CURRICULUM VITAE

Dr. Kenneth O. Stanley
Assistant Professor
School of EE and Computer Science
The University of Central Florida
Orlando, FL 32816

kstanley@cs.ucf.edu
voice (407) 473-0072
fax (407)823-5419
http://www.cs.ucf.edu/ kstanley

Degrees

Doctor of Philosophy in Computer Science, The University of Texas at Austin, August 2004.

Master of Science in Computer Science, The University of Texas at Austin, May 1999.

Bachelor of Science *magna cum laude* in Engineering, major in Computer Science Engineering, minor in Cognitive Science, University of Pennsylvania, May 1997.

Dissertation

Efficient Evolution of Neural Networks through Complexification, August 2004. Committee: Risto Miikkulainen (chair), Kenneth De Jong, Joydeep Ghosh, Benjamin Kuipers, Raymond Mooney, Bruce Porter.
Abstract: Artificial neural networks can potentially control autonomous robots, vehicles, factories, or game players more robustly than traditional approaches. Neuroevolution, i.e. the artificial evolution of neural networks, is a method for finding the right topology and connection weights to specify the desired control behavior. The challenge for neuroevolution is that difficult tasks may require complex networks with many connections, all of which must be set to the right values. Even if a network exists that can solve the task, evolution may not be able to find it in such a high-dimensional search space. This dissertation presents the NeuroEvolution of Augmenting Topologies (NEAT) method, which makes search for complex solutions feasible. In a process called complexification, NEAT begins by searching in a space of simple networks, and gradually makes them more complex as the search progresses. By starting minimally, NEAT is more likely to find efficient and robust solutions than neuroevolution methods that begin with large fixed or randomized topologies; by elaborating on existing solutions, it can gradually construct even highly complex solutions. In this dissertation, NEAT is first shown faster than traditional approaches on a challenging reinforcement learning benchmark task. Second, by building on existing structure, it is shown to maintain an "arms race" even in open-ended coevolution. Third, NEAT is used to successfully discover complex behavior in three challenging domains: the game of Go, an automobile warning system, and a real-time interactive video game. Experimental results in these domains demonstrate that NEAT makes entirely new applications of machine learning possible.

Professional Experience

Assistant Professor,
Department of Electrical Engineering and Computer Science, The University of Central Florida,
Since January 2005.

Postdoctoral Researcher,
Department of Computer Sciences, The University of Texas at Austin,
September 2004 to December 2005;
Research on real-time neuroevolution in NERO and developing a neuroevolution engine for the TIELT gaming research framework. Supervising Professor: Risto Miikkulainen.

Research Assistant,
Department of Computer Sciences, The University of Texas at Austin, 2000 to 2004;
IC2 Institute Digital Media Collaboratory at The University of Texas at Austin, Fall 2003.
Toyota Corporation, Spring and Summer 2004
Research on Neuroevolution: *NeuroEvolution of Augmenting Topologies (NEAT)*. Supervising Professor: Risto Miikkulainen.

Teaching Assistant, Department of Computer Sciences, The University of Texas at Austin, September 1997 to May 2000. Course: *Foundations of Computer Science* (for entering CS majors). Held office hours, attended classes, corrected papers and exams, and independently lectured to 50 students, 25 at a time. Received **TA Service Commendation**.

Research Intern, Hewlett-Packard Laboratories, Hewlett-Packard Company, Palo Alto, CA, Summer 1999. Applied neuroevolution techniques to failure prediction. Patent pending.

Software Development Intern, OLAP Division, Oracle Corporation, Waltham, MA, Summer 1997.
Upgraded object component technology behind Oracle's table component software.

Information Technology Intern, Goldman, Sachs & Co., New York City, NY, Summer 1996.
Developed system for organizing real-time securities data feeds.

Grants, Awards, and Honors

Winner, Independent Games Festival Student Showcase, Middleware Category, *2006 Game Developers Conference* (GDC'06, San Jose, CA), for the NERO video game. Recognizes "outstanding student-created independent PC games."

Best Paper Award in Computational Intelligence and Games, *IEEE 2005 Symposium on Computational Intelligence and Games* (CIG'05, Colechester, UK), for Stanley, K., Bryant, B., and Miikkulainen, R., Evolving Neural Network Agents in the NERO Video Game.

Fellowship and Funded Project Proposal: *Neuroevolution-based Video Game.* IC2 Institute Digital Media Collaboratory, Since October 2003.
Proposal delivered at the 2nd Annual Game Development Workshop on Artificial Intelligence. Based on the proposal, the IC2 Institute at the University of Texas committed to fund and support the development of a pioneering neuroevolution-based video game. IC2 has formed a project team of institute employees and student volunteers, including posts for project management, design, programming, art, and artificial intelligence. The game will use NEAT as its core AI technology.

Significant Contribution to Grant Proposal: *Collision Avoidance through Neuroevolution Reinforcement Learning.* Toyota Corporation, September 1, 2003 – August 31, 2005, $333,750. Principal Investigator: Risto Miikkulainen.

Best Paper Award in Genetic Algorithms, *Genetic and Evolutionary Computation Conference* (GECCO-2002, New York, NY), for Stanley, K. and Miikkulainen, R., Efficient Reinforcement Learning Through Evolving Neural Network Topologies.

Significant Contribution to Grant Proposal: *Cooperative Coevolution of Neural Networks in Sequential Decision Tasks.* National Science Foundation #IIS-0083776, September 5th 2000 – August 31st 2003, $419,114. Principal Investigator: Risto Miikkulainen.

Teaching Assistant Service Commendation, Department of Computer Sciences, The University of Texas at Austin, December 1999

Tau Beta Pi National Engineering Honor Society, 1996-97

Vice President, **Eta Kappa Nu Electrical Engineering and Computer Science Honor Society**, University of Pennsylvania Chapter, 1996-97

Golden Key National Honor Society, 1996-97

Magna Cum Laude Graduate, University of Pennsylvania, 1997

Dean's List, University of Pennsylvania, 1994-95

Software

NEAT (NeuroEvolution of Augmenting Topologies) software for evolving neural network topologies and weights. Released Summer 2001. Last update (v1.1) July 2002. Available at: http://www.cs.utexas.edu/users/nn/soft-view.php?RECORD_KEY(Software)=SoftID&SoftID(Software)=4

NERO (NeuroEvolving Robotic Operatives) video game software using real time NEAT (rtNEAT) as its core AI technology. The player can train virtual robots to perform tasks in real time. Released June 2005. Available at: http://www.nerogame.org

Three Online Animated Demos are available: (at http://www.cs.utexas.edu/users/kstanley/demos.html)
NEAT Complexification Demo. Strategies become more sophisticated as networks complexify.
NEAT Robot Hall Navigation Demo. Evolved simulated robots navigate a hallway.
Real-Time Interactive Neuroevolution Demo. Players evolve during a real-time game.

Impact and Publicity

NEAT is the featured method (given 54 pages) in the final chapter of the book: *AI Techniques for Game Programming*, by Mat Buckland, Premier Press, 2002.

Six publicly available software versions of NEAT have been produced by independent programmers:

- *Java NEAT* (released 6/02) by Ugo Vierucci, available at:
  http://www.cs.utexas.edu/users/nn/soft-view.php?RECORD_KEY(Software)=SoftID&SoftID(Software)=5
- *Windows NEAT* (released 9/02) by Mat Buckland, available at:
  http://www.cs.utexas.edu/users/nn/soft-view.php?RECORD_KEY(Software)=SoftID&SoftID(Software)=6
- *Matlab NEAT* (released 8/03) by Christian Mayr, available at:
  http://www.cs.utexas.edu/users/nn/soft-view.php?RECORD_KEY(Software)=SoftID&SoftID(Software)=23
- *Delphi NEAT* (released 1/04) by Mattias Fagerlund, available at:
  http://www.cambrianlabs.com/mattias/DelphiNEAT/
- *SharpNEAT* (released 4/04) by Colin Green, available at:
  http://sharpneat.sourceforge.net//
- *ANJI: Another NEAT Java Implementation* (released 9/04) by Derek James and Philip Tucker, available at: http://anji.sourceforge.net/

Derek James founded and currently runs an active NEAT Users Group with over 200 users from around the world at: http://groups.yahoo.com/group/neat

Over 2,000 NEAT software downloads since 8/2001

Over 50,000 NERO software downloads since 6/2005 (see http://www.nerogame.org)

Interviewed on KXAN News Austin (channel 36) about NERO on 5/23/05. Partial transcript posted on the web: http://www.kxan.com/Global/story.asp?S=3381601&nav=0s3caC93

NERO has received worldwide media coverage since its release:

- Slashdot 6/27/05: "AI researchers produce new kind of PC game."
  http://games.slashdot.org/article.pl?sid=05/06/27/2129214&tid=206&tid=10
- GarageGames News 6/27/05: "University of Texas uses Torque for AI game experiment."
  http://www.garagegames.com/news/8129
- Gamasutra 7/12/05: "Round-Up: NERO Fiddles, Germans Write, Pixel Corps."
  http://www.gamasutra.com/php-bin/news_index.php?next=5926&st=6927
- University of Texas Dept. of Computer Scienes Promotional Media, 6/2005: "Meet Dr. Kenneth Stanley and his virtual robots who learn."
  http://oea.cs.utexas.edu/imagine/ken_stanley/index.html
- University of Texas Featured Project 7/21/05: "Neural networks research produces NERO, a game in which characters get smarter."
  http://www.utexas.edu/research/projects/nero.html
- MIT Technology Review Blog by Brad King 6/28/05: "UT Game Group Unveils AI Project."
  http://king.trblogs.com/archives/2005/06/ut_game_group_u.html
- American Assoc. for Artificial Intelligence (AAAI) video games page: Untitled paragraph on NERO.
  http://www.aaai.org/AITopics/html/video.html
- Generation5 6/25/05: "NeuroEvolving Robotic Operatives (NERO)."
  http://www.generation5.org/news.asp?Action=Full&ID=766
- MSNBC Blog 6/30/05: "What are friends for?" Article mentions NERO.
  http://www.msnbc.msn.com/id/8382695/
- Nano News Press Releases 6/29/05: "The New Genre of Video Games."
  http://www.thenanotechnologygroup.org/index.cfm?Content=88&PressID=194
- Belgium; Tweakers.net 6/28/05: "Wetenschappers ontwikkelen nieuw computerspel."
  http://www.tweakers.be/nieuws/37837?t=1119994875
- France; ZDNet"Innovons" Blog 6/28/05: "NERO."
  http://blogs.zdnet.fr/index.php/2005/06/28/nero/
- Germany; Computer Magazine "ct" (in print) 7/2005: "Intelligenter spielen fur die Wissenschaft (Playing more intelligently for science)," p.59.
  http://www.heise.de/ct/
- Germany; PC Action Magazine (in print) 9/2005: "NERO," p.128.
  http://www.pcaction.de/
- Germany; 4players.de 6/28/05: "Nero macht euch zum Militar-Ausbilder."
  http://www.4players.de/4players.php/dispnews/PC-CDROM/Aktuelle_News/43212.html

- Germany; Golem.de IT News 6/28/05: “Spiel von KI-Forschern: Roboter ausbilden und kmpfen lassen.”
  http://www.golem.de/0506/38899.html
- Germany; Windows mobile News 6/30/05: “NERO: Neuro Evolving Robotic Operatives.”
  http://www.pocketpc-salzburg.at/modules.php?name=AvantGo&file=print&sid=742
- Hungary; Tech-tudomany 6/28/05: “Neveljen robothadsereget!”
  http://index.hu/tech/szoftver/nero0628/
- Latvia; Fizmati 6/29/05: “Studenti rada jauna tipa spli.”
  http://www.fizmati.lv/zinas/datorika/studenti_rada_jauna_tipa_speli/
- Netherlands; Gamer.nl 7/3/05: “Train kunstmatige intelligentie in gratis RTS NERO.”
  http://www.gamer.nl/nieuws/26841
- Portugal; Nogome 7/2005: “Project NERO: jogos.”
  http://www.nogome.com/nogome/archives/001130.php
- Russia; All-Games.ru 7/4/05:
  http://www.all-games.ru/news/2005/07/04/nn6892.html
- Russia; IGROMANIA (in print) 8/2005:
  http://www.igromania.ru/
- UK; Games Digest 7/2005: “AI researchers show off new game type.”
  http://www.games-digest.com/2005/07/ai_researchers_.html
- UK; Guardian Unlimited Blog 6/28/05: “New game genre invented by boffins?”
  http://blogs.guardian.co.uk/games/archives/2005/06/28/new_game_genre_invented_by_boffins.html#more
- UK; Personal Computer World 7/1/05: “Gaming revolution as players train computers.”
  http://www.pcw.co.uk/vnunet/news/2139176/games-artificial-intelligence

Students Supervised

Co-supervised 4 senior undergraduate students (with Prof. Miikkulainen) and a team of undergraduate programmers:

NERO Programming Team, 10/2003-12/2005. Over a dozen undergraduates worked on the NERO project as volunteer programmers under my supervision.

Ryan Cornelius, since 9/2004.
Independent study project, *Initializing NEAT from a Finite State Machine*.

Joseph Reisinger, 1/2003-5/2004.
Honors thesis project, *Modular NEAT*. Winner of a CRA Outstanding Undergraduate Awards Honorable Mention, a VIGRE grant from the Department of Mathematics, and a UROP award from the Department of Computer Sciences.

Kennon Ballou, 5/2001-8/2001.
Independent study project, *Species-Specific Variable Mutation Rates in NEAT*.

Timothy Andersen, 9/2001-5/2002.
Independent study project and Honors thesis project, *Neuro-Evolution through Augmenting Topologies Applied To Evolving Neural Networks To Play Othello*.

Scholarly Service

Co-Chair of the *Forum for Artificial Intelligence* at the University of Texas at Austin. 1/2001-5/2002. Planned and organized all aspects of talk series with invited speakers every two weeks.

Program Committee Member for *Genetic and Evolutionary Computation Conference* (GECCO-2004) and *Genetic and Evolutionary Computation Conference* (GECCO-2005)

Task Force Member for *IEEE Task Force on Coevolution* since 2003

Discussion Panels

Understanding Coevolution Workshop, *Genetic and Evolutionary Computation Conference* (GECCO-2002, New York, NY), July 2002.

Panel on Novel Uses of AI in Video Games, *2nd Annual Game Development Workshop on Artificial Intelligence, Interactivity, and Immersive Environments*, August, 2003. (Proposed a neuroevolution-based video game)

Coevolution Discussion Forum, *Genetic and Evolutionary Computation Conference* (GECCO-2005, Washington D.C.), June 2005.

Member of *American Association for Artificial Intelligence* (AAAI) since 2000, *International Society for Genetic and Evolutionary Computation* (ISGEC) since 2001

Reviewer for *Artificial Life* (2004), *BioSystems Journal* (2001), *IEEE Systems, Man and Cybernetics - Part B* (2003), *IEEE Transactions on Evolutionary Computation* (2003, 2005), *Information Fusion Journal* (2004,2005), *International Journal of Neural Systems* (2005) *JMLR* (2004,2005), *Neural Computation* (2002,2003)

Publications

Journal Articles

Kenneth O. Stanley, Bobby D. Bryant, and Risto Miikkulainen (2005). The NERO Real-Time Video Game. To appear in: *IEEE Transactions on Evolutionary Computation Special Issue on Evolutionary Computation and Games*, 9(6).

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

Kenneth O. Stanley and Risto Miikkulainen (2003). A Taxonomy for Artificial Embryogeny. *Artificial Life*, 9(2): 93–130.

Kenneth O. Stanley and Risto Miikkulainen (2002). Evolving Neural Networks through Augmenting Topologies. *Evolutionary Computation*, 10(2): 99–127.

Adrian Agogino, Kenneth O. Stanley, and Risto Miikkulainen (2000). Online Interactive Neuroevolution. *Neural Processing Letters*, 11(1):29–37.

Articles in Competitive Conferences

Thomas D'Silva, Roy Janik, Michael Chrien, Kenneth O. Stanley, and Risto Miikkulainen (2005). Retaining Learned Behavior During Real-time Neuroevolution. In: *Proceedings of the Artificial Intelligence and Interactive Digital Entertainment Conference* (AIIDE 2005, Marina Del Rey, CA). Menlo Park, CA: AAAI Press.

Kenneth O. Stanley, Nate Kohl, Rini Sherony, and Risto Miikkulainen (2005). Neuroevolution of an Automobile Crash Warning System. In: *Proceeedings of the Genetic and Evolutionary Computation Conference* (GECCO-2005, Washington D.C). New York, NY: The Association for Computing Machinery.

Shimon Whiteson, Peter Stone, Kenneth O. Stanley, Risto Miikkulainen, and Nate Kohl (2005). Automatic Feature Selection in Neuroevolution. In: *Proceeedings of the Genetic and Evolutionary Computation Conference* (GECCO-2005, Washington D.C). New York, NY: The Association for Computing Machinery.

Kenneth O. Stanley and Risto Miikkulainen (2004). Evolving A Roving Eye for Go. In: *Proceeedings of the Genetic and Evolutionary Computation Conference* (GECCO-2004, Seattle, WA). New York, NY: Springer-Verlag.

Joseph Reisinger, Kenneth O. Stanley, and Risto Miikkulainen (2004). Evolving Reusable Neural Modules. In: *Proceeedings of the Genetic and Evolutionary Computation Conference* (GECCO-2004, Seattle, WA). New York, NY: Springer-Verlag.

Kenneth O. Stanley, 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* (CEC 03, Canberra, Australia). Piscataway, NJ: IEEE.

Kenneth O. Stanley and Risto Miikkulainen (2002). Efficient Reinforcement Learning through Evolving Neural Network Topologies. In: *Proceeedings of the Genetic and Evolutionary Computation Conference* (GECCO-2002, New York, NY), 569–577. San Fransisco, CA: Kaufman.
Best Paper Award in Genetic Algorithms

Kenneth O. Stanley and Risto Miikkulainen (2002). Continual Coevolution through Complexification. In: *Proceeedings of the Genetic and Evolutionary Computation Conference* (GECCO-2002, New York, NY), 113–120. San Fransisco, CA: Kaufman.

Kenneth O. Stanley and Risto Miikkulainen (2002). Efficient Evolution of Neural Network Topologies. In: *Proceedings of the 2002 Congress on Evolutionary Computation* (CEC 02, Honolulu, HI), 1757–1762. Piscataway, NJ: IEEE.

Articles in Workshops and Symposia

Kenneth O. Stanley, Bobby D. Bryant, and Risto Miikkulainen (2005). Evolving Neural Network Agents in the NERO Video Game. In: *IEEE Symposium on Computational Intelligence and Games (CIG'05)* (Colchester, UK).
Best Paper Award at CIG'05 (out of 54 papers submitted)

Kenneth O. Stanley, Ryan Cornelius, Risto Miikkulainen, Thomas D'Silva, and Aliza Gold (2005). Real-time Learning in the NERO Video Game. In: *Proceedings of the Artificial Intelligence and Interactive Digital Entertainment Conference Demonstration Program* (AIIDE 2005, Marina Del Rey, CA). Menlo Park, CA: AAAI Press.

Joseph Reisinger, Kenneth O. Stanley, and Risto Miikkulainen (2005). Towards an Empirical Measure of Evolvability. In: *Proceeedings of the Genetic and Evolutionary Computation Conference Workshop Program* (GECCO-2005, Washington D.C). New York, NY: The Association for Computing Machinery.

Kenneth O. Stanley, Joseph Reisinger, and Risto Miikkulainen (2004). Exploiting Morphological Conventions for Genetic Reuse. In: *Proceeedings of the Genetic and Evolutionary Computation Conference Workshop Program* (GECCO-2004, Seattle, WA). New York, NY: Springer-Verlag.

Kenneth O. Stanley and Risto Miikkulainen (2003). Achieving High-Level Functionality through Complexification. In: *2003 AAAI Spring Symposium on Computational Synthesis* (Stanford, CA). (50% of submissions were accepted)

Kenneth O. Stanley and Risto Miikkulainen (2002). The Dominance Tournament Method of Monitoring Progress in Coevolution. In: *2002 Genetic and Evolutionary Computation Conference Workshop Program* (GECCO-2002, New York,NY), 242–248. San Fransisco, CA: Kaufman.

Technical Reports

Kenneth O. Stanley (2003). Learning Concept Drift with a Committee. Technical Report AI-00-285, Department of Computer Sciences, University of Texas at Austin. 14 pages.

Invited Talks

"Complexification in Coevolution," AAAI Fall Symposium on Coevolutionary and Coadaptive Systems, Arlington, Virginia, Novemeber 4, 2005

"Neuroevolution of an Automobile Crash Warning System," Toyota Higashifuji Technical Center, Mishuku, Japan, September 27, 2005

"A Taxonomy of Developmental Systems," Scalable, Evolvable, Emergent Design and Developmental Systems (SEEDS) Workshop, Genetic and Evolutionary Computation Conference (GECCO-2005), Washington D.C, June 26, 2005

"NERO." Experimental Gameplay Workshop, Game Developers Conference (GDC 2005), San Francisco, CA, March 10, 2005

"Complexification and Artificial Embryogeny." Crowley Davis Research Inc., Eagle, Idaho, December 7, 2004.

"Applications of NeuroEvolution of Augmenting Topologies." Computer Science Department, University of Trondheim, Norway, September 27, 2004.

"Efficient Evolution of Neural Networks through Complexification." Cognitive Science Seminar Series, University of California, San Diego, November 20, 2003.

"Efficient Evolution of Neural Networks through Complexification." Computer Science Department, University of California, Los Angeles, November 17, 2003.

"Competitive Coevolution of Complexifying Neural Networks for Video Games." 2nd Annual Game Development Workshop on Artificial Intelligence, Interactivity, and Immersive Environments, Austin, TX. August 21, 2003.

"Neuroevolution: Can Artificial Brains Be Evolved?" Forum for Artificial Intelligence, University of Texas at Austin. March 10, 2000.

Patents

Kenneth O. Stanley and Risto Miikkulainen (Patent Pending since August 4, 2005) . *Real-time NeuroEvolution of Augmenting Topologies* (rtNEAT). University of Texas at Austin.

Evan Kirshenbaum, Kenneth O. Stanley, and Bin Zhang (Patent Granted January, 2006). Deriving a genome representation for evolving graph structure weights. Hewlett-Packard Corporation.

References

Professor Risto Miikkulainen
Department of Computer Sciences,
The University of Texas at Austin
Austin, TX 78712
512-471-9571
risto@cs.utexas.edu
http://www.cs.utexas.edu/users/risto

Professor Raymond J. Mooney
Department of Computer Sciences,
The University of Texas at Austin
Austin, TX 78712
512-471-9558
mooney@cs.utexas.edu
http://www.cs.utexas.edu/users/mooney

Professor Benjamin J. Kuipers
Department of Computer Sciences,
The University of Texas at Austin
Austin, TX 78712
512-471-9561
kuipers@cs.utexas.edu
http://www.cs.utexas.edu/users/kuipers

Professor Kenneth A. De Jong
Department of Computer Science,
George Mason University
Fairfax, VA 22030
703-993-1553
kdejong@gmu.edu
http://cs.gmu.edu/faculty/dejong.html