AD4701 NEURO-FUZZY COMPUTING

Corresponding Lab, with code (If any): -
Course Prerequisites: -
Course Outcomes

AD4701	NEURO-FUZZY COMPUTING	L T P
	(Common to IT & CSE)	3 0 0

UNIT – I	ARTIFICIAL NEURAL NETWORK

Review of fundamentals – Biological neuron, artificial neuron, activation function, single layer perception – Limitation – Multilayer perception – Back Propagation Algorithm (BPA) – Recurrent Neural Network (RNN) – Adaptive Resonance Theory (ART) based network – Radial basis function network – online learning algorithms, BP through time – RTRL algorithms – Reinforcement learning

UNIT – II	NEURAL NETWORKS FOR MODELING AND CONTROL

Modelling of non-linear systems using ANN – Generation of training data – Optimal architecture–Model validation – Control of non-linear systems using ANN – Direct and indirect Neuro control schemes – Adaptive Neuro controller – Familiarization with neural network toolbox

UNIT - III	FUZZY SET THEORY

Fuzzy set theory – Fuzzy sets – Operation on fuzzy sets – Scalar cardinality, fuzzy cardinality, union and intersection, complement (Yager and Sugeno), equilibrium points, aggregation, projection, composition, cylindrical extension, fuzzy relation – Fuzzy membership functions

UNIT - IV	FUZZY LOGIC FOR MODELING AND CONTROL

Modelling of non-linear systems using fuzzy models – TSK model – Fuzzy logic controller – Fuzzification – Knowledge base – Decision making logic – Defuzzification – Adaptive fuzzy systems – Familiarization with fuzzy logic toolbox

UNIT - V	HYBRID CONTROL SCHEMES

Fuzzification and rule base using ANN – Neuro fuzzy systems – ANFIS – Fuzzy neuron– Introduction to GA – Optimization of membership function and rule base using Genetic Algorithm – Introduction to support vector machine – Particle swarm optimization – Case study – Familiarization with ANFIS toolbox

Total Periods:45

TEXT BOOKS

1. Laurence Fausett, “Fundamentals of Neural Networks”, Prentice Hall, Englewood Cliffs, N.J., 1994
2. Timothy J. Ross, “Fuzzy Logic with Engineering Applications”, McGraw Hill Inc., 2000

REFERENCE BOOKS

1. Goldberg, “Genetic Algorithm in Search, Optimization and Machine learning”, Addison Wesley Publishing Company Inc. 1989
2. Millon W.T., Sutton R.S. and Webrose P.J., “Neural Networks for Control”, MIT press, 1992.
3. Ethem Alpaydin,“Introduction to Machine learning (Adaptive Computation and Machine Learning series)’,MIT Press, 2nd Edition, 2010.
4. Zhang Huaguang and Liu Derong, “Fuzzy Modeling and Fuzzy Control Series: Control Engineering”, 2006.

COURSE OUTCOMES

After the completion of this course, students will be able to:

C403.1	To study various fundamental concepts of artificial neural networks and fuzzy logic
C403.2	To understand models of ANN
C403.3	To learn the fuzzy set theory and fuzzy rules
C403.4	To design and implement the fuzzy logic controller with a case study using simulation toolbox
C403.5	To design hybrid control schemes, selected optimization algorithms with a case study using simulation toolbox

Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P010	PO11	PO12	PSO1	PSO2	PSO3	PSO4
C403.1	3	3	3	3	2	-	-	-	-	2	2	2	1	3	3	2
C403.2	3	3	3	3	2	-	-	-	-	2	2	2	3	3	3	2

C403.3	3	3	3	3	2	-	-	-	-	2	2	2	2	2	3	2
C403.4	3	3	3	3	2	-	-	-	-	2	2	2	3	3	3	2
C403.5	3	3	3	3	2	-	-	-	-	2	2	2	3	3	3	2

MAPPING BETWEEN CO AND PO, PSO WITH CORRELATION LEVEL 1/2/3

RELATION BETWEEN COURSE CONTENT WITH COs

UNIT I - ARTIFICIAL NEURAL NETWORK

Sl. No	Course Content	Knowledge level	Books Referred	Course Outcomes
1	Review of fundamentals – Biological neuron, artificial neuron,	BL2	T1	C403.1
2	Activation function,	BL2,B L1	T1	
3	Single layer perception – Limitation – Multilayer perception	BL2, BL4	T1	
4	Back Propagation Algorithm (BPA)	BL2, BL4	T1	
5	Recurrent Neural Network (RNN)	BL2,B L4	T1	
6	Adaptive Resonance Theory (ART) based network	BL2,B L4	T1	
7	Radial basis function network	BL2,B L4	T1	
8	Online learning algorithms, BP through time	BL2,B L4	T1	
9	RTRL algorithms – Reinforcement learning	BL2,B L4	T1	

UNIT II - NEURAL NETWORKS FOR MODELING AND CONTROL

Sl. No.	Course Content	Knowledge level	Books referred	Course Outcomes
1	Modelling of non-linear systems using ANN	BL2, BL1	T1	C403.2
2	Generation of training data	BL2	T1	
3	Optimal architecture	BL2,BL1	T1	
4	Model validation	BL2	T1	
5	Control of non-linear systems using ANN	BL2	T1	
6	Direct and indirect Neuro control schemes	BL2, BL1	T1	
7	Adaptive Neuro controller	BL2	T1	
8	Familiarization with neural network toolbox	BL4	T1	

UNIT III FUZZY SET THEORY

Sl. No.	Course Content	Knowledge level	Books Referred	Course Outcomes
1	Fuzzy set theory – Fuzzy sets	BL2, BL3	T1	C403.3
2	Operation on fuzzy sets	BL2, BL3	T1	
3	Scalar cardinality, fuzzy cardinality, union and intersection, complement (Yager and Sugeno)	BL2, BL3	T1	
4	Equilibrium points, aggregation, projection,	BL2, BL3	T1	
5	composition, cylindrical extension	BL2, BL3	T1	
6	Fuzzy relation	BL2, BL3	T1	
7	Fuzzy membership functions	BL2, BL1	T1	

UNIT IV FUZZY LOGIC FOR MODELING AND CONTROL

Sl.No.	Course Content	Knowledge level	Books Referred	Course Outcomes
1	Modelling of non-linear systems using fuzzy models	BL3	T1	
2	TSK model	BL2, BL3, BL4	T1	
3	Fuzzy logic controller	BL2, BL3, BL4	T1	
4	Fuzzification	BL2, BL3, BL4	T1	

5	Knowledge base – Decision making logic	BL2, BL3, BL4	T1	**C403.4**
6	Defuzzification	BL2, BL3,BL4	T1	
7	Adaptive fuzzy systems	BL2, BL3,BL4	T1	
8	Familiarization with fuzzy logic toolbox	BL2, BL3, BL4	T1	
9	Types of Fuzzy Inference System	BL2, BL3, BL4	T2	

UNIT V- HYBRID CONTROL SCHEMES

Sl. No.	Course Content	Knowledgelevel	Books Referred	Course Outcomes
1	Fuzzification and rule base using ANN	BL3, BL4	T2	**C403.5**
2	Neuro fuzzy systems	BL2, BL3	T2	
3	ANFIS – Fuzzy neuron	BL2, BL3, BL4	T2	
4	Introduction to GA	BL2, BL3, BL4	T2	
5	Optimization of membership function and rule base using Genetic Algorithm	BL2, BL3, BL4	T2	
6	Introduction to support vector machine	BL2, BL3, BL4	T2	
7	Particle swarm optimization	BL2, BL3,BL4	T2	
8	Case study	BL2, BL3,BL4	T2	
9	Familiarization with ANFIS toolbox	BL2, BL3,BL4	T2	

BL1- Remembering, BL2- Understanding, BL3 – Applying, BL4 –Analyzing, BL5 – Evaluating, BL6 – Creating

S. No	Content beyond syllabus	PO Mapping	PSO Mapping
1.	Design and Optimization of an Adaptive Neuro-Fuzzy Inference System (ANFIS) Using Particle Swarm Optimization (PSO) for Smart Traffic Signal Control	PO5	PSO1

(A) PROGRAM OUTCOMES (POs)

Engineering graduates will be able to:

1. **Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions:** Design solution for complex engineering problems and design systems components or process that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems:** Use research- based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environmental and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-Long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

((B) PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

1. To Build next generation of highly skilled graduates with a strong knowledge in Artificial Intelligence and Data Science to contribute and innovate new technologies for societal needs

2. To Create Engineers to promote collaborative learning and to exhibit their employability skills and practise the ethics of their profession through innovation or entrepreneurship.

3. To Pursue graduate studies in the field of Data Science and to be committed in lifelong research towards social, political and technical issues.

4. To Exhibit innovative thoughts in Engineering, Problem Solving and Critical Thinking skills to excel in interdisciplinary domains.

(C) PROGRAM SPECIFIC OBJECTIVES (PSOs)

1. To understand, analyze and apply the AI based efficient domain specific processes for problem-solving, inference, perception, knowledge representation and learning to design computer based systems for varying complexity.

2. To implement search algorithms, neural networks, machine learning and data analytics to create innovative solutions from idea to product for successful career and entrepreneurship.

3. To develop intelligent solutions and project development skills using Data Science technologies to cater to the societal needs.

4. To provide a concrete foundation and enrich their abilities to qualify for Employment, Higher Studies and Research in Artificial Intelligence and Data Science with ethical values.

	UNIT I - ARTIFICIAL NEURAL NETWORK Review of fundamentals – Biological neuron, artificial neuron, activation function, single layer perception – Limitation – Multilayer perception – Back Propagation Algorithm (BPA) – Recurrent Neural Network (RNN) – Adaptive Resonance Theory (ART) based network – Radial basis function network – online learning algorithms, BP through time – RTRL algorithms – Reinforcement learning		
	UNIT-I/PART-A	**CO**	**BL**
1	Define an artificial neuron.	**CO1**	**BL1**
2	What is the function of an activation function in neural networks?	**CO1**	**BL1**
3	Give two examples of commonly used activation functions.	**CO1**	**BL1**
4	What is a single-layer perceptron?	**CO1**	**BL1**
5	State one major limitation of a single-layer perceptron.	**CO1**	**BL2**
6	What is meant by the term “linearly separable”?	**CO1**	**BL1**
7	Describe the structure of a multilayer perceptron (MLP).	**CO1**	**BL2**
8	What is the role of the hidden layer in MLP?	**CO1**	**BL1**
9	Define backpropagation.	**CO1**	**BL1**
10	State two assumptions of the backpropagation algorithm.	**CO1**	**BL1**
11	List the steps of the backpropagation algorithm.	**CO1**	**BL2**
12	What is a recurrent neural network (RNN)?	**CO1**	**BL2**
13	Give one application of RNNs.	**CO1**	**BL1**
14	What is the vanishing gradient problem in RNNs?	**CO1**	**BL2**
15	Define adaptive resonance theory (ART).	**CO1**	**BL1**
16	What is the significance of vigilance parameter in ART?	**CO1**	**BL1**
17	Differentiate between ART1 and ART2.	**CO1**	**BL2**
18	What is a radial basis function (RBF) network?	**CO1**	**BL2**
19	State one advantage of RBF over MLP.	**CO1**	**BL1**
20	What is the purpose of the radial basis function in RBF networks?	**CO1**	**BL2**
21	Define online learning in neural networks.	**CO1**	**BL1**
22	What is backpropagation through time (BPTT)?	**CO1**	**BL1**
23	How does BPTT handle temporal dependencies?	**CO1**	**BL2**
24	What is the main difference between BPTT and traditional BP?	**CO1**	**BL2**
25	What is the purpose of the radial basis function in RBF networks?	**CO1**	**BL1**
26	Define online learning in neural networks.	**CO1**	**BL2**
	Unit – I / PART- B		
1	Explain the working of a biological neuron and compare it with an artificial neuron.	**CO1**	**BL3**
2	Discuss in detail the architecture, working, and limitation of a single-layer perceptron.	**CO1**	**BL3**
3	Derive and explain the backpropagation algorithm with an example.	**CO1**	**BL4**
4	Describe the architecture and training of a multilayer perceptron (MLP) with neat diagrams.	**CO1**	**BL3**
5	Explain the concept of Recurrent Neural Networks (RNNs). What are their advantages and limitations?	**CO1**	**BL4**
6	Describe the Adaptive Resonance Theory (ART) network. Explain how pattern stability is	**CO1**	**BL4**

	achieved.		
7	Explain the working and architecture of a radial basis function (RBF) network. Compare it with MLP.	**CO1**	**BL3**
8	Discuss various online learning algorithms and compare them with batch learning.	**CO1**	**BL3**
9	Describe Backpropagation Through Time (BPTT) and Real-Time Recurrent Learning (RTRL) algorithms.	**CO1**	**BL4**
10	What is reinforcement learning? Explain its key components and how it differs from supervised learning	**CO1**	**BL3**
	PART C		
1.	Design a small multilayer perceptron to solve a binary classification problem, derive from first principles and discuss how your chosen learning rate and activation functions affect convergence.	**CO1**	**BL6**
	UNIT II - NEURAL NETWORKS FOR MODELING AND CONTROL Modelling of non-linear systems using ANN – Generation of training data – Optimal architecture–Model validation – Control of non-linear systems using ANN – Direct and indirect Neuro control schemes – Adaptive Neuro controller – Familiarization with neural network toolbox		
	UNIT-II/PART-A		
1	What is a non-linear system?	**CO2**	**BL1**
2	Why are non-linear systems difficult to model using traditional techniques?	**CO2**	**BL1**
3	What makes artificial neural networks suitable for non-linear system modeling?	**CO2**	**BL1**
4	Define system identification in the context of ANN.	**CO2**	**BL1**
5	What is meant by training data in ANN-based modeling?	**CO2**	**BL2**
6	State two methods for generating training data.	**CO2**	**BL1**
7	What is the significance of input-output mapping in system modeling?	**CO2**	**BL1**
8	What is meant by model generalization in ANN?	**CO2**	**BL1**
9	Define model validation.	**CO2**	**BL1**
10	List two methods used for model validation.	**CO2**	**BL1**
11	What is overfitting in the context of neural network models?	**CO2**	**BL1**
12	How can overfitting be prevented during training?	**CO2**	**BL2**
13	Define optimal neural network architecture.	**CO2**	**BL1**
14	List the parameters that influence the architecture of an ANN.	**CO2**	**BL1**
15	What is the role of hidden layers in non-linear system modeling?	**CO2**	**BL1**
16	Explain the concept of direct neuro control.	**CO2**	**BL1**
17	What is indirect neuro control?	**CO2**	**BL2**
18	Differentiate between direct and indirect neuro control schemes.	**CO2**	**BL1**
19	Define adaptive neuro control.	**CO2**	**BL2**
20	What is meant by adaptation in the context of neuro controllers?	**CO2**	**BL2**
21	List two advantages of using adaptive neuro controllers.	**CO2**	**BL1**
22	What is meant by model-based control in ANN?	**CO2**	**BL1**
23	Describe one application of ANN in non-linear control.	**CO2**	**BL1**
24	What is the purpose of the neural network toolbox in MATLAB?	**CO2**	**BL1**
25	Mention two features of the neural network toolbox.	**CO2**	**BL2**
26	Define plant modeling in ANN.	**CO2**	**BL1**

	UNIT-II/PART-B		
1	Describe the procedure for modeling a non-linear system using artificial neural networks.	**CO2**	**BL5**
2	Explain the different methods of training data generation for non-linear system modeling.	**CO2**	**BL6**
3	Discuss the importance of optimal architecture in ANN and how it affects performance.	**CO2**	**BL4**
4	Explain various model validation techniques used in ANN-based system modeling.	**CO2**	**BL4**
5	Compare and contrast direct and indirect neuro control strategies with suitable examples.	**CO2**	**BL5**
6	Describe the structure and functioning of an adaptive neuro controller.	**CO2**	**BL3**
7	Explain the steps involved in designing a neural network controller for a non-linear system.	**CO2**	**BL3**
8	Discuss the use of MATLAB's Neural Network Toolbox in designing and training ANN models.	**CO2**	**BL3**
9	Describe a case study of a non-linear system modeled and controlled using ANN.	**CO2**	**BL4**
10	Evaluate the challenges and limitations of ANN-based modeling and control of non-linear systems.	**CO2**	**BL3**
	PART C		
1	Evaluate the effectiveness of neural networks in system modeling and control applications. Compare neural network-based control systems with traditional control systems in terms of adaptability, robustness, and learning capabilities.	**CO2**	**BL5**
	UNIT III FUZZY SET THEORY Fuzzy set theory – Fuzzy sets – Operation on fuzzy sets – Scalar cardinality, fuzzy cardinality, union and intersection, complement (Yager and Sugeno), equilibrium points, aggregation, projection, composition, cylindrical extension, fuzzy relation – Fuzzy membership functions		
	UNIT-III/PART-A		
1	What is a fuzzy set?	**CO3**	**BL1**
2	Differentiate between a crisp set and a fuzzy set.	**CO3**	**BL1**
3	Define the membership function in fuzzy set theory.	**CO3**	**BL1**
4	What is the range of a fuzzy membership function?	**CO3**	**BL2**
5	What is the union of two fuzzy sets?	**CO3**	**BL2**
6	What is the intersection of two fuzzy sets?	**CO3**	**BL1**
7	Define complement of a fuzzy set.	**CO3**	**BL1**
8	What is Yager's complement function?	**CO3**	**BL2**
9	What is Sugeno's complement function?	**CO3**	**BL2**
10	Define scalar cardinality of a fuzzy set.	**CO3**	**BL1**
11	What is fuzzy cardinality?	**CO3**	**BL1**
12	Explain the term “equilibrium point” in fuzzy sets.	**CO3**	**BL2**
13	Define fuzzy relation with an example.	**CO3**	**BL1**
14	What is meant by cylindrical extension in fuzzy set theory?	**CO3**	**BL1**
15	Define aggregation in the context of fuzzy sets.	**CO3**	**BL1**
16	What is a projection in fuzzy relation?	**CO3**	**BL1**
17	Define composition of fuzzy relations.	**CO3**	**BL2**
18	Differentiate between max-min and max-product composition.	**CO3**	**BL1**
19	List two types of fuzzy membership functions.	**CO3**	**BL1**
20	What is a triangular membership function?	**CO3**	**BL2**

21	Define trapezoidal membership function.	**CO3**	**BL1**
22	What is a Gaussian membership function?	**CO3**	**BL1**
23	Explain the use of sigmoid membership functions.	**CO3**	**BL1**
24	What does the height of a fuzzy set indicate?	**CO3**	**BL1**
25	Define alpha-cut in fuzzy sets.	**CO3**	**BL2**
26	What is the support of a fuzzy set?	**CO3**	**BL1**
	Unit –III/PART- B		
1	Define fuzzy sets. Explain the properties and operations on fuzzy sets with examples.	**CO3**	**BL3**
2	Discuss union, intersection, and complement operations in fuzzy sets with Yager and Sugeno formulations.	**CO3**	**BL3**
3	Explain scalar and fuzzy cardinality. Give examples.	**CO3**	**BL4**
4	Describe fuzzy relations and explain composition operations in detail.	**CO3**	**BL3**
5	What are equilibrium points in fuzzy sets? How are they determined?	**CO3**	**BL3**
6	Explain cylindrical extension and projection in fuzzy relation theory.	**CO3**	**BL4**
7	Discuss various fuzzy membership functions with diagrams and mathematical expressions.	**CO3**	**BL3**
8	Elaborate on aggregation and composition in fuzzy sets with suitable examples.	**CO3**	**BL4**
9	Compare and contrast crisp and fuzzy sets using at least five points with examples.	**CO3**	**BL3**
10	Explain the application of fuzzy set theory in real-world systems with at least two use cases.	**CO3**	**BL4**
	PART C		
1	Evaluate the role of fuzzy set theory in handling uncertainty in real-world decision-making systems. Compare fuzzy logic with classical (crisp) logic, highlighting advantages and limitations.	**CO3**	**BL5**
	UNIT IV- FUZZY LOGIC FOR MODELING AND CONTROL Modelling of non-linear systems using fuzzy models – TSK model – Fuzzy logic controller – Fuzzification – Knowledge base – Decision making logic – Defuzzification – Adaptive fuzzy systems – Familiarization with fuzzy logic toolbox		
	UNIT-IV/PART-A		
1	What is a fuzzy logic controller?	**CO4**	**BL1**
2	Define fuzzification.	**CO4**	**BL1**
3	What is the purpose of defuzzification in fuzzy systems?	**CO4**	**BL1**
4	Mention any two features of the TSK (Takagi-Sugeno-Kang) model.	**CO4**	**BL1**
5	What is a knowledge base in a fuzzy logic system?	**CO4**	**BL2**
6	List any two advantages of adaptive fuzzy systems.	**CO4**	**BL1**
7	What does the fuzzy logic toolbox in MATLAB provide?	**CO4**	**BL1**
8	Define decision-making logic in fuzzy control systems.	**CO4**	**BL1**
9	What is a nonlinear system?	**CO4**	**BL1**
10	Define fuzzy modeling.	**CO4**	**BL1**
11	What is the purpose of using fuzzy logic for nonlinear system modeling?	**CO4**	**BL2**
12	What is the TSK model in fuzzy logic?	**CO4**	**BL1**
13	Differentiate between Mamdani and TSK fuzzy models.	**CO4**	**BL1**
14	What is a fuzzy logic controller (FLC)?	**CO4**	**BL2**
15	List the main components of a fuzzy logic controller.	**CO4**	**BL1**

16	Define fuzzification.	**CO4**	**BL1**
17	What is the role of membership functions in fuzzification?	**CO4**	**BL2**
18	What is a knowledge base in fuzzy systems?	**CO4**	**BL1**
19	Mention the two main components of the knowledge base.	**CO4**	**BL1**
20	Define decision-making logic in de-fuzzy control systems.	**CO4**	**BL2**
21	What is inference mechanism in fuzzy logic?	**CO4**	**BL1**
22	Name any two defuzzification methods.	**CO4**	**BL1**
23	What is the role of defuzzification in fuzzy systems?	**CO4**	**BL1**
24	Define adaptive fuzzy systems.	**CO4**	**BL1**
25	Mention the difference between centroid and bisector defuzzification methods.	**CO4**	**BL2**
26	What is a fuzzy logic controller?	**CO4**	**BL1**
	Unit –IV/PART- B		
1	Explain the structure and working of a fuzzy logic controller with a suitable block diagram.	**CO4**	**BL3**
2	Discuss the modeling of nonlinear systems using fuzzy models with an example.	**CO4**	**BL4**
3	Describe the TSK fuzzy model in detail. How does it differ from Mamdani-type models?	**CO4**	**BL3**
4	Write notes on the following components of a fuzzy system: Fuzzification, Knowledge base.	**CO4**	**BL4**
5	Explain the concept of adaptive fuzzy systems and their applications in control systems.	**CO4**	**BL5**
6	Write short notes on the components of a fuzzy logic controller.	**CO4**	**BL6**
7	Discuss the structure and operation of a TSK (Takagi-Sugeno-Kang) fuzzy model.	**CO4**	**BL2**
8	Explain the process of fuzzification with an example and types of membership functions.	**CO4**	**BL3**
9	Describe the structure and role of the knowledge base in fuzzy logic systems.	**CO4**	**BL3**
10	Explain the decision-making logic in fuzzy systems and how rules are evaluated.	**CO4**	**BL5**
	PART C		
1	Evaluate the application of fuzzy logic in modeling and control systems. How does fuzzy logic enhance system performance in nonlinear or uncertain environments compared to conventional control methods?	**CO4**	**BL6**
	UNIT V HYBRID CONTROL SCHEMES Fuzzification and rule base using ANN – Neuro fuzzy systems – ANFIS – Fuzzy neuron– Introduction to GA – Optimization of membership function and rule base using Genetic Algorithm – Introduction to support vector machine – Particle swarm optimization – Case study – Familiarization with ANFIS toolbox		
	UNIT-V/PART-A		
1	What is fuzzification in fuzzy systems?	**CO5**	**BL1**
2	Define the term “rule base” in fuzzy inference systems.	**CO5**	**BL1**
3	What is an artificial neural network (ANN)?	**CO5**	**BL1**
4	How can ANN be used to generate fuzzy rules?	**CO5**	**BL1**
5	Define a neuro-fuzzy system.	**CO5**	**BL2**
6	What is ANFIS?	**CO5**	**BL1**
7	Name two advantages of using ANFIS over classical fuzzy logic systems.	**CO5**	**BL1**
8	What are the layers in the ANFIS architecture?	**CO5**	**BL1**
9	Define a fuzzy neuron.	**CO5**	**BL1**
10	How is a fuzzy neuron different from a conventional neuron?	**CO5**	**BL1**
11	What is the role of learning algorithms in neuro-fuzzy systems?	**CO5**	**BL1**

12	Define genetic algorithm (GA).	**CO5**	**BL1**
13	What is selection in GA?	**CO5**	**BL1**
14	What is crossover in genetic algorithms?	**CO5**	**BL1**
15	What is mutation in GA?	**CO5**	**BL1**
16	How are membership functions optimized using GA?	**CO5**	**BL1**
17	What is a fitness function in GA-based optimization?	**CO5**	**BL2**
18	Define support vector machine (SVM).	**CO5**	**BL1**
19	Mention one application of SVM in classification problems.	**CO5**	**BL1**
20	What is kernel trick in SVM?	**CO5**	**BL2**
21	What is particle swarm optimization (PSO)?	**CO5**	**BL1**
22	What is the role of particles in PSO?	**CO5**	**BL1**
23	Mention one advantage of using PSO over GA.	**CO5**	**BL1**
24	What is the use of the ANFIS toolbox in MATLAB?	**CO5**	**BL2**
25	Define the term “rule base” in fuzzy inference systems.	**CO5**	**BL1**
	Unit –V/PART- B		
1	Explain in detail the process of fuzzification and rule generation using artificial neural networks.	**CO5**	**BL3**
2	Describe the architecture and working of a neuro-fuzzy system with an example.	**CO5**	**BL4**
3	Explain the Adaptive Neuro-Fuzzy Inference System (ANFIS) in detail.	**CO5**	**BL3**
4	Discuss the training process of ANFIS and its advantages in function approximation.	**CO5**	**BL4**
5	Illustrate the working of a fuzzy neuron and compare it with a conventional artificial neuron.	**CO5**	**BL5**
6	Explain how genetic algorithms can be used to optimize fuzzy membership functions.	**CO5**	**BL6**
7	Discuss the steps involved in optimizing a fuzzy rule base using GA.	**CO5**	**BL3**
8	Write a detailed note on the components and working of genetic algorithms.	**CO5**	**BL3**
9	Describe how GAs help in improving the performance of fuzzy inference systems.	**CO5**	**BL4**
10	What is support vector machine (SVM)? Explain its working principle with a diagram.	**CO5**	**BL5**
	PART- C		
1	Evaluate the effectiveness of hybrid control schemes that integrate fuzzy logic with neural networks or PID controllers for dynamic system control.	**CO5**	**BL5**