Computational Intelligence Course in Undergraduate Computer Science and Engineering Curricula

Dr. Afsaneh Minaie, Utah Valley University

Afsaneh Minaie is a professor of Computer Engineering at Utah Valley University. Her research interests include gender issues in the academic sciences and engineering elds, Embedded Systems Design, Mobile Computing, Wireless Sensor Networks, and Databases.

Paymon Sanati-Mehrizy, Icahn School of Medicine at Mount Sinai

Paymon is currently a medical student at the Icahn School of Medicine at Mount Sinai. He completed his undergraduate studies in Biology from the University of Pennsylvania in May 2012. Currently, his research interests consist of higher education curricula, both with universities and medical schools.

Dr. Ali Sanati-Mehrizy

Dr. Ali Sanati-Mehrizy is a graduate of the Milton S. Hershey Pennsylvania State University College of Medicine. He completed his undergraduate studies in Biology from the University of Utah. In July 2013, he will begin a Pediatrics residency at the UMDNJ-Newark University Hospital. His research interests involve pediatric hematology and oncology as well as higher education curricula, both with universities and medical schools.

Dr. Reza Sanati-Mehrizy, Utah Valley University

REZA SANATI MEHRIZY is a professor of Computing Sciences Department at Utah Valley University, Orem, Utah. He received his MS and PhD in Computer Science from University of Oklahoma, Norman, Oklahoma. His research focuses on diverse areas such as: Database Design, Data Structures, Articial Intelligence, Robotics, Computer Integrated Manufacturing, Data Mining, Data Warehousing and Machine Learning.

Computational Intelligence in the Undergraduate Computer Science and Engineering Curricula

Abstract

Computational Intelligence (CI) is the study of adaptive mechanisms to enable or facilitate intelligence behavior in complex, uncertain and changing environments[1]. These adaptive mechanisms include those artificial intelligence paradigms that exhibit an ability to learn or adapt to new situations, generalize, abstract, discover and associate[1]. The paradigms of CI are inspired from biology and nature. These paradigms include neural networks, evolutionary computing, swarm intelligence, fuzzy systems, and artificial immune systems[6].

Computational Intelligence is one of the most actively researched areas in computer science and engineering. The field of CI is making contributions and has applications within several disciplines including biology, computer science, chemistry, economics, electromagnetics, immunology, information science, robotics, control engineering and automation, industrial fault diagnosis, linguistics, material science, music, and physics[6].

Educational excellence requires exposing students to the current edge of research. To ensure that student projects are along the same trajectory that the industry is moving, educators must continually introduce emerging techniques, practices, and applications into the curriculum. The field of computational intelligence is growing rapidly. It is essential that the emerging field of computing intelligence be integrated into the computer science and engineering curriculums. This paper is a study of different approaches that are used by different institutions of higher education around the world to integrate computing intelligence concepts in their computer science and engineering curriculum.

Introduction

Computational intelligence (CI) is a set of nature-inspired computational methodologies and approaches to address complex real-world problems. A formal definition for CI is given by Komar as "the computational models and tools of intelligence capable of inputting raw numerical sensory data directly, processing them by exploiting the representational parallelism and pipelining of the problem, generating reliable and timely responses and withstanding high fault tolerance"[2]. CI is an offshoot of artificial intelligence (AI) in which the emphasis is placed on heuristic algorithms such as fuzzy systems, neural networks and evolutionary computation. It is usually contrasted with "traditional", "symbolic" or "good old fashioned artificial intelligence". Traditional AI is very good in inductive[3] and analogy-based learning[4]; however, it is inefficient to realize supervised learning. In supervised learning, the trainer provides a number of training input / output instances for the learning system. The learning system has to adapt its internal parameters so as to generate the correct output instance in response to a given input

instance. Neural network models can perform supervised learning very well. Except for the heuristic algorithm, traditional AI is not competent to handle real world optimization problems. However, genetic algorithm (GA) is a new tool that has a good potential to optimize the parameters of the intelligent systems. Classical AI was incompetent to serve the increasing demand of search, optimization and machine learning in information systems with large biological and commercial databases and factory automations for steel, aerospace, power, and pharmaceutical industries[2]. The failure of the traditional AI opened up new avenues for the non-conventional models in various engineering applications. These new computational tools gave rise to a new discipline called computational intelligence[1]. CI could be defined as Nature-inspired method (s) + real-world (training) data = Computational intelligence[5].

The IEEE Neural Network Society changed its name in 2004 to IEEE Computational Intelligence Society. The Computational Intelligence Society uses the tag-line "Mimicking Nature for Problem Solving" to describe Computational Intelligence, although mimicking nature is not a necessary element.

The three main pillars of CI are fuzzy logic, neural networks, and evolutionary computation. In addition to these three pillars, Computational Intelligence also encompasses elements of learning, adaptation, heuristic and meta-heuristic optimization, as well as any hybrid methods that use a combination of one or more of these techniques. More recently, emerging areas such as artificial immune systems, swarm intelligence, chaotic systems, and others, have been added to the range of Computational Intelligence techniques.

Computational Intelligence techniques have been successfully employed in a wide range of application areas, including decision support, generic clustering and classification, consumer electronic devices, stock market and other time-series prediction, combinatorial optimization, medical, biomedical and bioinformatics problems, and many, many others. Although CI techniques are often inspired by nature, or mimics nature in some way, CI applications are not restricted to solving problems from nature.

Educational excellence requires exposing students to the current edge of research. To ensure that student projects are along the same trajectory that the industry is moving, educators must continually introduce emerging techniques, practices, and applications into the curriculum. The ACM/IEEE Computer Science Curricula 2013 (Ironman Draft) lists Intelligent Systems (IS) under Knowledge Areas[22]. The field of computational intelligence is growing quickly, and there is an increasing interest in providing students with a foundation in the area. It is crucial that the emerging field of computational intelligence be integrated into the computer science and engineering curricula. The following are examples of how the computational intelligence concepts are integrated into computer science and engineering programs:

Missouri University of Science and Technology

The CI course was implemented for the first time at the Missouri S & T in Spring of 2004 as an experimental courses in the computer engineering, electrical engineering, mechanical engineering, and system engineering. This course is an introductory course and is offered at the 300 level. Both the graduate level and undergraduate level students are allowed to enroll. The prerequisite for this course is a prior course on Statistics and some programming background. This course has been offered every year and is a permanent course in the computer engineering, electrical engineering, and system engineering curricula. By offering this course as a 300 level course, the undergraduate students are exposed to the emerging field of the CI paradigms, which then allows them to enroll in full semester course on either neural networks, fuzzy logic for control or evolutionary computation, which are offered at the Missouri S & T[6].

Their CI course is designed around five paradigms of the CI, namely, artificial immune systems (AIS), evolutionary computing, fuzzy systems, neural networks (NNs), and swarm intelligence. These paradigms can be combined to form hybrids. Hybrid intelligent systems are developed by the integration of two or more paradigms. Hybrid systems are able to capitalize on individual strengths and eliminate weakness of different CI paradigms, thus, offering powerful algorithms for solving complex problems[6].

Their interdisciplinary CI course introduces their students to major paradigms of CI in a single semester. Over the last five years, eighteen undergraduate and sixty-three graduate students from nine different disciplines across their schools and colleges have taken this course. Several of their CI students have succeeded in publishing their projects in refereed conference proceedings and journals. A majority of their graduate students who took this course ended up with a thesis topic involving one or more paradigms of CI. Overall, their CI course has been very successful and rewarding.

American University – Washington DC

At the American University, they have developed a one credit course called Artificial Intelligence as a recruitment tool. Their computer science program relies on recruiting internally, encouraging current students who are undecided about their major to consider computer science. This course is intended for non-computer science majors. The course gives students a taste of various technical topics in AI and CI, ranging from expert systems to neural networks, without requiring any programming or mathematics background. This course uses a combination of hands-on exercises and software demonstrations to illustrate the principles behind AI and CI. They have created a course that avoids theory as much as possible and focuses instead on hands-on demonstrations and simple explanations. They have written a series of software demonstrations explicitly for this course. Five topics were covered in this course which were searching, expert systems, natural language, neural networks, and genetic algorithms. Survey results from students at the end of the course were universally positive[9].

Victoria University of Wellington – New Zealand

At Victoria University of Wellington, due to their program and resource constraints, they are unable to teach an entire course on computational intelligence. Instead, they have integrated machine learning and computational intelligence techniques in an existing undergraduate course on Artificial Intelligence[43]. They have redesigned their Introduction to Artificial Intelligence from mainly symbolic intelligence to a more balanced structure covering the essential of machine learning and computational intelligence concepts. The topics on the symbolic side (traditional AI) include the essential background of Prolog, search, agents, knowledge / rule based systems, planning and natural language processing[43]. The following topics are covered from the machine learning and computational intelligence part of the course: an overview of machine learning, simple learning methods, neural learning and evolutionary computations. Students from the School of Engineering and Computer Science usually take this elective course. There are four assignments for the course, two for the symbolic intelligence and two for machine learning and computational intelligence. Through these four assignments, students gain hands-on experience in applying these techniques to real-world applications. This course offers essential background and training for the students to start doing research in the area of computational intelligence. This course also serves as a platform for students to use computational intelligence methods to solve engineering and industrial applications. Feedbacks from their students have been very positive. While some students think that the course is challenging and the workload is heavy, many students have commented that they learned a lot and enjoyed the topics discussed in the second part of the course[43].

Carnegie Mellon University

At Carnegie Mellon University (CMU), they are offering a minor in Neural Computation. This minor is an intercollege jointly sponsored by their school of Computer Science, the Mellon College of Science, and the College of Humanities and Social Sciences. It is coordinated by their Center for Neural Basis of Cognition (CNBC). This minor is open to students in any major of any college at Carnegie Mellon. This minor seeks to attract undergraduate students from computer science, engineering, biology, statistics, and others. This minor requires a total of five courses. Four courses are drawn from neural computation, neuroscience, cognitive psychology, and intelligence system analysis areas, and one additional depth elective chosen one of the core areas that is outside of the student's major. This depth elective can be replaced by a one-year research project in computational neuroscience[27].

Models for Integration of Computing Intelligence in Curriculums

Table 1 provides a list of computing intelligence course offerings of selected universities around the world. Course offerings of sixty one universities were studied. From this study, it can be seen that universities are using six models to integrate computing intelligence concepts into their computer science and engineering curriculum:

1. Offering an undergraduate course on computational intelligence or one of its paradigms.
2. Offering a graduate course on computational intelligence.
3. Integrating computational intelligence paradigms into their traditional courses.
4. Offering a graduate degree on computational intelligence
5. Offering a minor in Computational Intelligence
6. Using computational intelligence concepts as a recruitment tool.

Model 1 is used by several universities such as the Missouri University of Science and Technology, Central Washington University, and Case Western Reserve University. Out of sixty-one universities studied, twenty seven (44%) are offering an undergraduate course on computational intelligence or one of its paradigms.

Armstrong Atlantic State University, University of Iowa, Rensselaer Polytechnic Institute, and Athabasca University utilize Model 2 by offering a graduate course on computational intelligence. Nineteen universities are offering a graduate course on CI or one of its paradigms. The majority of universities that have graduate programs are offering a graduate course on computational intelligence or one or two of its paradigms.

Some programs are using Model 3 and integrating computational intelligence paradigms into their existing courses. Usually, those concepts are integrated into their existing artificial intelligence courses. For example, San Diego State University[41], College of Staten Island[51], and University of Hartford[50] have integrated Neural Network concepts as a module in their Artificial Intelligence undergraduate course. The majority of the undergraduate computer science programs are offering Artificial Intelligence and Machine learning courses. Model 3 is a good option for those programs. They can integrate a module on some of the CI paradigms in those classes.

Many universities are offering graduate programs on CI and using Model 4. University of Essex[29], Rensselaer Polytechnic Institute[31], University of Surrey[34], University of Sheffield[35], and University of Kent[36] are using Model 4.

Carnegie Melon University[27] is using Model 5 and is offering a Minor in Neural Computation. Undergraduate Computer Science and Engineering students are exposed to the paradigms of computational intelligence in this program. In this minor, students have the option of doing research for a year on Neural Computation.

American University is using Model 6 and is recruiting undergraduate computer science students by offering a fun course on CI concepts[8].

Universities	Undergraduate Computational Intelligence Course	Graduate Computational Intelligence Course	Computational Intelligence Concepts as a Module in Other Classes	Comments
Missouri University of Science & Technology[6]	Computational Intelligence (CE)	None		Teaching five paradigms of CI
University of Hartford[7]	None (CE or CS)	None		CS 351 - AI
American University[8]	None (CS)			CS 568 – AI One Credit AI & CI for recruitment
Shandong Normal University[10]	CI Course			A tutoring system for CI course
Armstrong Atlantic State University[11]	CS Undergraduate can also take these courses as elective.	CSCI 8100 – Computational Intelligence (CS) CSCI 5820G Machine Learning(CS) CSCI 5825G Artificial Intelligence (CS)		7 Paradigms
Central Washington University[12]	CS 475 – Computational Intelligence CS 455 – AI CS 458 – AI Project			No Engineering programs. Computer Engineering Technology
University of Wisconsin – Madison[13]	539 Introduction To Artificial Neural Networks And Fuzzy Systems (CS) CE – None 540 Introduction To Artificial Intelligence	760 Machine Learning 761 Advanced Machine Learning		
Case Western Reserve University[14]	EECS 484 Computational Intelligence I: Basic Principles (CS & CE) EECS 440- Machine Learning	EECS 591 Intelligence Systems II		
Villanova university[15]	CSC 4500 -Artificial Intelligence(CS) CSC 4510 -Machine Learning(CS) ECE 5444 - Introduction to Fuzzy Logic (CE) ECE 5445 - Intro to	CSC 8520 - Artificial Intelligence CSC 8750 - Expert Systems		

	Neural Networks (CE)			
The City College of New York [16]	**CSc 44800 – Artificial Intelligence (CE Elective)** **CSc 59944 – Neural Computing** **CSc 11900 – Pattern Recognition**			**Computation & Signal Processing Track**
University of California – Santa Cruz[17]	**CMPS – AI** **CMPS – Machine Learning and Data Minning**			**CE Program**
University of Illinois [18]	**ECE 448 – Introduction to AI**			**CE**
University of Wisconsin – Madison [19]		**ECE 539 – Introduction to Artificial Neural Network and Fuzzy Systems**		**CE Program**
University of Rhode Island[20]	**ELE 568- Neural Engineering(CE)**	**ELE 581 Special Topics in Artificial Intelligence**		**CE program**
University of Maryland [21]	**ENEE 459M – Machine Learning and Data Mining(CE)** **CMSC 421 – Into AI (CS)**	**CMSC 726 – Machine Learning** **CMSC 722 – AI Planning**		
Bucknell University [23]	**ELEC - Neural Signal and Systems (BME)**	**None**		
Brigham Young University[24]	**CS 470 – AI (CE)**			
University of Utah[25]	**CS 5300 Artificial Intelligence** **CS 5350 Machine Learning**	**6300 Artificial Intelligence** **6350 Machine Learning**		**CE None**
UC San Diego[26]	**CSE 150 – AI – Search and reasoning (CS)** **CSE 151 – AI – Statistical Approaches(CS)**			**CS**
Carnegie Mellon University[27]	**18794 – Pattern Recognition Theory (CE)** **15381 – AI: Representation and Problem Solving(CE)** **15-386 Neural**	**15-491 Special Topic: CMRoboBits: Creating Intelligent Robots** **15-494 Special Topic: Cognitive Robotics**		**Center for the Neural Basis of Cognition** **Minor in Neural Computation**

	Computation **15-486 Artificial Neural Networks**	**15-883 Computational Models of Neural Systems** **18-819E – Special Topics in Applied Physics: Neural Technology, Sensing, and Simulation (CE)**		
Stanford University[28]	**CS221: Artificial Intelligence: Principles and Techniques** **CS229- Machine Learning** **EE 294 A – AI** **EE 294 B – Probabilistic Models in AI** **EE 294C – Machine Learning**			**CS**
University of Essex[29](U.K.)	**Genetic Programming and its Applications**	**CE889-7-AU: ARTIFICIAL NEURAL NETWORKS** **CE888-7-SP: FUZZY LOGIC HYBRID SYSTEMS** **CE802-7-AU: MACHINE LEARNING AND DATA MINING** **CE886-7-SP: EVOLUTIONARY COMPUTATION AND GENETIC PROGRAMMING** **CE801-7-AU: INTELLIGENT SYSTEMS AND ROBOTICS**		**Offering an MSc in Computational Intelligence**
University of Iowa[30]	**22C:145 Artificial Intelligence**	**56:235 – Computational Intelligence (CE)**		
Rensselaer Polytechnic		**CpE 358 – Computational**		**Graduate Certificate – Computational**

Institute[31]		**Intelligence** **CS 374 – Intro. AI** **CS 348 – Evolutionary Computing**		**Intelligence**
Utah Valley University[32]	**ECE 4800 – Artificial Neural Network**			**An Elective course**
University of Waterloo (Canada)[33]	**ECE 57ACooperative and Adaptive Algorithms (CE)** **ECE 457B: Computational Intelligence: Fuzzy Logic and Neural Networks Fundamentals (CE)** **SYDE 422 Machine Intelligence** **SYDE 558 Fuzzy Logic and Neural Networks** **CS 486 Introduction to Artificial Intelligence** **CS 485 Machine Learning**			
University of Surrey-Guildford[34]**(United Kingdom)**				**MSc Computational Intelligence & Computational Biology**
University of Sheffield[35]**(United Kingdom)**				**MSc Computational Intelligence through department of Automation Control & Systems Engineering**
University of Kent[36] **(United Kingdom)**				**MSc Computational Intelligence** **Two years**
Athabasca University[37] **(Canada)**		**COMP 658 – Computational Intelligence**		
Iowa State University [38]		**Com S 573. Machine Learning.** **Com S 574. Intelligent Multiagent**		**Center for Computational Intelligence**

		Systems. **Com S 672. Computational Models of Learning.** **Com S 673. Advanced Topics in Artificial Intelligence and Cognitive Modeling.**		
University of Georgia [39]	**CSCI 4330 Artificial Intelligence and the Web**	**CSCI 9999- Computational Intelligence**		
Bircham International University [40] (Australia)				**Master in Computational Intelligence**
Arizona State University [41]	**CSE 471 Intro. AI (CE)** **CSE 571 AI (CE)**			**Computational Intelligence and Algorithms area of research**
University of Nairobi [42]				**Master of Science in Computational Intelligence**
University Complutense de Madrid [45]	**Evolutionary Computation**			
University of Salzburg [46] (Austria)	**Natural Computation**			
Fluminense Federal University[47] (Brazil)	**Introduction to Computational Intelligence**			EE Dept. (elective course)
Cairo University[52]	**Computational Intelligence in Operations Research and Decision Support**			
Technische Universität München[52] (Germany)	**Computational Intelligence**			
Cologne University of Applied Sciences[52] (Germany)		**Computational Intelligence**		
Technische Universität Braunschweig[52] (Germany)	**Computational Methods in Bionik I**			
University of Magdeburg[52]	**Evolutionary Algorithms, and**			

(Germany)	Intelligent Systems			
University of Piraeus[52] (Greece)	Artificial and Computational intelligence			
Jadavpur University[52] (India)		Artificial Intelligence and Soft Computing, and Computational Intelligence		M.S. in Computer Science
University College Dublin[52] (Irland)	Natural Computing			BSc Computer Science
University of Salerno[52] (Italy)		Artificial and Computational Intelligence		M.S. in Computer Science
University of Bari[52] (Italy)	Computational Intelligence			
University of Catania[52] (Italy)	Evolutionary Algorithms for Security, and Natural Computation			B.S. in Applied Computer Science
Universita' degli Studi di Milano[52] (Italy)		Intelligent Systems		MS in Computer Science
CETYS University[52] (Mexico)	Fuzzy Logic and Neural Networks			Undergraduate students of the Engineering Department
University of the Philippines[52] (Philippines) MS		Computational Intelligence I		MS Computer Science
Nicolaus Copernicus University[52] (Poland)		Computational Intelligence		MSc in computer sciences and in informatics (elective)
KFUPM[52] (Saudi Arabia)		Evolutionary Computation		MS in Computer Engineering/Science (elective)
Istanbul Technical University[52] (Turkey)		Evolutionary Computing, and Nature-Inspired Computing		MS & PhD in Computer Science and Computer Engineering (elective)
University of Portsmouth[52]	Fuzzy Systems and Networks			BSc in Computer Science

(United Kingdom)				(elective)
University of Ulster[52] (United Kingdom)	Intelligent Systems			BSc Honors (Computer Science) and BEng Honors (Electronics and Computer Systems) (elective)
Connecticut College[52]	Computational Intelligence			Computer Science (elective)
South Carolina State University[52]	CS496 Neuroinformatics and brain-computer interface			B.S. in Computer Science (elective)
University of South Florida[52]	Fuzzy Set Theory			Elective
University of Texas at El Paso[52]	Topics in Soft Computing (B.Sc. in Computer Science)	Topics in Intelligent Computing (M.Sc. and Ph.D. in Computer Science)		(elective)

Table 1: A Survey of Universities with Regard to Computational Intelligence Offerings

Utah Valley University

Utah Valley University (UVU), with a fall 2012 student headcount of over 31,500 students, is located in the Orem/Provo community, Utah's second largest urban area with a population of about 530,499 (U.S. Census, 2011 est.). The Computer Science department at UVU offers a Bachelor's Degree in Computer Science with two areas of specialization, including Computer Science (traditional), and Computer Networking. It also offers Software Engineering degree as well as Computer Engineering degree. The Bachelor of Science in Computer Science program was one of the first Bachelor of Science programs implemented at UVU in 1993. The program's goal has been to provide a quality program that meets accreditation standards while providing the students with a skill set that allows them to succeed in computing careers. The curriculum content for the Computer Science degree is based on the 2008 ACM Curriculum Report. The Computer Science degree at UVU is accredited by Accreditation Board for Engineering and Technology (ABET) in 2002 and currently has more than 500 students.

To integrate Computational Intelligence concepts into our curriculum, we decided to use the first model by offering an undergraduate course on Artificial Neural Networks. This course was offered as a senior level elective course for the first time in the Fall 2012 semester. Offering this course as a required course was not an option for us, so not every student is going to be exposed to this material. This course is an elective course for the computer science and computer

engineering students. There is only one elective course in our Computer Engineering curriculum. Students have the option of taking the Artificial Neural Network course or another course. So, 50% of our CE students are exposed to a CI paradigm. The textbook chosen for this class was "*Neural Networks and Learning Machines*" by Simon Haykin. There were twelve students in this class, and students commented that their experiences with the class were very positive.

Summary and Concluding Remarks

Computational Intelligence is a relatively new area that is becoming increasingly more important in society today and in the future, especially due to the growing possibilities of gathering data and the need for intelligence systems. CI deals with nature-inspired computational methodologies and approaches to solve complex problems for real world challenges to which traditional approaches are ineffective or infeasible.

Even though interest in CI has been increasing amongst the computer scientists and engineers in recent years, institutions that offer courses dedicated to the topic are still in the minority. The courses that are offered in this area are mostly designed and taught at the graduate level. Integration of computational intelligence concepts in undergraduate computer science and engineering have started slowly in many universities worldwide.

When should CI concepts be introduced into computer science and engineering curricula? Some scientists believe that it should be introduced as early as possible, which is the approach taken by the American University[8]. Some believe that it should be offered as a senior level required course. The second option might be harder to implement, since adding a new course to the curriculum is not an easy task, as often times eliminating another course would be necessary. Offering it as an elective course is not a good option either, since every student will not benefit from this experience. It seems that adding the concepts slowly as modules to existing courses is a good solution for integrating the CI concepts into the computer science and engineering curricula, which is the approach taken by San Diego State University[41].

From the study, it seems that the majority of courses offered in the area of computational intelligence are elective courses and not all the undergraduate students are going to be exposed to the computational intelligence concepts. One solution is to integrate the CI concepts as a module in a required course in these curricula.

As the industry is constantly involved in the development of technology and products to solve issues with computational intelligence, tomorrow's computer scientists and engineers must be educated on the CI concepts. It is crucial that CI paradigms be integrated into undergraduate computer science and engineering curricula.

References

1. Engelbrecht, A, "Computational Intelligence: An Introduction", Wiley, 2005.

2. Komar, Amit, "Computational Intelligence: Principles, Techniques, and Applications", Springer, 2005.

3. Quinlan, J. R., "Induction of Decision Trees", Machine Learning, Vol. 1, No. 1, PP. 81-106.

4. Winston, P., "Learning Structural Descriptions from Examples", Ph.D. Dissertation, MIT Technical Report AI-TR-231, 1970.

5. Fulcher, John, "Computational Intelligence: A Compendium", Springer, 2008.

6. Venayagamoorthy, G., "A Successful Interdisciplinary Course on Computational Intelligence", IEEE Computational Intelligence Magazine, February 2009.

7. University of Hartford, http://www.hartford.edu/ceta/undergraduate/engineering/CompE , accessed on January 6, 2013.

8. American University, http://www.american.edu/cas/cs/courses.cfm , accessed on January 6, 2013.

9. Black, Michael, "A One-Credit Artificial Course for a General Audience", Proceedings of Consortium for Computing Sciences in Colleges Conference, 2010.

10. Hong, LIU, "A Tutoring System for Computational Intelligence Course", IEEE, 2009.

11. Armstrong Atlantic State University, http://www.armstrong.edu/Science_and_Technology/ice/ice_bs_in_computer_science , accessed on January 6, 2013.

12. Central Washington University, http://www.cwu.edu/computer-science/undergraduate-programs , accessed on January 6, 2013.

13. University of Wisconsin – Madison, http://www.cs.wisc.edu/academic-programs/courses/cs-course-descriptions , accessed on January 6, 2013.

14. Case Western Reserve University, http://engineering.case.edu/eecs/node/225 , accessed January 6, 2013.

15. Villanova university, http://www1.villanova.edu/villanova/engineering/departments/electrical/undergrad/catalog.html , accessed on January 6, 2013.

16. The City College of New York, http://www.ccny.cuny.edu/ , accessed on January 6, 2013.

17. University of California – Santa Cruz, http://ua.soe.ucsc.edu/ , accessed on January 6, 2013.

18. University of Illinois, http://www.ece.illinois.edu/courses/ , accessed on January 6, 2013.

19. University of Wisconsin – Madison, http://courses.engr.wisc.edu/ece/ece539.html , accessed on January 6, 2013.

20. University of Rhode Island, http://www.ele.uri.edu/schedule/s13 , accessed on January 6, 2013.

21. University of Maryland, http://www.cs.umd.edu/class/ , accessed on January 6, 2013.

22. ACM/IEEE Computer Science Curricula 2013 (Ironman Draft), http://ai.stanford.edu/users/sahami/CS2013/ironman-draft/cs2013-ironman-v1.0.pdf , accessed on March 25, 2013.

23. Bucknell University, http://www.bucknell.edu , accessed on January 6, 2013.

24. Brigham Young University, http://byu.edu, accessed on January 6, 2013.

25. University of Utah, http://www.cs.utah.edu , accessed on January 6, 2013.

26. UC San Diego, http://www.ucsd.edu , accessed on January 6, 2013.

27. Carnegie Melon University, http://coursecatalog.web.cmu.edu/schoolofcomputerscience/courses/ , accessed on January 6, 2013.

28. Stanford University, http://cs.stanford.edu/Courses/ , accessed on January 6, 2013.

29. University of Essex, http://www.essex.ac.uk/csee/Default.aspx , accessed on January 6, 2013.

30. University of Iowa, http://www.engineering.uiowa.edu/ece , accessed on January 6, 2013.

31. Rensselaer Polytechnic Institute, https://www.rpi.edu/dept/cct/public/eship/aboutus.html, accessed on January 6, 2013.

32. Utah Valley University, http://www.uvu.edu , accessed on January 6, 2013.

33. University of Waterloo, https://ece.uwaterloo.ca/Undergrad/Q/, accessed on January 6, 2013.

34. University of Surrey- Guildford, http://www.surrey.ac.uk/, accessed on January 6, 2013.

35. University of Sheffield, http://www.shef.ac.uk, accessed on January 6, 2013.

36. University of Kent, http://www.kent.ac.uk/, accessed on January 6, 2013.

37. Athabasca University, http://www.athabascau.ca , accessed on January 6, 2013.

38. Iowa State University, http://www.registrar.iastate.edu, accessed on January 6, 2013.

39. University of Georgia, http://www.uga.edu/, accessed on January 6, 2013.

40. Bircham International University, http://www.iarcedu.com , accessed on January 6, 2013.

41. Sondak, Norman, and Vernon Sondak, "Neural Networks and Artificial Intelligence", ACM, 1989.

42. University of Nairobi, http://sci.uonbi.ac.ke/degree_courses/931 , accessed on March 19, 2013.

43. Zhang, Mengjie, "Experience of Teaching Computational Intelligence in an Undergraduate Level Course", Computational Intelligence Magazine, IEEE, Aug. 2011.

45. University Complutense de Madrid, http://www.fdi.ucm.es/profesor/ccervigon/ , accessed on March 19, 2013.

46. University of Salzburg, http://www.cosy.sbg.ac.at/~helmut/Teaching/NaturalComputation/index.html , accessed

on March 19, 2013.

47. Fluminense Federal University, Electrical Engineering Department, http://teaching.softcomputing.es/, 2010.

48. Institute of Automatic Control Engineering, http://www.lsr.ei.tum.de/teaching/courses/courses-in- winter/computational-intelligence/ , accessed on March 19, 2013.

49. Zhang, Mengjie, "Experience of Teaching Computational Intelligence in an Undergraduate Level Course", IEEE Computational Intelligence Magazine, July 14, 2011.

50. Russell, Ingrid, "Neural Networks in the Undergraduate Curriculum", Consortium for Computing in Small Colleges Conference, 1991.

51. Imberman, Susan, "Teaching Neural Networks Using LEGO Handy Board Robots in an Artificial Intelligence Course", SIGCSE 2003.

52. IEEE Computational Intelligence Society, http://cis.ieee.org/university-curricula/178-computational- intelligence-course-database.html , accessed on March 22, 2013.