INSTITUTO POLITÉCNICO NACIONAL

SECRETARÍA ACADÉMICA

DIRECCIÓN DE EDUCACIÓN SUPERIOR

SYNTHESIZED SCHOOL PROGRAM

ACADEMIC UNIT: Escuela Superior de Cómputo

ACADEMIC PROGRAM: Ingeniería en Sistemas Computacionales.

LEARNING UNIT: Fuzzy Systems Applied to Engineering **LEVEL:** III

PURPOSE OF THE LEARNING UNIT:
The student builds automation and control systems engineering process based on techniques and technologies of fuzzy systems.

CONTENTS:

I. Introduction to Fuzzy Systems and Fuzzy Logic Concepts.
II. Fuzzy Sets, Fuzzy Relations, Fuzzy Graphs, and Fuzzy Arithmetic.
III. Fuzzy If-Then Rules, Fuzzy Implications and Approximate Reasoning.
IV. Fuzzy Logic in Control Engineering.
V. Hierarchical Intelligent Control.
VI. Fuzzy Logic in artificial Intelligence, Database, Information Systems, and Patter Recognition.

TEACHING PRINCIPLES:
In the unit will apply a Projects-Based learning process, through inductive, deductive and heuristic methods using analysis techniques, technical data, charts, cooperative presentation, exercise-solving and the production of the learning evidences. Moreover, an autonomous learning will be encouraged by the development of a final project.
It is the responsibility of the teacher to monitor the characteristics of both the final project as deciding the complexity of the programs carried out by fixing the time of preparation and delivery.

EVALUATION AND PASSING REQUIREMENTS:
The program will evaluate the students in a continuous formative and summative way, which will lead into the completion of learning portfolio. Some other assessing methods will be used, such as revisions, practical´s, class participation, exercises, learning evidences and a final project.

Other means to pass this Unit of Learning:

- Evaluation of acknowledges previously acquired, with base in the issues defined by the academy.
- Official recognition by either another IPN Academic Unit of the IPN or by a national or international external academic institution besides IPN with a current cooperation agreement.

REFERENCES:

- Berkan, R. C., Trubatch S. L. (1997). *Fuzzy Systems Design Principles: building fuzzy if-then rule bases*; New York – USA: IEEE PRESS, Inc. ISBN: 0-780311515. (Book in the library of the ESCOM).
- Constantin V. A. (1995). *Fuzzy Logic and Neurofuzzy Applications Explained*. United States of America: Prentice Hall PTR. ISBN 0-133684652. (Book in the library of the ESCOM).
- Lin, Chin-Teng, Lee, C. S. George. (1996). *Neural Fuzzy Systems: A neuro-fuzzy synergism to intelligent systems*. EU: Prentice Hall. ISBN 0-132351692. (Book in the library of the ESCOM).
- Ross, T. J., (2010). *Fuzzy logic with engineering applications*, (3a. Edition), EU: McGraw-Hill, Inc. 1 - 606. ISBN: 0-470743768.
- Yen, J., Langari, R. (1999). *Fuzzy Logic: Intelligence, control, and Information*. Upper Saddle River, New Jersey USA: Prentice Hall, 07458. ISBN-0-135258170. Book in the library of the ESCOM). ISBN-13: 978-1848000698.

INSTITUTO POLITÉCNICO NACIONAL

SECRETARÍA ACADÉMICA

DIRECCIÓN DE EDUCACIÓN SUPERIOR

ACADEMIC UNIT: Escuela Superior de Cómputo.
ACADEMIC PROGRAM: Ingeniería en Sistemas Computacionales
LATERAL OUTPUT: Analista Programador de Sistemas de Información.
FORMATION AREA: Professional.
MODALITY: Presence.

LEARNING UNIT: Fuzzy Systems Applied to Engineering.
TYPE OF LEARNING UNIT: Theorical - Practical, Optative.
VALIDITY: August, 2011
LEVEL: lll.
CREDITS: 7.5 Tepic, 4.39 SATCA

ACADEMIC AIM

This program contributes to the profile of graduated on Ingeniería en Sistemas Computacionales, to develop the abilities of design and implementation of fuzzy systems in Engineering for the development of computer systems in process automation, intelligent control, information systems, in pattern recognition, in data analysis and medical computing systems. It also develops strategic thinking, creative thinking, collaborative and participatory working, leadership and assertive communication.

This program relates horizontally with the learning units: Supervised Artificial Neural Networks, Genetic Algorithms, and vertically with: Unsupervised Artificial Neural Networks, Computational Intelligence in Control Engineering, Terminal Work I and Terminal Work II.

AIM OF THE LEARNING UNIT:
The student builds automation and control systems engineering process based on techniques and technologies of fuzzy systems.

CREDITS HOURS

THEORETICAL CREDITS / WEEK: 3.0

PRACTICAL CREDITS / WEEK: 1.5

THEORETICAL HOURS / SEMESTER: 54

PRACTICAL HOURS / SEMESTER: 27

AUTONOMOUS LEARNING HOURS: 54

CREDITS HOURS / SEMESTER: 81

LEARNING UNIT DESIGNED BY:
Academia de Ingeniería de software.

REVISED BY:
Dr. Flavio Arturo Sánchez Garfias.
Subdirección Académica

APPROVED BY:
Ing. Apolinar Francisco Cruz Lázaro.
Presidente del CTCE

AUTHORIZED BY: Comisión de Programas Académicos del Consejo General Consultivo del IPN

Ing. Rodrigo de Jesús Serrano Domínguez
Secretario Técnico de la Comisión de Programas Académicos

THEMATIC UNIT: I **TITLE:** Introduction to Fuzzy Systems and Fuzzy Logic Concepts.

UNIT OF COMPETENCE

The student classifies elements and basic concepts of systems based on fuzzy logic, based on the theory of fuzzy sets.

No.	CONTENTS	Teacher led-instruction HOURS		Autonomous Learning HOURS		REFERENCES KEY
		T	P	T	P	
1.1 1.1.2 1.1.3 1.1.4	Fuzzy logic. The history and motivations of fuzzy logic. Why use fuzzy logic for control? And myths about fuzzy logic. Intelligence, control and information.	1.0		2.5		1B, 2B, 7B, 10C, 11B.
1.2 1.2.1 1.2.2	Basic concepts of fuzzy logic: Introduction, two exemplary problems and toolbox of MATLAB. Introduction fuzzy set, linguistic variables and possibility distributions. Introduction fuzzy rules.	1.0	1.0	1.5	2.0	
	Subtotals:	2.0	1.0	4.0	2.0	

TEACHING PRINCIPLES

This thematic unit must start with the frame of the course and team building. Thematic unit will be addressed through the strategy of project-Based learning, using the inductive method. This unit uses learning techniques such as elaboration of worksheets, conceptual maps and cooperative presentation. Development of practice and proposal of project.

LEARNING EVALUATION

Diagnostic Test .
Project Portfolio:

Proposal of project.	10%
Reports worksheets, concept maps.	15%
Report of Practicals.	10%
Cooperative Presentation.	10%
Self-Evaluation Rubrics.	5%
Cooperative Evaluation Rubrics.	5%
Written Learning Evidence.	45%

THEMATIC UNIT: II **TITLE:** Fuzzy Sets, Fuzzy Relations, Fuzzy Graphs, and Fuzzy Arithmetic.

UNIT OF COMPETENCE

The student performs simulations of generic fuzzy inference units, based on basic concepts of sets, relations and fuzzy arithmetic.

No.	CONTENTS	Teacher led-instruction HOURS		Autonomous Learning HOURS		REFERENCES KEY
		T	P	T	P	
2.1	Classical sets and fuzzy sets.	0.5		0.5		
2.1.1	Representation and operations of fuzzy sets.					1B, 2B, 3B, 4B, 7B,10C,
2.1.2	Types of Membership functions, law of excluded middle and the law of contradiction, and hedges.	1.0		1.0		
2.2	Operations of fuzzy sets.					
2.2.1	Intersection and union of fuzzy sets.					
2.2.2	Complement of fuzzy set.					
2.3	Properties of fuzzy sets.					
2.3.1	The cardinality of fuzzy sets.	1.0	0.5	1.0	2.5	
2.3.2	Support and alpha-level cuts.					
2.3.3	Resolution identity and convex fuzzy sets.					
2.3.4	A geometric interpretation of fuzzy sets and possibility theory.					
2.4	Fuzzy relations and the compositions of fuzzy relations.	0.5		1.0		
2.5	Fuzzy graphs and fuzzy numbers.	0.5		1.0		
2.6	Function with fuzzy arguments.	0.5				
2.7	Arithmetic operations on fuzzy numbers.	0.5		0.5		
	Subtotals:	4.5	0.5	5.0	2.5	

TEACHING PRINCIPLES

This unit will be projects-Based learning strategy, using the inductive method. This unit uses learning techniques such as elaboration of worksheets, conceptual maps and cooperative presentation. Development of practice, learning evidences and advances of the project.

LEARNING EVALUATION

Project Portfolio:

Advancement Project.	15%
Reports worksheets and concept maps.	5%
Report of Practical.	15%
Cooperative Presentation.	10%
Self-Evaluation Rubrics	5%
Rubric of Co-Evaluation	5%
Written Learning Evidence	45%

THEMATIC UNIT: III **TITLE:** Fuzzy If-Then Rules, Fuzzy Implications and Approximate Reasoning.

UNIT OF COMPETENCE

The student develops fuzzy logic control systems, based on structures of fuzzy If-Then rules.

No.	CONTENTS	Teacher led-instruction HOURS		Autonomous Learning HOURS		REFERENCES KEY
		T	P	T	P	
3.1	Basics and types of fuzzy rules.	1.0		1.5		1B, 2B, 4B, 6B, 7B, 10C, 11B
3.1.1	Fuzzy mapping rules.					
3.1.2	Fuzzy implication rules.					
3.2	Fuzzy rule-based models for function approximation.	1.0		1.5		
3.2.1	Fuzzy partition, mapping a fuzzy subspace to a local model.					
3.2.2	Fusion of local models through interpolative reasoning and defuzzification.					
3.3	A theoretical foundation of fuzzy mapping rules.	1.0	0.5	1.5	2.5	
3.3.1	Types of fuzzy rule-based models.					
3.3.2	The Mamdani model and TSK model.					
3.3.3	Standard additive model.					
3.4	Fuzzy implications and approximate reasoning.	1.0	0.5	1.5	2.5	
3.4.1	Propositional logic.					
3.4.2	First-order predicate calculus.					
3.4.3	Fuzzy logic.					
	Subtotals:	4.0	1.0	6.0	5.0	

TEACHING PRINCIPLES

This unit will be projects-Based learning strategy, trough deductive methods, with the techniques of elaboration of worksheets, conceptual maps and exercise-solving. Cooperative presentation. Development of practical, the productions of the learning evidences and advance of the project.

LEARNING EVALUATION

Project Portfolio:

Advance of the Project.	15%
Reports concept maps and exercise-solving.	5%
Report of Practical.	15%
Cooperative Presentation.	15%
Cooperative Evaluation Rubrics.	5%
Rubric of Co-Evaluation.	5%
Written Learning Evidence	40%

THEMATIC UNIT: IV **TITLE:** Fuzzy Logic in Control Engineering.

UNIT OF COMPETENCE

The student applies different methods of fuzzy logic to solve control engineering problems, based on development tools and visual programming technologies.

No.	CONTENTS	Teacher led-instruction HOURS		Autonomous Learning HOURS		REFERENCES KEY
		T	P	T	P	
4.1	Introduction and fundamental issues in control engineering.	0.5		0.5		1B, 2B, 5B, 6B, 8B, 10C, 11B
4.2	Control design process.	1.5		1.5		
4.2.1	Selection of design methodology.					
4.2.2	Determination of technical design objectives.					
4.2.3	Development of the plant model.					
4.2.4	Control design and example.					
4.3	Semiformal aspects of the design process.	0.5		1.0		
4.3.1	Fuzzy logic control.					
4.3.2	Mamdani Architecture for fuzzy control.					
4.4	Design of a generic Mamdani type fuzzy controller.	1.5	0.5	1.5	2.5	
4.4.1	Derivation of the rules.					
4.4.2	Determining the normalization factors.					
4.4.3	Evaluation of the generic Mamdani controller.					
4.4.4	Extending the generic Mamdani controller.					
4.4.5	Additional design examples.					
4.5	The Sugeno-Takagi architecture.	1.5	0.5	1.5	2.5	
	Subtotals:	5.5	1.0	6.0	5.0	

TEACHING PRINCIPLES

This unit will be projects-Based learning strategy, trough heuristic methods, with the techniques of elaboration of worksheets, conceptual maps and cooperative presentation. Development of practical, the production of the learning evidences and advance of the project

LEARNING EVALUATION

Portfolio of Evidences:

Advance of the Project.	20%
Reports of worksheet and concept maps.	5%
Report of Practical.	15%
Cooperative Presentation.	10%
Self-Evaluation Rubrics.	5%
Cooperative Evaluation Rubrics.	5%
Written Learning Evidence	40%

THEMATIC UNIT: IV **NAME:** Hierarchical Intelligent Control.

UNIT OF COMPETENCE

The student experience different types of hierarchical control, based on the theory of fuzzy logic and control strategies.

No.	CONTENTS	Teacher led-instruction HOURS		Autonomous Learning HOURS		REFERENCES KEY
		T	P	T	P	
5.1 5.1.2 5.1.3 5.1.4	Introduction to intelligent control. Architecture of hierarchical control. Implementation issues and the role of fuzzy logic. Other Hierarchical architectures.	0.5		1.5		1B, 2B, 3B, 5B, 7C, 8C.
5.2 5.2.1 5.2.2	Fuzzy logic in hierarchical control. Fuzzy logic-based gain scheduling and autotuning. Fuzzy logic-based mode fusion of low-level controllers.	1.0	0.5	1.0	1.0	
5.3 5.3.1 5.3.2 5.3.3	Case Studies. Hierarchical controller for GE`s recuperative turboshaft engine. Autotuning a PID controller. Fuzzy logic-based parameter optimizer in a hierarchical process control system.	1.0		1.0		
5.4	Control strategy in fuzzy control.	0.5		1.5		
	Subtotals:	3.0	0.5	5.0	1.0	

TEACHING PRINCIPLES

This unit will be projects-Based learning strategy, trough heuristic methods, with the techniques of elaboration of conceptual maps and cooperative presentation. Development of practical, the productions of the learning evidences and advance of the project.

LEARNING EVALUATION

Project Portfolio:

Advance of the Project.	20%
Reports of concept maps.	5%
Report of Practical.	20%
Cooperative Presentation.	15%
Self-Evaluation Rubrics.	5%
Cooperative Evaluation Rubrics.	5%
Written evidence of learning	30%

N° THEMATIC UNIT: VI **TITLE:** Fuzzy Logic in artificial Intelligence, Database, Information Systems, and Pattern Recognition.

UNIT OF COMPETENCE

The student design expert systems, pattern recognition systems and information systems based on fuzzy and neurofuzzy systems.

No.	CONTENTS	Teacher led-instruction HOURS		Autonomous Learning HOURS		REFERENCES KEY
		T	P	T	P	
6.1.	Artificial Intelligence.	0.5		1.5		
6.1.1	Fuzzy logic in frame-based representation.					1B, 3B, 4B, 5B, 7C, 8C
6.1.2	Fuzzy logic in expert systems and intelligent agents.					
6.1.3	Fuzzy logic in mobile robot navigation.		0.5		1.0	
6.1.4	Fuzzy logic in emotional intelligent agents and some applications.					
6.2	Fuzzy logic in database and information systems.	0.5		1.5		
6.2.1	Fuzzy logic in database systems.					
6.2.2	Fuzzy relational data model and its operations.					
6.2.3	Design theory for fuzzy relational databases.					
6.2.4	Fuzzy object - oriented databases.					
6.3	Fuzzy logic in pattern recognition.	1.0	0.5	2.0	2.5	
6.3.1	Unsupervised clustering.					
6.3.2	Fuzzy c-means algorithm.					
6.3.3	Classifier design.					
6.3.4	Supervised pattern recognition.					
6.4	Applications in medical image segmentation.	0.5	0.5	1.5	2.5	
	Subtotals:	2.5	1.5	6.5	6.0	

TEACHING PRINCIPLES

This unit will be projects-Based learning strategy, using the heuristic methods, with the techniques of elaboration of worksheet, conceptual maps and cooperative presentation. Development of practicals, and Final Project Report.

LEARNING EVALUATION

Portfolio of Evidences:

Final Project.	20%
Reports of worksheet and concept maps.	10%
Report of Practical.	25%
Cooperative Presentation.	5%
Self-Evaluation Rubrics.	5%
Cooperative Evaluation Rubrics.	5%
Written Learning Evidence	30%

RECORD OF PRACTICALS

No.	NAME OF THE PRACTICAL	THEMATIC UNITS	DURATION	ACCOMPLISHMENT LOCATION
1	Introduction to the tools of fuzzy system design with Matlab and Aptronix.	I	3.0	Computer Labs.
2	Basic concepts in fuzzy systems.	II	3.0	
3	Types of fuzzy rules and defuzzification.	III	3.0	
4	Fuzzy implication and approximate reasoning.	III	3.0	
5	Fuzzy Logic Control of Mamdani type.	IV	3.0	
6	Characteristics of the Sugeno-Takagi architecture and its applications	IV	3.0	
7	Design and programming of hierarchical control systems.	V	1.5	
8	Mobile robot navigation using fuzzy logic.	VI	1.5	
9	Fuzzy expert systems in medicine.	VI	3.0	
10	Pattern recognition using fuzzy logic.	VI	3.0	
		TOTAL OF HOURS	27.0	

EVALUATION AND PASSING REQUIREMENTS:
The practical are considered mandatory to pass this unit of learning.
The practices contribute 10% of the grade of thematic unit I.
The practices contribute 15% of the grade of thematic unit II.
The practices contribute 15% of the grade of thematic unit III.
The practices contribute 15% of the grade of thematic unit IV.
The practices contribute 20% of the grade of thematic unit V.
The practices contribute 25% of the grade of thematic unit VI.
These practices are considered a prerequisite for establishing the learning unit.
The practices contribute 20% of the final grade.
Laboratory work is evaluated based on the written report.
The criteria for evaluation of the practices are: objective, introduction and description of the topic, test simulations and / or programs carried out, theoretical solution or desktop test, source code, screens execution, results analysis, conclusions and references.

PERIOD	UNIT	EVALUATION TERMS
1	I y II	Continuous evaluation 55% and written learning evidence 45%
2	III y IV	Continuous evaluation 60% and written learning evidence 40%
3	V y VI	Continuous evaluation 70% and written learning evidence 30%
		The learning unit I and II is 30% worth of the final score The learning unit III is 35% worth of the final score The learning unit IV is 35% worth of the final score Other means to pass this Learning Unit: • Evaluation of acknowledges previously acquired, by developing a computer program and a written evidence of learning. • Official recognition by either another IPN Academic Unit of the IPN or by a national or international external academic institution besides IPN agreement which has. If accredited by Special Evaluation or a certificate of proficiency, this will include a practical part which contribute 50% of the grade and a theoretical part that will provide the remaining 50%, based on guidelines established by the academy.

CLAVE	B	C	BIBLIOGRAFÍA
1	X		Berka, R. C. Trubatch S. L. (1997). *Fuzzy systems design principles: Building fuzzy if-then rule bases*. New York–USA: Wiley-IEEE PRESS, Inc. ISBN: 0-780311515.
2	X		Constantin, V. A. (1995). *Fuzzy logic and neurofuzzy applications explained*. United States of America: Prentice Hall PTR. ISBN 0-133684652.
3	X		Di Gesu, V., Masulli, F., Petrosino, A., (2006). *Fuzzy Logic and applications: 5th internacional workshop, WILF 2003, Naples, Italy, October 2003, revised selected papers*. 1ª. Edición, Springer, 1- 342. ISBN 3-540310193.
4		X	Kosko, B. (1992). *Neural networks and fuzzy systems: A dynamical systems approach to machine intelligence*. E.U: Prentice Hall. Englewood Cliffs. ISBN 0-136114350.
5	X		Leiviska, K., (2010). *Industrial applications of soft computing: paper, mineral and metal processing industries*. Physica-Verlag HD. 1 – 227. ISBN 3-790824887.
6	X		Lin, Chin-Teng, Lee, C. S. George. (1996). *Neural Fuzzy Systems: A neuro-fuzzy synergism to intelligent systems*. EU: Prentice Hall. ISBN 0-132351692.
7	X		Ross, T. J., (2010). *Fuzzy logic with engineering applications*, (3ª. edition), EU: McGraw-Hill, Inc. 1 - 606. ISBN: 0-470743768.
8		X	Shaw, I. S., (2010). *Fuzzy control of industrial systems: theory and applications*. 1ª. Edición, Springer, EU, 1 – 224. ISBN 1441950559.
9		X	Teodorescu, H. N., Kandel, A., Jain, L. C., (1999). *Fuzzy and nuero-fuzzy systems in medicine*. 1ª. Edición, CRC Press LLC, EU, 1- 394. ISBN 0-849398061.
10		X	Wesley, H. J., (1997). *MATLAB SUPPLEMENT TO Fuzzy and Neural Approaches in Engineering*. John Wiley & Sons, Inc., New York, EU, 1-210. ISBN 0-471192473.
11	X		Yen, J., Langari, R. (1999). *Fuzzy logic: intelligence, control, and information*. Prentice Hall, Upper Saddle River, New Jersey, EU, 07458. 1 - 558. ISBN 0-135258170

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SECRETARÍA ACADÉMICA

DIRECCIÓN DE EDUCACIÓN SUPERIOR

TEACHER EDUCATIONAL PROFILE PER LEARNING UNIT

1. GENERAL INFORMATION

ACADEMIC UNIT: Escuela Superior de Cómputo.

ACADEMIC PROGRAM: Ingeniería en Sistemas Computacionales **NIVEL** III

FORMATION AREA:

Institutional	Basic Scientific	Professional	Terminal and Integration

ACADEMY: Ingeniería de Software **LEARNING UNIT:** Fuzzy Systems Applied to Engineering

SPECIALTY AND ACADEMIC REQUIRED LEVEL: Masters Degree or Doctor in Electric Engineering or Computer Science

2. AIM OF THE LEARNING UNIT:

The student builds automation and control systems engineering process based on techniques and technologies of fuzzy systems.

3. PROFFESSOR EDUCATIONAL PROFILE:

KNOWLEDGE	PROFESSIONAL EXPERIENCE	ABILITIES	APTITUDES
• Concepts of fuzzy set theory. • Concepts of fuzzy logic theory. Main components of a fuzzy system. • Troubleshooting process automation and control, information systems and pattern recognition. • Knowledge of the Institutional Educational Model. • English.	• In teaching as a facilitator of knowledge higher level of two years. • In the management of laboratory computers for one year. • Experience in the design and implementation of fuzzy systems. • Experience in group management and collaborative work.. • Two year experience in the Institutional Educational Model.	• Ability to manage groups. • Teaching skills. • Ability to design and building automation systems, intelligent control and fuzzy systems. • Capacity for analysis and synthesis. • Ability to solve problems. • Ease of teamwork and leadership. • Applications of institutional educational model.	• Responsible. • Tolerant. • Honest. • Respectful. • Collaborative. • Participative. • Interested to learning. • Assertive

DESIGNED BY	REVISED BY	AUTHORIZED BY
M. en C. Edmundo René Durán Camarillo. COORDINATING PROFESOR M. en C. José Luis Calderón Osorno M. en C. Ignacio Ríos de la Torre COLLABORATING PROFESSORS	Dr. Flavio Arturo Sánchez Garfias SUBDIRECTOR ACADÉMICO	Ing. Apolinar Francisco Cruz Lázaro DIRECTOR

Date: 2011