Phenomena*, Wolff, R.S. and Yaeger, L., Telos/Springer-Verlag (1993)
- T2 and Technology, Supplementary Chapter for T2 Special Edition Laserdisc of *Terminator 2: Judgment Day*, Carolco/Pioneer (1993)
- On-Line Hand-Printing Recognition with Neural Networks, Lyon, R.F. and Yaeger, L.S., (invited) Proceedings of MicroNeuro '96 (1996)
- 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)
- 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
- 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)
- T2 and Technology, Supplemental Chapter for T2 Ultimate Edition DVD of *Terminator 2: Judgment Day*, Carolco/Artisan Entertainment (2000)
- 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)
- 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)
- 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)
- 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)

- 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)
- 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)
- How evolution guides complexity, Yaeger, L. S., *HFSP J.* 3(5):328-339 (2009)
- 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)
- 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)
- 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)
- Evolved Neural Networks Approach the Edge of Chaos, Williams, S. and Yaeger, L., in *Advances in Complex Systems, special topical issue on Guided Self-Organization* (submitted, 2012)