Intelligent Control (0640734)

Lecture (1)

Intelligent Control Systems: An Introduction

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Course Title: Intelligent Control Systems

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Semester: First, 2020-2021

Time: (12:00-15:00) Saturday.

Office Hours: (13:00-15:00) Wednesday.

Appointments to discuss the course should be made by email.

Course Material:

http://www.philadelphia.edu.jo/academics/kaubaidy/page.php?id=7

Course Description:

Industrial systems are complex and have nonlinear behaviors, therefore, new methodologies are required to design and develop intelligent controllers. Intelligent control systems are becoming very important for both academia and industry. Control methodologies are required to improve the performance of control complex and nonlinear systems. These controller are based on soft computing tools such are fuzzy logic, neural network and evolutionary computation.

Lectures: 45 hours/semester, 3 hours/week.
Homework and assignments: 4
Semester project: 2 projects for each student .

Course Objectives:

The main objective of this course is to :

- Provide a general introduction to intelligent systems .
- Provide examples of rule-based control systems.
- Describe design requirements of intelligent controllers.
- Study a range of methodologies for specifying and designing intelligent systems.
- Understand control methodologies developed using soft computing tools such as fuzzy logic, neural nets and GAs.
- Describe and apply systems engineering methods and techniques in the design and analysis of intelligent control systems for mechatronics applications.
- The course will involve several design projects.

Prerequisites:

Students are expected to be familiar with control systems, artificial intelligence, systems design and implementation, programming with machine language and C++, systems modeling and simulation techniques.

Intended Learning Outcomes:

On completing the course, students will enable to have to following skills:

Knowledge and understanding:

A1. Know the advantages and drawbacks of intelligent controllers and therefore when to apply them

A2. Understand how to derive, develop, and apply intelligent controllers

Intellectual skills:

B1 Comprehend advanced mathematical models and intelligent systems

B2. Design intelligent systems for various applications.

Professional and practical skills

C1. Simulate and analyze responses to advanced controller concepts

C2. Apply intelligent controllers to physical systems

General and transferrable skills

D1. Apply intelligent decision making techniques to engineering systems

D2. Optimize system performance.

Grades:

Assignments, Project & Presentation:	20%,
Mid Exam:	30%
Final Exam:	50%

Projects:

- Define your own project and write a proposal.
- Experimental investigation requires a programming project and a final report.
- Final report contents: Project title, Objective, Introduction, Hardware design, Software design, Conclusion, References.
- Team projects are allowed, but they must be significant!

Timetable:

Week	Material to be covered	Task
1	An introduction to classical and intelligent control systems.	
2	Intelligent systems and applied artificial intelligence.	
3	Artificial neural networks: fundamentals.	HW1
4	Intelligent control concepts.	Project Selection
5	Artificial neural networks: architectures	Assignment1
6	Artificial neural networks: applications.	Project (Phase1)
7	Introduction to fuzzy logic.	Mid Exam
8	Fuzzy control and stability.	HW2
9	Control applications of fuzzy logic.	Assignment2

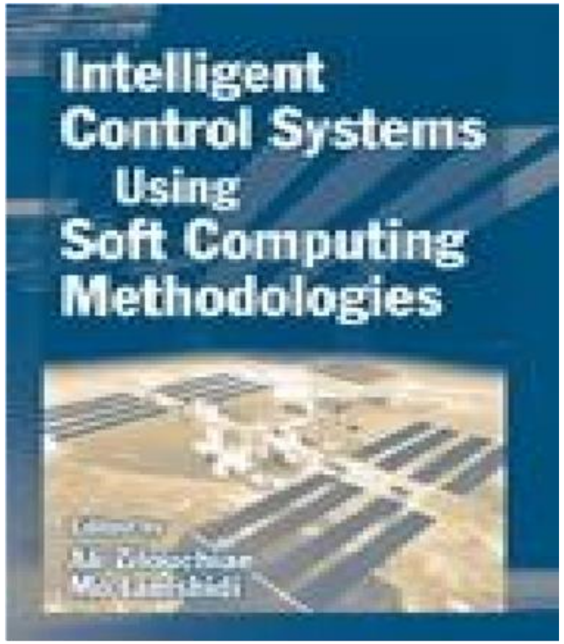
Timetable:

Week	Material to be covered	Task
10	Neuro-fuzzy controller: theory and design.	
11	Neuro-fuzzy controller: applications.	Assignment3
12	Probabilistic and evolutionary algorithms.	
13	Optimization of intelligent systems using GA.	Project (Phase2)
14	Intelligent control systems: research paper analysis	
15	Intelligent control systems: design methods.	Project (Phase3)
16	Mini Projects	Final Exam

Text Books:

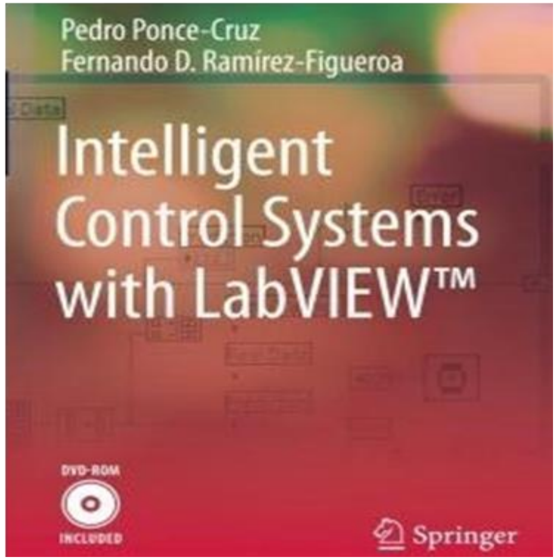
1. **Intelligent Control Systems Using Soft Computing Methodologies,** By: Ali Zilouchian & Mo Jamshidi, CRC Press, 2001, ISBN:0-8493-1875-0. Available online:
   https://b-ok.asia/book/593496/3c6d6e?regionChanged=&redirect=7850341

- ✓ This book comprises most of the lecture notes for the course and is required reading for all students.
- ✓ All selected material in this book is examinable.



2. **Intelligent Control Systems with LabVIEW**, By: Pedro Ponce-Cruz, Fernando D. Ramírez-Figueroa, Springer, 2010, ISBN 978-1-84882-683-0. Available online:
   https://b-ok.asia/book/812190/493ebf?regionChanged=&redirect=7855146

- ✓ This book is optional, but provides further detail on the practical aspects of the course.

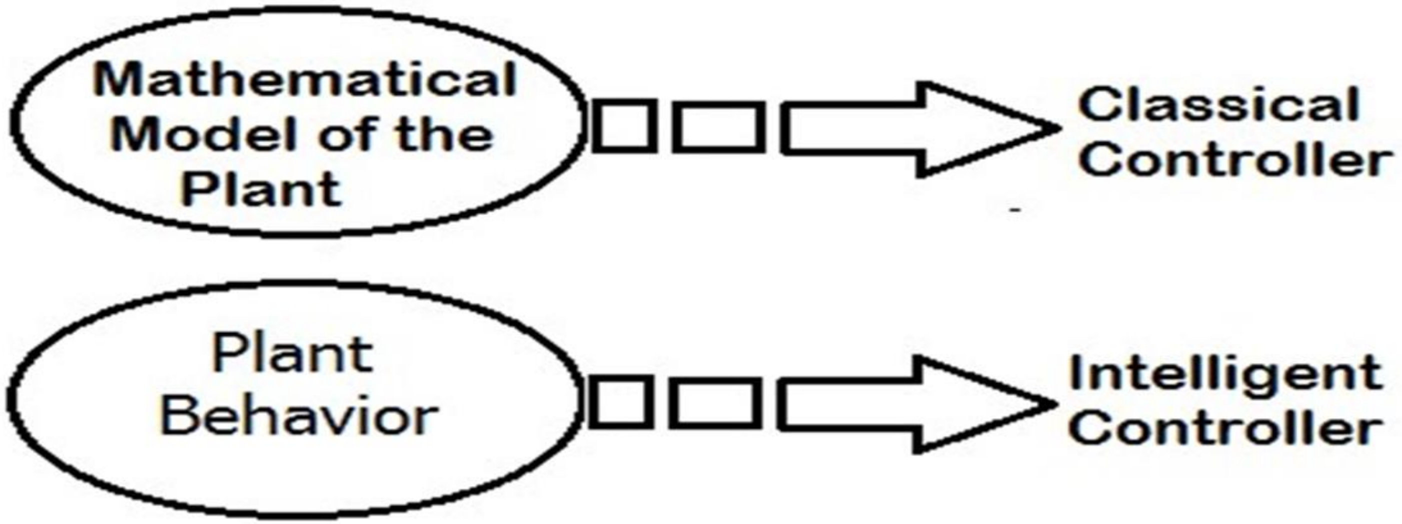


Why Intelligent Control Systems?

- Control systems theory has always been at the heart of Mechatronics.
- Many control methods have been developed, each has its own advantages and disadvantages.
- Control methods can be divided into two categories:
  - ✓ Classical Control; obtain a model of the plant to be controlled!
  - ✓ Intelligent Control; does not need to know all about the plant to be controlled.
- Mechatronics are complex systems.

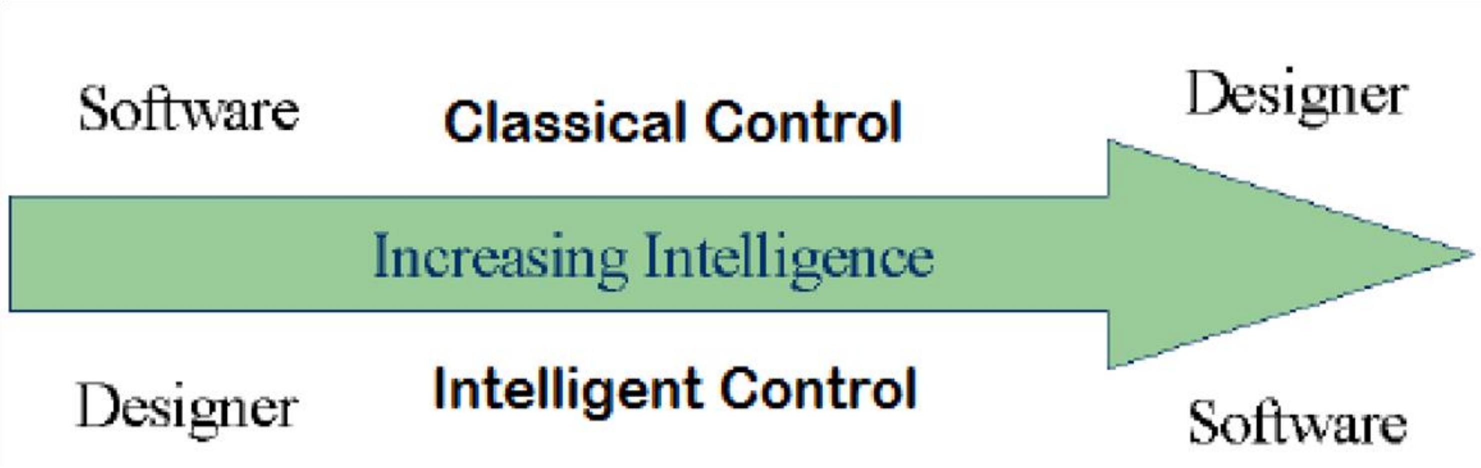
Distinguishing between Classical and Intelligent Control:

- The mathematical approach is used in developing a classical control system, the designer must mathematically model the plant.
- In developing an intelligent control, the designer doesn’t need to know the model of the plant to be controlled, only the plant behavior is required. In many cases, the plant may be too complex to be modeled.



Classical and Intelligent Control:

- For classical control, the designer must model the plant and therefore the intelligence (or knowledge) lies with him. The intelligence is shifted towards the designer.
- For intelligent control, the software abstractly models the plant and therefore the intelligence (or knowledge) lies with it. The intelligence is shifted towards the software.



Classical and Intelligent Control:

	Classical Control	Intelligent Control
Basic Concept	Mathematical Modeling - Designer designed the system which includes system dynamics	Abstract Modeling - Designer input the behavior to the system and then system attempt to abstractly define the system
Characteristics	Need to know prior information about the system dynamics	Does not need to know all about the system dynamics and conditions
	Suitable for system that can be easily model	Appropriate for complex system
Examples of Methods	Open loop system	Fuzzy logic
	Closed loop system	Artificial Neural Network
	System Modeling	Genetic Algorithm
		Support vector machine
		Swarm Intelligence
		Particle Intelligence

Classical Control Methodology:

Solve the control problem by doing the following steps:

- Develop a model of the plant to be controlled.
- Design a controller using the mathematical model.
- Study plant performance using the mathematical model of the closed loop system.
- Implement the controller and evaluate the performance of the closed loop system (again, possibly leading to redesign).

Methods for Classical Control:

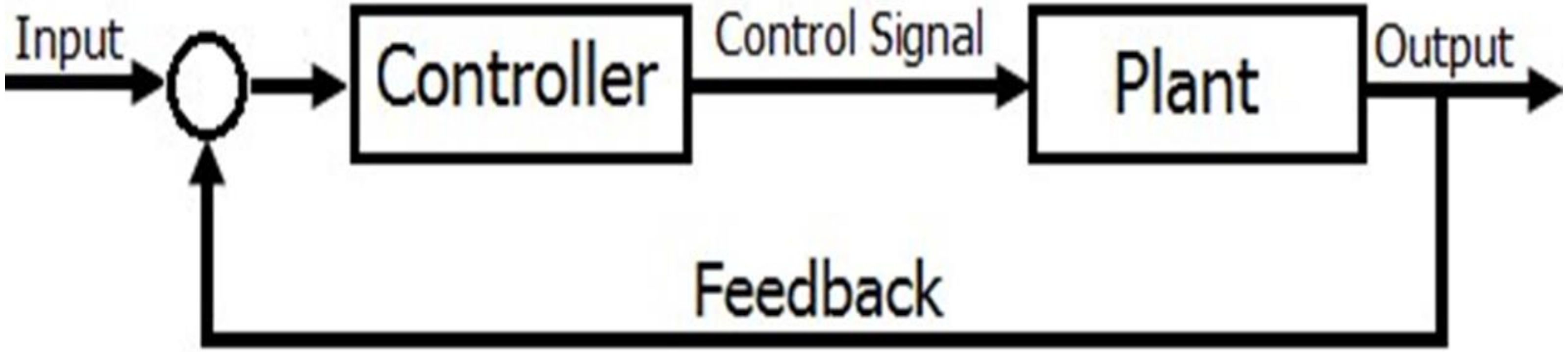
Open-Loop Control System:

A signal is sent to a plant in order to make it move to a certain position. There is no relationship or feedback from the plant to ensure that it went to the desired position.

Methods for Classical Control:

Closed-Loop Control System:

The difference between the desired position and actual position is used by the controller to generate a control signal to the plant. There is feedback from the plant to ensure that it went to the desired position.



Methods for Intelligent Control:

No System Modeling:

The designer only has to input the appropriate stimuli to the intelligent control and evaluate it on its output.

The intelligent control itself develops a model of the system to be controlled.

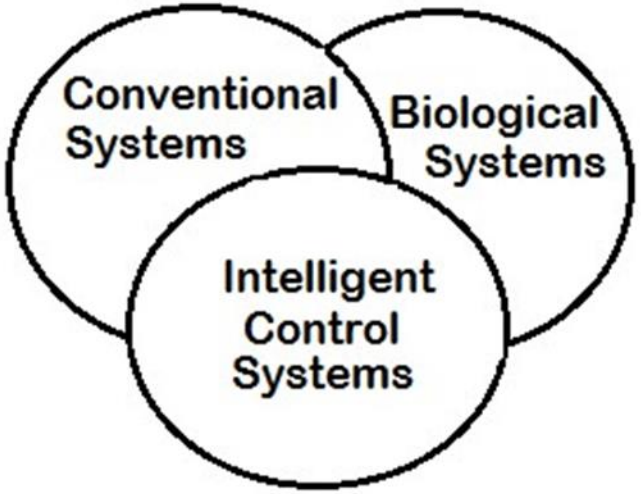
Humans can perform complex tasks without knowing exactly how they do them.

The types of intelligent control includes: fuzzy logic, artificial neural networks, genetic programming, and others.

Definition of intelligent systems:

Intelligence is a mental quality that consists of the abilities to;

- learn from experience,
- adapt to new situations,
- understand and handle abstract concepts, and
- use knowledge to manipulate one's environment.



Artificial Intelligence (AI):

AI is defined as "the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings".

- The definition of **intelligent systems** is a function of expectations and the status of the present knowledge: perhaps the *"intelligent systems" of today are the "classical systems" of tomorrow.*

Definition of intelligent systems:

- During the last four decades, researchers have proposed many model-based control strategies that involve various phases such as modeling, analysis, simulation, implementation and verification.
- Zadeh has considered this decade as the era of intelligent systems

  "I believe the system analysis and controls should embrace soft computing and assign a higher priority to the development of methods that can cope with imprecision, uncertainties and partial truth."
- Intelligent control is designed to seek control methods that provide a level of intelligence and autonomy in the control decision that allows for improving the system performance.

Soft computing & Hard computing:

- In hard computing, the prime objectives of the computations are precision and certainty.
- In soft computing, the precision and certainty carry a cost.
- Therefore, it is realistic to consider the integration of computation, reasoning, and decision making in order to provide a framework for the trade off between precision and uncertainty.
- The principal partners in such a consortium are fuzzy logic, neural network computing, generic algorithms and probabilistic reasoning as well as their integration.
- Intelligent systems underlie what is called “soft computing.”

Soft computing Tools:

- Soft computing tools are commonly used to enhance AI and incorporate human expert knowledge in computing processes.
- Their applications include the design of intelligent autonomous systems (controllers) and dealing with unknown parameters.
- Soft computing can:
  - ✓ learn from experience,
  - ✓ universalize into domains where direct experience is absent,
  - ✓ can perform mapping from inputs to the outputs faster than serial analytical representations by using parallel computer architectures that simulate biological processes.
- Intelligent control techniques that emulate characteristics of biological systems offer opportunities for creating control products with new capabilities.

Soft computing & Hard computing:

- Intelligent control has different tools for emulating the biological behavior that could solve problems as human beings do. The main tools for IC are;
  - ✓ Fuzzy logic systems are based on the experience of a human operator, expressed in a linguistic form (IF–THEN rules).
  - ✓ Artificial neural networks emulate the learning process of biologic neural networks, so that the network can learn different patterns using a training method, supervised or unsupervised.
  - ✓ Evolutionary methods are based on evolutionary processes such as natural evolution. These are essentially optimization procedures.
- Predictive methods are mathematical methods that provide information about the future system behavior.

Design of Intelligent Control Systems:

- The study of intelligent control systems requires;
  - ✓ defining some important expressions that clarify these systems,
  - ✓ understanding the desired application goals, and also
  - ✓ understanding different tools of soft computing.

- Several software development platforms are used for developing intelligent control systems. The LabVIEW is one of the most important software platforms used by researchers for developing engineering applications and could be connected with different hardware systems, as well as running standalone programs for simulating the controller's performance (validating the controller by simulation then implementing it). In addition, LabVIEW is a graphical program that is very easy to learn.

Soft computing Tools:

Neural Networks:

- For many decades, it has been a goal of engineers and scientists to develop a machine with simple elements similar to one found in the human brain.
- Artificial neural networks (ANNs) are composed of many simple elements emulating various brain activities and operating in parallel. The network function is determined largely by the connections between these elements. Neural networks can be trained to perform complex functions due to the nature of their nonlinear mappings of input to output data set.
- Recently, the NN has been applied successfully to many fields of Engineering.

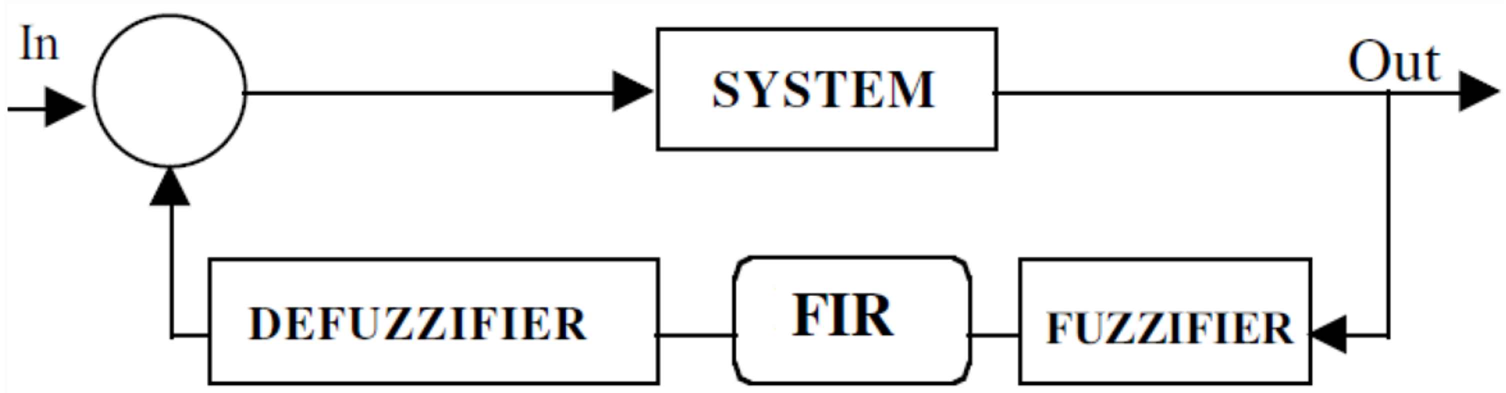
Soft computing Tools:

Fuzzy Logic:

- The first paper in fuzzy set theory was written by Zadeh in 1965. In this paper he was implicitly advancing the concept of human approximate reasoning to make effective decisions on the basis of available imprecise linguistic information.
- The first implementation of Zadeh's idea was accomplished in 1975 by Mamdani, and demonstrated the viability of fuzzy logic control for a small model steam engine.
- After this pioneer work, many consumer products as well as other high tech applications using fuzzy technology have been developed.

Why Fuzzy Logic Control?

- FL provides a framework for both information and knowledge-based systems. So called knowledge-based methodology is much closer to human thinking and natural language than the traditionally classical logic.
- FL controller utilizes fuzzy logic to convert the linguistic control strategy based on expert knowledge into an automatic control strategy.



Soft computing Tools:

Evolutionary Computation:

There are various approaches to evolutionary optimization algorithms including evolution concept, genetic programming and genetic algorithms. These algorithms are similar in their basic concepts of evolution and differ in their approach to parameter representation.

Genetic Algorithm (GA) is an evolutionary algorithm which has performed well in noisy, nonlinear and uncertain processes. GAs are desirable tools for optimizing problems with exceeding complexity.

Genetic Programming (GP) is a symbolic-based nonlinear optimization. The GP paradigm computationally simulates the Darwinian evolution process by applying fitness-based selection and genetic operators to a population of parse trees of a given programming language. It departs from the conventional GA primarily with regard to its representation scheme.

Soft computing Tools: Hybrid Systems:

- Fuzzy logic, neural networks and evolutionary computations are complementary methodologies in the design and implementation of IC systems.
- Each approach has its merits and drawbacks. To take advantage of the merits and eliminate their drawbacks, several integration of these methodologies have been proposed;
  1. **Neuro-fuzzy systems:** provide the fuzzy systems with automatic tuning systems using NN as a tool.
  2. **Fuzzy neural network:** retain the functions of NN with fuzzification of some of their elements. For instance, fuzzy logic can be used to determine the learning steps of NN structure.
  3. **Fuzzy-neural hybrid systems:** utilize both fuzzy logic and neural networks in a system to perform separate tasks for decouple subsystems.
  4. **GP-Fuzzy System**, a population comprising fuzzy rule-bases (symbolic structures) that are candidate solutions to the problem, evolves in response to selective pressure induced by their relative success at implementing the desired behavior.

Controller Design Constraints:

Cost: What is the total cost to implement the controller?

Time: How much time will it take to develop the controller?

Complexity: How much computation power and memory size will it take to implement the controller?

Manufacturability: Does the designed controller need special requirements?

Reliability: What is its “mean time between failures?”

Adaptability: Can the proposed design be adapted to other similar applications.

References:

1. Gupta, M. and Sinha, N. (eds.), Intelligent Control Systems: Theory and Applications, IEEE Press, Piscataway, NJ, 1996.
2. Lime, C.M. and Hiyama, T., Application of Fuzzy Control to a Manipulator, IEEE Trans. on Robotics and Automation, Vol. 7, 5,1991.
3. Li, W., Neuro-Fuzzy Systems for Intelligent Robot Navigation and Control Under Uncertainty, Proc. of IEEE Robotics and Automation Conf., 1995.
4. Nedungadi, A., Application of Fuzzy Logic to Solve the Robot Inverse Kinematic Problem, Proc. of Fourth World Conf. on Robotics Research, 1, 1991.
5. Jang, J., Sun, C., and Mizutani, E., Neuro Fuzzy and Soft Computing, Prentice Hall, Upper Saddle River, NJ, 1997.