

Course Syllabus
ECE 7930 - Special Topics in Electrical Engineering
“Computational Intelligence and Its Applications
in Control Engineering”
Fall 2002, Independent Study Course.

[This course is equivalent to ECE/MAE7350 “Intelligent Control Systems”.](#)

Synopsis from http://www.ece.usu.edu/academics/graduate_courses.html

***7350. Intelligent Control Systems.

Intelligent control strategies, including neural network, fuzzy logic, associated memory networks, and rule-based control systems. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as MAE 7350. (3 cr) (F)

This course is also scalable to ECE6930 under the same course title.

Instructor: Dr YangQuan Chen,
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Office Hours: Friday 2:30 PM to 5:00 PM or by appointment.

Prerequisites: Undergraduate control systems (ECE4310, ECE5320) and graduate linear multivariable systems (ECE6320). A good working knowledge of C and C++ programming and Matlab/Simulink, Linear algebra, Vector calculus etc. No prior knowledge about computational intelligence is assumed. Knowledge with “Nonlinear and adaptive control” (ECE6330) will be an added advantage but not compulsory.

Credits: 3

Course Load: 8 hours per week. 15 weeks. From Aug. 26, 2002 to Dec. 6, 2002.

Course Requirements:

4 Projects (with presentations)	80 points
1 Literature Survey Report	20 points

(The details will be sent via email.)

There is no Mid-term Exam and Final Exam.

For ECE6930 level, there are only two projects focused on NN and FL.

Notes:

1. This course is designed for 15 weeks Fall independent study.
2. To get 3 credits, you have to spend at least 8 hours a week and 120 hours in total in this course, although you have the *flexibility* to arrange your efforts.

3. A weekly group discussion is encouraged (but not compulsory) in the Instructor's office in the course office hour. Friday 2:30pm-5:00pm.
4. Computer simulations will be necessary for some projects. Matlab/Simulink is the preferred computing environment for these simulations. In some projects, C/C++ programming is required.
5. A CD containing the essential course materials can be borrowed from the Instructor.

Course Description:

With the advance of increasingly faster computing hardware and cheaper memory chips, *computational intelligence*, also known as a part of “*soft computation*”, a relatively new area of research, is becoming more and more important in many engineering and non-engineering disciplines including control engineering. In this information-rich world, the plant to be controlled is becoming more and more complex and control objective is given in a more and more “high-level” fashion – not just the “zero steady state error”, “smaller overshoot” or the like requirements. The performance is usually multi-objective. There is another concern about the prior knowledge about the plant and about how to better control the complicated system. In practice, we know that, usually, there do exist some rules or site knowledge from the site-operators about the system and the control. However, these rules, usually linguistic, may contain certain fuzziness.

Therefore, new computational tools are needed to effectively design the controller to achieve the multi-objective performance indices with significant uncertainties, nonlinearities, and fuzziness in the description of the model of the plant to be controlled.

Computational Intelligence is a collection of the possible computational tools to solve the above problems in control engineering. This course will equip the student with the essential knowledge and useful resources to solve some of the systems control problems not easily solved using previously learned conventional control methods. Specifically, this course will focus on the following

1. Using NN/FL to model the complex static/dynamic systems;
2. Using NN/FL as a tool to construct the complex nonlinear controller to better control the complex dynamic systems;
3. Using EC as a tool to perform the multi-objective design of controllers.
4. Gain hands-on experience on MATLAB toolboxes for NN and FL to solve practical control design problems.
5. Gain hands-on experience on MO EC for controller design.
6. Survey on the state-of-art applications of Computational Intelligence in control engineering.
7. Get familiar with the Internet resources on computational intelligent related to control engineering.

For ECE6930 level, we shall focus on NN and FL and the survey on their applications in systems control.

Text: No formal single textbook available for this course. For each part, several reference textbooks will be designated as follows¹:

¹ [1],[2],[5],[7],[8] can be borrowed from the Instructor. [10] is available from Prof. Haupt, Head of the ECE Dept. of USU.

Note: Before you decide to invest your time in any specific book for this course study, please consult the Instructor first.

Overview Textbooks:

[1]. Robert E. King. “*Computational Intelligence in Control Engineering*”. Marcel Dekker, Inc. New York. Control Engineering Series of Reference Books and Textbooks, Neil Munro Editor. 1999 (ISBN 0-8247-1993-X). (295 pages)

<http://www.lar.ee.upatras.gr/reking/compuint.htm>

[2] Yong-Zai Lu. “*Industrial Intelligent Control: Fundamentals and Applications*”. John Wiley and Sons, Chichester. 1996. (ISBN 0-471-95058-0) (325 pages)

NN: Neural Networks Textbooks:

[3]. YangQuan Chen and Dingyu Xue (Eds.): “*Fundamentals On Which Neural Net Works*”. Nov. 2001. (Internal Lecture Notes, 604 pages, PDF file available)

[4]. YangQuan Chen and Dingyu Xue (Eds.): “*Further Topics on Artificial Neural Networks*”. Nov. 2001. (Internal Lecture Notes, 580 pages, PDF file available)

[5]. Simon Haykin. “*Neural Networks – a comprehensive foundation*” (2nd Ed.) Prentice Hall, Upper Saddle River, NJ 07458. 1999. (ISBN 0-13-273350-1) (842 pages).

[6]. Magnus Nørsgaard, Ole Ravn, Niels K. Poulsen and Lars K. Hansen. “*Neural Networks for Modelling and Control of Dynamic Systems*” Springer-Verlag, London, 2000. (Advanced Textbook Series in Control and Signal Processing)

<http://www.iau.dtu.dk/nbook/>

FL: Fuzzy Logic Textbooks:

[7] Kevin M. Passino and Stephen Yurkovich. “*Fuzzy Control*”. Addison-Wesley – an Imprint of Addison-Wesley Longman, Inc. 1998. (ISBN 0-201-18074-X) (475 pages)

[8] J.-S. R. Jang, C.-T. Sun, and E. Mizutani. “*Neuro-Fuzzy and Soft Computing – a computational approach to learning and machine intelligence*”. MATLAB Curriculus Series. Prentice Hall, Upper Saddle River, NJ 07458, 1997. (ISBN 0-13-261066-3) (614 pages) <http://neural.cs.nthu.edu.tw/jang/book/>

[9] Jerry M. Mendel. “*Uncertain Rule-Based Fuzzy Logic Systems: Introduction and New Directions: An expanded and richer fuzzy logic*”. Prentice Hall. 2001. 560 pp. ISBN: 0-13-040969-3 <http://sipi.usc.edu/~mendel/book/>

EC: Evolutionary Computation Textbooks:

[10]. R.L. Haupt and Sue Ellen Haupt, Practical Genetic Algorithms, New York: John Wiley & Sons, 1998. <http://www.engineering.usu.edu/ece/faculty/randy/gabook.html>

[11]. Carlos A. Coello Coello, David A. Van Veldhuizen, Gary B. Lamont. “*Evolutionary Algorithms for Solving Multi-Objective Problems*” Series: GENETIC ALGORITHMS AND EVOLUTIONARY COMPUTATION (Volume 5). Kluwer Academic Publishers, 2002. ISBN 0-306-46762-3 (June 2002). (610 pages)

<http://www.cs.cinvestav.mx/~EVOCINV/bookinfo.html>

[12]. Other books at EvoWeb <http://evonet.dcs.napier.ac.uk/index.html>

Online Research Papers:

- <http://citeseer.nj.nec.com/>

Survival URLs:

Neural Networks:

- <http://www.iau.dtu.dk/nbook/>
- <http://www.theorem.net/theorem/neuralnets.html>
- http://www.mathtools.net/MATLAB/Neural_Networks/index.html
- <http://www.emsl.pnl.gov:2080/proj/neuron/neural/>

Fuzzy Logic:

- http://www.mathtools.net/MATLAB/Fuzzy_Logic/index.html
- <http://neural.cs.nthu.edu.tw/jang/>
- <http://sipi.usc.edu/~mendez/software/> (Type-2 fuzzy logic)
- <http://www-2.cs.cmu.edu/Groups/AI/html/faqs/ai/fuzzy/part1/faq.html>
- <http://fuzzy.iau.dtu.dk/> (username: guest; password: erudit)

Evolutionary Computation:

- <http://www.lania.mx/~ccoello/EMOO/EMOOsoftware.html>
- K. C. Tan's MOEA: <http://vlab.ee.nus.edu.sg/~kctan/moea.htm>
- Yun Li's Group: <http://www.elec.gla.ac.uk/groups/control/ieee-cacsdec/>
- <http://www.aic.nrl.navy.mil/galist/> (Please subscribe it)
- <http://evonet.dcs.napier.ac.uk/index.html>
- The Hitchhiker's Guide to Evolutionary Computation
<ftp://ftp.cerias.purdue.edu/pub/doc/EC/Welcome.html>

Journals:

IEEE Computational Intelligence Periodicals Package: (www.ieee.org)

1. IEEE Trans. On Neural Networks
(*USU SCITECH* Call #: QA 76.87 .I44)
2. IEEE Trans. On Fuzzy Systems
(*USU SCITECH* Call #: QA 248 .I43)
3. IEEE Trans. On Evolutionary Computation
(*USU SCITECH* Call #: QA76.87 I347)

IFAC Journals (www.ifac-control.org)

4. IFAC Journal: Engineering Applications of Artificial Intelligence
<http://www.elsevier.nl/locate/engappai>
(*USU SCITECH* Call #: **not subscribed**)
5. IFAC Journal: Automatica <http://www.elsevier.nl/locate/automatica>
(*USU SCITECH* Call #: TJ 212 .A74)
6. IFAC Journal: Control Engineering Practice <http://www.elsevier.nl/locate/conengprac>
(*USU SCITECH* Call #: **not subscribed**)

Other Control Journals

7. IEEE Transactions on Automatic Control
(*USU SCITECH* Call #: TJ 212 .I452)
8. IEEE Transaction on Robotics and Automation
(*USU SCITECH* Call #: TJ210.2.I332)

9. IEEE Trans. On Systems, Man, and Cybernetics, Part-B.
(USU SCITECH Call #: Q 300 .I433)
10. IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)
(USU SCITECH Call #: Q 334 .I43)
11. IEEE Transactions on Knowledge and Data Engineering.
(USU SCITECH Call #: QA 76.76 .E95I36)
12. More at <http://www.emsl.pnl.gov:2080/proj/neuron/neural/neural.journals.html>

Conferences:

- ❑ 2001 IEEE International Symposium on Computational Intelligence in Robotics and Automation (IEEE CIRA 2001) July 29 - August 1, 2001²
- ❑ <http://www.nda.ac.jp/cc/CIRA2003/>

Suggested Course Project Topics:

1. Walking Robot Analysis and Control
2. Visual Servoing Control Using Neural Network.
3. Dynamic Sensor Fusion for Mobile Robot.
4. Multi-objective (MO) PID Tuning by Evolutionary Computation (EC)
5. Nonlinear PID control by NN
6. Batch Process Control
7. Water-level control of the coupled water tanks using Fuzzy Logic.
8. Multi-objective Loop-shaping
9. Conditional integration rule-based control
10. Evolving hardware for controller implementation, etc.

Further notes:

You have the freedom to define your course project topic so as to relate it to your thesis research. However, every one in ECE7930 has to work on

- ❑ one project on NN modeling (NARMA or RBF etc),
- ❑ **and**, one project on NN-controller
- ❑ **and**, one project on FL control **or** modeling
- ❑ **and**, one project on multi-objective evolutionary computation (MOEC) for controller design (e.g. MO PID design)
- ❑ **and**, a survey on computational intelligence in control engineering

For ECE6930, one has to complete

- ❑ one project on NN modeling **or** NN-controller
- ❑ **and**, one project on FL modeling **or** FL-controller
- ❑ **and**, a survey on NN **and** FL in control engineering

Software packages will be recommended for each project – again, you have the freedom to use other software packages. Coding from scratch is discouraged.

² IEEE CIRA 2001 Conference Proceedings can be borrowed from the Instructor.

Appendix-1

Foreword of the book [1]³

by George N. Saridis, Professor Emeritus, Rensselaer Polytechnic Institute

In the last 50 years, Automatic Control Theory has developed into a well-established engineering discipline that has found application in space technology, industry, household appliances and other technological implementations. It was designed to monitor and correct the performance of systems without the intervention of a human operator. Lately, with the growth of digital computers and the universal acceptance of systems theory, it was discovered and used in softer fields of human interest such as ecology, economics, biology, etc. In the meanwhile, being a dynamic discipline, Automatic Control with the aid of the digital computer has evolved from simple servomechanisms to an autonomous self-organizing decision-making methodology that was given the name of Intelligent Control. Several manifestations of Intelligent Control have been proposed by various scientists in the literature. Fuzzy, Neural, Hierarchical Intelligent, Cerebellar and Linguistic control systems are typical examples of such theoretically developed Intelligent Controls.

However, the application of such sophisticated methodologies to real life problems is far behind the theory. The areas with the highest need and the smallest tolerance for adopting the techniques resulting from such theoretical research are the industrial complexes. The main reason is the lack of suitable intelligent computational algorithms and interfaces designed especially for their needs. This book attempts to correct this by first presenting the theory and then developing various computational algorithms to be adapted for the various industrial applications that require Intelligent Control for efficient production.

The author, who was one of the first to actually implement Intelligent Control in industry, accomplishes this goal by developing step by step some of the most important Intelligent Computational Algorithms. His industrial experience, coupled with a strong academic background, has been channeled into creating a book that is suitable for graduate academic education and a manual for the practicing industrial engineer. Such a book fills a major gap in the global literature on Computational Intelligence and could serve as a text for the developing areas of biological, societal and ecological systems. I am very proud to introduce such an important work.

³ I'm writing a book review for this book. Feedback comments from the class are welcome.