CHOICE BASED CREDIT SYSTEM
CBCS

M.E. DEGREE (Control and Instrumentation) PROGRAMME

CURRICULUM AND DETAILED SYLLABI FOR

I TO IV SEMESTERS

CORE & ELECTIVE COURSES

FOR THE STUDENTS ADMITTED FROM THE ACADEMIC YEAR 2018-2019 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING

(A Govt. Aided ISO 9001-2008 certified Autonomous Institution affiliated to Anna University)

MADURAI – 625 015, TAMILNADU

Phone: 0452 – 2482240, 41

Fax: 0452 2483427

Web: www.tce.edu

Department of Electrical and Electronics Engineering

VISION

- Transforming the individuals into globally competent electrical engineers to fulfill the technological needs of the society.

MISSION

- Establishing world class infrastructure in Electrical Engineering.
- Enhancing the knowledge of the faculty in cutting edge technologies through continuous improvement programmes.
- Providing well balanced curriculum in graduate, postgraduate and doctoral programmes.
- Adopting innovative content delivery, assessment and continuous improvement methods to achieve desired outcomes.
- Facilitating industry institution interaction in teaching & learning, consultancy and research activities to accomplish the technological needs of the society.
- Encouraging the faculty and students to carry out innovative research work
- Practicing ethical standards by the faculty and students.
- Motivating the students for active participation in co-curricular and extracurricular activities.

Programme Educational Objectives (PEO's)

PEO 1: Graduates of the programme will have successful career in Instrumentation, automation and inter-disciplinary fields.

PEO 2: Graduates of the programme will have professional competency to address the technological needs of society and industrial problems ethically.

PEO 3: Graduates of the programme will excel in research and contribute to technological development in control and instrumentation.

PEO 4: Graduates of the programme will demonstrate life-long independent and reflective learning skills in their career.

PEO 5: Graduates of the programme will exhibit project management skills and ability to work in collaborative, multidisciplinary tasks in their profession.

Programme Outcomes (POs) for M.E. Control and Instrumentation

After the successful completion of the M.Tech. (Control & Instrumentation) programme, students should be able to:

PO1. Scholarship of Knowledge

Acquire state-of-art knowledge in instrumentation, control and automation, with an ability to discriminate, evaluate, analyze and synthesize existing and new knowledge, and integration of the same for enhancement of knowledge.

PO2. Critical Thinking

Analyze complex problems in instrumentation, control and automation engineering critically, apply independent judgement for synthesizing information to make intellectual and/or creative advances for conducting research in a wider theoretical and practical and policy context.

PO3. Problem Solving

Think laterally and originally, conceptualise and solve instrumentation, control and automation problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors.

PO4. Research Skill

Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyse and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in instrumentation, control and automation domains.

PO5. Usage of modern tools

Create, Select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex instrumentation control and automation engineering activities with an understanding of the limitations.

PO6. Collaborative and Multidisciplinary work

Possess knowledge and understanding of group dynamics, recognise opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.

PO7. Project Management and Finance

Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economical and financial factors.

PO8. Communication

Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

PO9. Life-long Learning

Recognise the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

PO10. Ethical Practices and Social Responsibility

Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

PO11. Independent and Reflective Learning

Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

M.E./M.Tech Programme Structure (CBCS)

Credit Distribution:

S.No	Category		Credits
A.	**Foundation Course**		**3 - 6**
B.	**Programme Core Courses***		**19 – 25**
C.	**Elective Courses**		**17 – 23**
	a.	Programme Elective	15 – 21
	b.	Open Elective	2 – 6
D.	**Common Core Course**		**2**
E.	**Mini Project and Dissertation**		**27**
E	Value Added Courses (Not to be included in CGPA) - Mandatory		**4**
	Minimum Credits to be earned for the award of the degree		**68** (from A to E) and 4 (from F)

*TCP and Laboratory courses are Mandatory in the Programme Core Courses.

Credit Details:

Theory: 3 Credits
Theory Cum Practical (TCP) : 3 Credits,
Lab: 2 Credits
Open Elective: 2 Credits
Mini Project: 2 Credits
Dissertation Phase I: 10 Credits
Dissertation Phase I: 15 Credits
Common Core: Research Methodology and IPR: 2 Credits

THIAGARAJAR COLLEGE OF ENGINEERING
MADURAI- 625 015
(A Govt. Aided, ISO 9001:2008 certified Autonomous Institution affiliated to Anna University)

CHOICE BASED CREDIT SYSTEM

Categorization of Courses

Degree: M.E. **Programme: Control and Instrumentation** **Batch: 2018-19**

A. FOUNDATION COURSES: Total Credits to be earned: (03-06)

S.No.	Course Code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
		THEORY				
1.	18CI110	Calculus of Variation & Applied Mathematics	2	1	-	3

B. CORE COURSES Credits to be earned: (19-25)

S.No.	Course Code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
THEORY						
1	18CI120	Systems Theory	2	1	-	3
2	18CI130	Process Control	3	-	-	3
3	18CI210	Industrial Automation	3	-	-	3
THEORY CUM PRACTICAL						
1.	18CI160	Transducers Engineering	2	-	2	3
2	18CI260	Digital Control system Design	2	-	2	3
PRACTICALS						
1.	18CI170	Control and Instrumentation Laboratory	-	-	4	2
2.	18CI270	Control and Automation Laboratory	-	-	4	2

C. ELECTIVE COURSES: Credits to be earned: (17-23)

a. Programme Electives **Credits to be earned:15-21**

S.No.	Course code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
THEORY						

Control						
1	18CIPB0	Embedded System Design	2	-	2	3
2	18CIPC0	Adaptive Control	3	-	-	3
3	18CIPD0	System Identification	3	-	-	3
4	18CIPE0	Non linear control	3	-	-	3
5	18CIPF0	Model Predictive control	3	-	-	3
6	18CIPG0	Robotics	3	-	-	3
7	18CIPH0	Intelligent Controllers	2	-	2	3
8	18CIPJ0	Optimal Control And Filtering	2	1	-	3
9	18CIPK0	Robust Control	3	-	-	3
10	18CIPL0	State Estimation	3	-	-	3
11	18CIPV0	Deep Learning	2	1	-	3
Instrumentation						
12	18CIPA0	Industrial Instrumentation	3	-	-	3
13	18CIPM0	Bio-Medical Instrumentation	3	-	-	3
14	18CIPP0	MEMS	3	-	-	3
15	18CIPQ0	Multi sensor data fusion	3	-	-	3
16	18CIPR0	Advanced Digital Signal Processing	3	-	-	3
17	18CIPS0	Power Plant Instrumentation and Control	3	-	-	3
18	18CIPT0	Machine Learning	2	-	2	3
19	18CIPU0	Internet of Things	2	-	2	3
20	18CIPU0	Internet of Things	3	-	-	3

b. Open Electives **Credits to be earned:2-6**

D. Common Core Course

S.No.	Course Code	Name of the Course	Number of Hours / Week			Credit	Pre requisite if any
			L	T	P		
1.	18PG250	Research Methodology and IPR	2	-	-	2	Nil

E. Mini Project and Dissertation **Credits to be earned:27**

Mini Project: 2 Credits

Dissertation Phase I: 10 Credits

Dissertation Phase I: 15 Credits

F. Value added Courses (Not to be included in CGPA)

Credits to be earned: 04

Minimum credits to be earned for the award of the degree =68 (From A to E) and 4 from F

Thiagarajar College of Engineering: Madurai-625015

Department of Electrical and Electronics Engineering

M.E. CONTROL AND INSTRUMENTATION ENGINEERING

For the students admitted from 2018-19

Scheduling of Courses

Semester	Theory					Theory Cum Practical	Laboratory	Project	Total credits
I	18CI110 Calculus of Variation & Applied Mathematics (3 Credits)	18CI120 Systems Theory (3 Credits)	18CI130 Process Control (3 Credits)	18CIPX0 Prog. Elective 1 (3 Credits)	-	18CI160 Transducers Engineering (3 Credits)	18CI170 Control and Instrumentation Laboratory (2 Credits, 4 hours)		17
II	18CI210 Industrial Automation (3 Credits)	18CIPX0 Prog. Elective 2 (3 Credits)	18CIPX0 Prog. Elective 3 (3 Credits)	18CIPX0 Prog. Elective 4 (3 Credits)	18PG250 Research Methodology and IPR (2 Credits)	18CI260 Digital Control system Design (3 Credits)	18CI270 Control and Automation Laboratory (2 Credits, 4 hours)	18CI280 Mini Project (2 Credits)	21
III	18CIPX0 Prog. Elective 5 (3 Credits)	-	-	-	18PGPX0 Open Elective (2 Credits)	-	-	18CI380 Dissertation Phase I (10 Credits)	15
IV	-	-	-	-	-	-	-	18CI480 Dissertation Phase II (15 Credits)	15

A student has to complete 2 audit courses of 24 hours duration. The courses will normally be conducted on week-ends.

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015

M.E. DEGREE (Control and Instrumentation) PROGRAM

COURSES OF STUDY

(For the students admitted from 2018-2019)

FIRST SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
18CI110	Calculus of Variation & Applied Mathematics	FC	2	1	-	3
18CI120	Systems Theory	PC	3	-	-	3
18CI130	Process Control	PC	3	-	-	3
18CIPX0	Programme Elective-I	PE				3
THEORY CUM PRACTICAL						
18CI160	Transducers Engineering	PC	3	-	-	3
PRACTICAL						
18CI170	Control and Instrumentation Laboratory	PC	-	-	4	2
Total						**17**

SECOND SEMESTER

Course code	Name of the course	Category	No. of Hours / Week			Credits
			L	T	P	C
THEORY						
18CI210	Industrial Automation	PC	3	-	-	3
18CIPx0	Programme Elective II	PE				3
18CIPx0	Programme Elective III	PE				3
18CIPx0	Programme Elective IV	PE				3
18PG250	Research Methodology and IPR	CC	2	-	-	2
THEORY CUM PRACTICAL						
18CI260	Digital Control system Design	PC	3	-	-	3
PRACTICAL						
18CI270	Control and Automation Laboratory	PC	-	-	4	2

18CI280	Mini Project		- - 4	2
Total				**21**

THIRD SEMESTER

Course code	Name of the course	Category	No. of Hours / Week	Credits
			L T P	C
THEORY				
18CIPx0	Programme Elective-V	PE		3
18yyGx0	Open Elective-I	OE		2
PRACTICAL				
18CI340	Dissertation Phase I	PC	- - 20	10
Total				**15**

FOURTH SEMESTER

Course code	Name of the course	Category	No. of Hours / Week	Credits
			L T P	C
PRACTICAL				
18CI410	Dissertation Phase II	PC	- - 30	15
Total			**- - 30**	**15**

Total credits: 68

AUDIT COURSES

Course code	Name of the course	Category	No. of Hours / Week	Credits
			L T P	C
18PGAA0	Professional Authoring	AC	2 - -	2
18PGAB0	Value Education	AC	2 - -	2

FC : Foundation Course
PC : Programme Core
PE : Programme Elective
OE : Open Elective
L : Lecture
T : Tutorial
P : Practical

Note:
1 Hour Lecture is equivalent to 1 credit
1 Hour Tutorial is equivalent to 1 credit
2 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015
M.E. DEGREE (Control and Instrumentation) PROGRAM
SCHEME OF EXAMINATIONS

(For the Students admitted from 2018-2019)

FIRST SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY								
1	18CI110	Calculus of Variation & Applied Mathematics	3	50	50	100	25	50
2	18CI120	Systems Theory	3	50	50	100	25	50
3	18CI130	Process Control	3	50	50	100	25	50
4	18CIPX0	Programme Elective-I	3	50	50	100	25	50
THEORY CUM PRACTICAL								
6	18CI160	Transducers Engineering	3	50	50	100	25	50
PRACTICAL								
7	18CI170	Control and Instrumentation Laboratory	3	50	50	100	25	50

SECOND SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY								
1	18CI210	Industrial Automation	3	50	50	100	25	50
2	18CIPx0	Programme Elective II	3	50	50	100	25	50
3	18CIPx0	Programme Elective III	3	50	50	100	25	50
4	18CIPx0	Programme Elective IV	3	50	50	100	25	50
5	18PG250	Research Methodology and IPR	3	50	50	100	25	50
THEORY CUM PRACTICAL								
6	18CI260	Digital Control system Design	3	50	50	100	25	50

PRACTICAL								
7	18CI270	Control and Automation Laboratory	3	50	50	100	25	50
8	18CI280	Mini Project	-	150	150	300	75	150

THIRD SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY								
1	18CIPx0	Programme Elective-V	3	50	50	100	25	50
2	18yyGx0	Open Elective-I	3	50	50	100	25	50
PRACTICAL								
3	18CI340	Dissertation Phase I	-	150	150	300	75	150

FOURTH SEMESTER

S.No	Course code	Name of the course	Duration of Terminal Exam. in Hrs.	Marks			Minimum Marks for Pass	
				Continuous Assessment *	Terminal Exam	Max. Marks	Terminal Exam	Total
PRACTICAL								
1	18CI410	Dissertation Phase II	-	150	150	300	75	150

* CA evaluation pattern will differ from course to course and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

Programme Electives

S.No.	Course code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
THEORY						
Control						
1	18CIPB0	Embedded System Design	2	-	2	3
2	18CIPC0	Adaptive Control	3	-	-	3
3	18CIPD0	System Identification	3	-	-	3
4	18CIPE0	Non linear control	3	-	-	3
5	18CIPF0	Model Predictive control	3	-	-	3
6	18CIPG0	Robotics	3	-	-	3
7	18CIPH0	Intelligent Controllers	2	-	2	3
8	18CIPJ0	Optimal Control And Filtering	2	1	-	3
9	18CIPK0	Robust Control	3	-	-	3
10	18CIPL0	State Estimation	3	-	-	3
11	18CIPV0	Deep Learning	2	1	-	3
Instrumentation						
12	18CIPA0	Industrial Instrumentation	3	-	-	3
13	18CIPM0	Bio-Medical Instrumentation	3	-	-	3
14	18CIPP0	MEMS	3	-	-	3
15	18CIPQ0	Multi sensor data fusion	3	-	-	3
16	18CIPR0	Advanced Digital Signal Processing	3	-	-	3
17	18CIPS0	Power Plant Instrumentation and Control	3	-	-	3
18	18CIPT0	Machine Learning	2	-	2	3
19	18CIPU0	Internet of Things	2	-	2	3

Audit Courses

S.No.	Course code	Name of the Course	Number of Hours / Week			Credit
			L	T	P	
1	18PGAA0	Professional Authoring	2	-	-	2
2	18PGAB0	Value Education	2	-	-	2

18CI110	CALCULUS OF VARIATION & APPLIED MATHEMATICS	Category	L	T	P	Credit
		FC	2	1	0	3

Preamble

An engineering PG student needs to have some basic mathematical tools and techniques to apply in diverse applications in Engineering. This emphasizes the development of rigorous logical thinking and analytical skills of the student and appraises him the complete procedure for solving different kinds of problems that occur in engineering. Based on this, the course aims at giving adequate exposure in Linear Algebra to find the singular value decomposition and Pseudo inverse of the matrix, Jointly distributed random variables, Test of hypotheses for Large Samples, Random Process to deal the Random Experiments with the state space S and parameter set T, stationary Functions, Gaussian Process, Calculus of Variations to find the maximum or minimum value of a definite integral involving certain functions.

Prerequisite

- Matrix,
- Probability and Statistics,
- Calculus.

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Use Cholesky, QR and SVD methods to decompose a given matrix	Apply
CO2.	Calculate Pseudo inverse for a given matrix	Apply
CO3.	Calculate expected value, covariance and correlation from jointly distributed random variables.	Apply
CO4.	Test the hypothesis using Z-Test about a population mean and population proportion.	Apply
CO5.	Calculate the response of a linear dynamic system with stochastic input	Apply
CO6.	Find optimal value of the given functional involving several variables and higher derivatives.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	M	M	M	M	M	-	-	-	-	-
CO2.	S	M	M	M	M	M	L	-	-	-	-
CO3.	S	M	M	M	M	M	-	-	-	-	-
CO4.	S	M	M	M	M	-	-	-	-	-	-
CO5.	S	M	M	M	M	M	-	-	-	-	-
CO6.	S	M	M	M	M	M	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	0	0
Understand	20	20	30	30
Apply	70	70	70	70
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Determine the Cholesky decomposition for $\begin{bmatrix} 16 & -3 & 5 & -8 \\ -3 & 16 & -5 & -8 \\ 5 & -5 & 24 & 0 \\ -8 & -8 & 0 & 21 \end{bmatrix}$
2. Determine the singular value decomposition of i) $\begin{pmatrix} 1 & 2 \\ 1 & 1 \\ 1 & 3 \end{pmatrix}$ ii) $\begin{bmatrix} 1 & 1 & 3 \\ 1 & 1 & 3 \end{bmatrix}$ iii) $\begin{bmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{bmatrix}$
3. construct QR decomposition of the matrix i) $\begin{pmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{pmatrix}$ ii) $\begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$

Course Outcome 2(CO2)

1. Define generalised eigen vectors.
2. Find the canonical basis for the matrix A = $\begin{pmatrix} 2 & 2 & 2 \\ 0 & 4 & 0 \\ 3 & -3 & 1 \end{pmatrix}$
3. Obtain the generalized inverse of A = $\begin{pmatrix} 2 & 2 & -2 \\ 2 & 2 & -2 \\ -2 & -2 & 6 \end{pmatrix}$

Course Outcome 3(CO3)

1. The current I and resistance R in a circuit are independent continuous RVs with the following density functions.
   f(i) = 2i, 0≤i≤1
   = 0 else where,
   g(r) = $\frac{r^2}{9}$, 0≤ri≤3

= 0 else where,

find the p.d.f of the voltage E in the circuit where E = IR

2. Each front tire on a particular type of vehicle is supposed to be filled to a pressure of 26 psi.
   Suppose the actual air pressure in each tire is a random variable—*X* and *Y* for the left tire, with
   joint pdf

   $$f(x, y) = \begin{cases} k(x^2 + y^2) & 20 \le x \le 30,\ 20 \le y \le 30 \\ 0 & otherwise \end{cases}$$

   a. What is the value of *K*?
   b. What is the probability that both tires are under 'f '.
   c. What is the probability that the difference in air pressure between the two tires is at most 2psi?
   d. Determine the (marginal) distribution of air pressure in the right tire alone.
   e. Are *X* and *Y* independent rv's?

3. An instructor has given a short quiz consisting of two parts. For a randomly selected student,
   let *X* _ the number of points earned on the first part and *Y* _ the number of points earned on the
   second part. Suppose that the joint pmf of *X* and *Y* is given in the accompanying table.

P(x,y)	0	5	10	15
0	.02	.06	.02	.10
5	.04	.15	.20	.10
10	.01	.15	.14	.01

   a. If the score recorded in the grade book is the total number of points earned on the two parts,
   what is the expected recorded score *E*(*X* +*Y*)?
   b. If the maximum of the two scores is recorded, what is the expected recorded score?

4. Compute the covariance and correlation coefficient 'r' for *X* and *Y* where joint pdf of X and Y
   is given by $f(x, y) = \begin{cases} 24xy & 0 \le x \le 1,\ 0 \le y \le 1,\ x + y \le 1 \\ 0 & otherwise \end{cases}$

Course Outcome 4(CO4)

1. Determine the confidence level for each of the following large-sample one-sided confidence
   bounds:
   a. Upper bound: $\bar{x} + .84s/\sqrt{n}$
   b. Lower bound: $\bar{x} - 2.05s/\sqrt{n}$
   c. Upper bound: $\bar{x} + .67s/\sqrt{n}$

2. A manufacturer of sprinkler systems used for fire protection in office buildings claims that the true average system-activation temperature is 130°. A sample of n=9 sys- tems, when tested, yields a sample average activation temperature of 131.08°F. If the distribution of activation times is normal with standard deviation 1.5°F, does the data contradict the manufacturer's claim at significance level $\alpha = .01$?

(i). Parameter of interest: $\mu =$ average activation temperature.

(ii) . Null hypothesis: $H_0 : \mu = 130(null\, value = \mu_0 = 130)$

(iii). Alternative hypothesis: $H_a : \mu \ne 130$ (a departure from the claimed value in *either* direction is of concern).

(iv). Test statistic value: $z = \dfrac{\bar{x} - \mu_0}{\sigma/\sqrt{n}} = = \dfrac{\bar{x} - 130}{1.5/\sqrt{n}}$

3.In a certain factory there are two independent processes manufacturing the same item.The average weight in a sample of 250 items is found to be 120 ozs with a standard deviation of 12ozs. While the corresponding figures in a sample of 400 items from the other processes are 124 and 14. Obtain the standard error of difference between two sample means. Is the difference significant ? Also find the 99% confidence limits for the difference in the average weights of items produced by the two processes respectively.

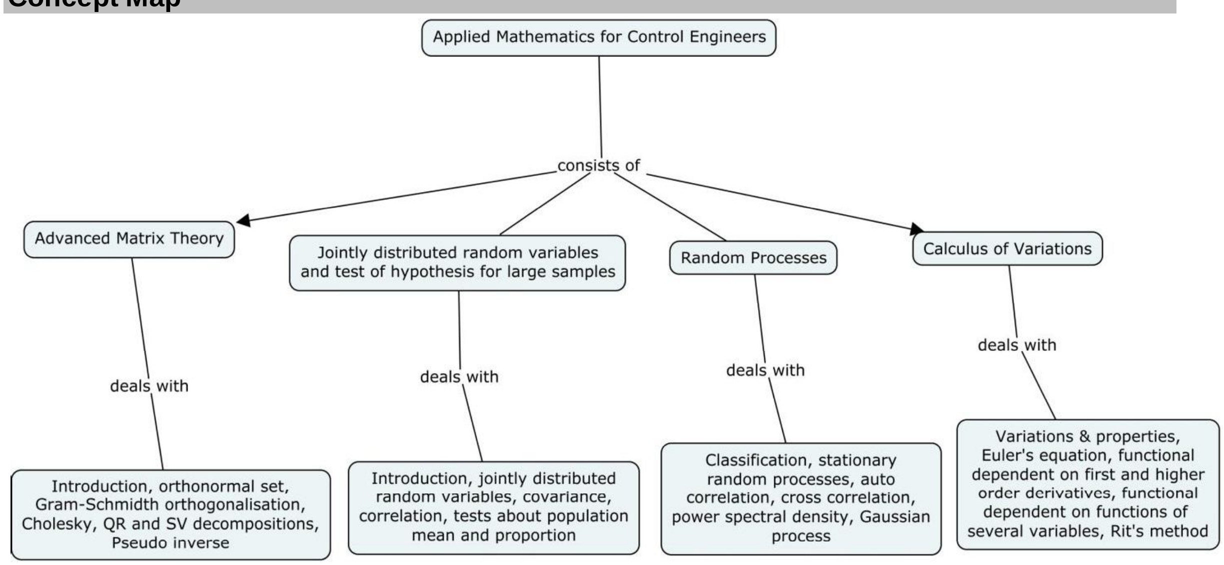
Course Outcome 5(CO5)

1. What is wide sense stationary process.
2. Check whether the random process X(t) =A$e^{i\omega t}$ is a WSS if E[A]=0
3. A wide sense stationary noise process N(t) has an autocorrelation function $R_{nn}(\tau) = Pe^{-3|\tau|}$ where P is a constant. Find its power spectrum.

Course Outcome 6(CO6)

1. Write the Solution of the Eulers equation v(y(x))= $\int F(y, \acute{y})$dx.
2. Determine the extremals of $\int_0^2 (y^{12} + z^{12} + 2y^3)$dx satisfying the conditions y(0)=0,y($\frac{\pi}{2}$)= 1,z(0)=1 and z($\frac{\pi}{2}$) = 0.
3. Apply Ritz method to find approximate solution of the problem y'' +y+x=0, 0≤x≤1,, y(0) =0= y(1).
4. Prove that the extremal of the isometric problem v(y(x))= $\int_1^4 y'^2$ dx, y(1)=3, y(4)=24 subject to $\int_1^4 y$ dx= 36 is a parabola
5. Calculate the extremals of the functional $V[y(x)] = \int_0^{\frac{\pi}{2}} \left[y^{11^2} - y^2 + x^2 \right] dx$ given that $y(0) = 1, y(\frac{\pi}{2}) = 0, y^1(0) = 0, y^1(\frac{\pi}{2}) = -1.$

Concept Map



Syllabus

Advanced Matrix Theory
Introduction of vector space, basis, dimension & inner product spaces-Orthonormal sets-Gram-Schmidt orthogonalization process-Cholesky decomposition- QR decomposition Singular Value Decomposition – Pseudo inverse.(Treatment as per text books 1 & 2).

Jointly Distributed Random Variables & Test of Hypotheses for large samples : Introduction –Jointly distributed Random Variables – Expected Values –Covariance-Correlation-Basic properties of Confidence Intervals – Hypotheses and Test Procedures – Tests About a population mean & Population Proportion (Treatment as per text books 3 & 4).

Random Process
Classification – Stationary random processes – Auto Correlation – Cross Correlation – Power spectral density – Linear system with random input – Gaussian Process. (Treatment as per text books 5 & 6).

Calculus of Variations
Variations and its properties –Euler's equation – Functional dependent on first and higher order derivatives – Functional dependent on functions of several independent variables – Some applications – Direct methods: Ritz method. (Treatment as per text book 8).

Reference Books

1. Steven J. Leon, "Linear Algebra with Applications", Ninth edition, Pearson Education Limited, 2015.
2. Bronson,R, " Matrix Operations, Schaums Outline Series", McGraw Hill, New York, 1989.
3. S.C.Gupta, V.K.Kapoor ," Fundamental of Mathematical Statistics",10th Revised Edition, Sultan Chand & Sons Educational Publisher, New Delhi.
4. Jay L.Devore, " Probability and Statistics for Engineering and the Sciences", 8th Edition, Brooks/Cole Cengage Learning, 2012.
5. Peyton Z. Peebles Jr. Ph.D, "Probability, Random variables and Random signal principles", Second Edition, Mc Graw-Hill, New Delhi, 1987.
6. T.Veerarajan "Probability, Statistics and Random Processes" Tata McGraw-Hill, New Delhi, 2003.
7. Paul L.Meyer, "Introductory Probability and statistical applications", Addison-Wesley,1981.
8. Gupta .A.S. ,"Calculus of variations and applications", Prentice Hall of India, New Delhi, 1999.

Course Contents and Lecture Schedule

Module No	Topic	No. of Lecture Hours
1.0	**Advanced Matrix Theory**	
1.1	Introduction of vector space, basis, dimension & inner product spaces	2
1.2	Orthonormal sets-Gram-Schmidt orthogonalization process	1
	Tutorial	1
1.3	Cholesky decomposition-QR decomposition	2
1.4	Singular Value Decomposition – Pseudo inverse	2
	Tutorial	1
2.0	**Jointly Distributed Random Variables & Test of Hypotheses for large samples**	
2.1	Introduction to random variables	1
2.2	Jointly distributed Random Variables	2

2.3	Expected Values –Covariance-Correlation	2
	Tutorial	1
2.4	Basic properties of Confidence Intervals – Hypotheses and Test Procedures	2
2.5	Tests about a population mean & Population Proportion	2
	Tutorial	1
3.0	**Random Process**	
3.1	Classification, Stationary random processes	2
3.2	Auto Correlation, Cross Correlation	2
	Tutorial	1
3.3	Power spectral density	1
3.4	Linear system with random input	2
3.5	Gaussian Process	1
	Tutorial	1
4.0	**Calculus of Variations**	
4.1	Variations and its properties	1
4.2	Euler's equation	2
4.3	Functional dependent on first and higher order derivatives	2
	Tutorial	1
4.4	Functional dependent on functions of several independent variables, Some applications	2
4.5	Direct method: Ritz method	1
	Tutorial	1
	Total	**40**

Course Designers:

1. Dr.A.P. Pushpalatha appmat@tce.edu

2. Dr.T. Lakshmi tlakshmimdu@tce.edu

3. Mr.AR. Murugan armmat@tce.edu

		Category	L	T	P	Credit
18CI120/18PSPA0	**SYSTEMS THEORY**	PC/PE	2	1	0	3

Preamble

Modern control theory is a powerful technique for the analysis and design of linear and nonlinear, time-invariant or time varying MIMO systems. The classical design methods suffer from certain limitations due to the fact that the transfer function model is applicable only to linear time invariant systems, and that there too it is generally restricted to single-input, single-output (SISO) systems. This course aims at giving an adequate exposure in state space analysis, state space controller design, MIMO system, Non-linear system, stability analysis.

Prerequisite

Control Systems

Course Outcomes

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

CO	Course Outcomes	Blooms level
1	Analyze the characteristics of the developed state space model for the given electrical (or) electromechanical system	Analyze
2	Design a pole placement controller with or without observer for the given system to achieve desired specifications	Apply
3	Design an optimal state regulator / stochastic optimal regulator for the given system	Apply
4	Explain the characteristics of MIMO system	Understand
5	Develop the phase plane trajectories of the given nonlinear system	Apply
6	Analyze the stability of the given nonlinear system using describing function method	Analyze
7	Analyze the stability of the given linear and nonlinear system using Lyapunov stability theory	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**S**	**S**	**M**	**M**							**M**
CO2	**S**	**M**	**M**	**M**							**M**
CO3	**S**	**M**	**M**								
CO4	**M**	**L**	**L**								
CO5	**S**	**M**	**M**	**M**							**M**
CO6	**S**	**S**	**M**	**M**							**M**
CO7	**S**	**S**	**M**	**M**							**M**

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	20	20	10	10
Understand	20	20	20	20
Apply	40	40	50	50

Analyze	20	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Consider the hydraulic system shown in fig.1. Derive state space equations for the system with water levels h_1 and h_2 in the two tanks as the state variables x_1 and x_2 respectively and discharges q_1, q_{12} and q_2 as the outputs y_1,$y_2$and y_3 respectively.

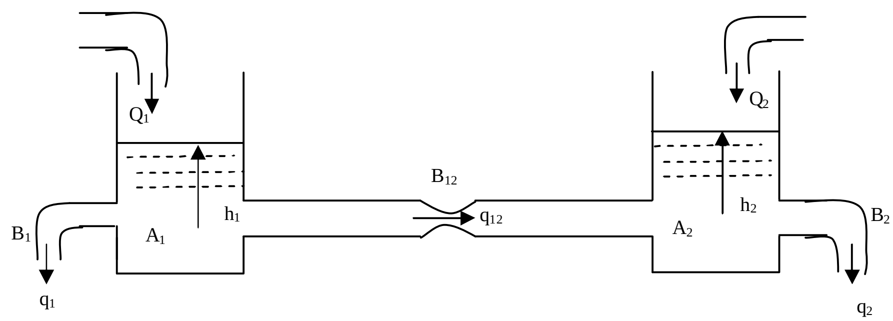


fig.1

2. Obtain the state model of the electrical network shown in fig.2 by choosing v1 (t) and v2 (t) as state variables.

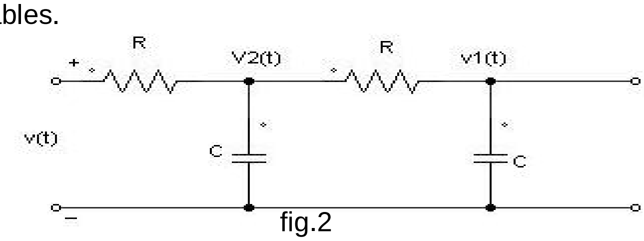


fig.2

3. A feedback system is characterized by the closed loop transfer function:

$$T(S) = \frac{s^2 + 3s + 3}{s^3 + 2s^2 + 3s + 1}$$

Draw a suitable signal flow graph and there from construct a state model of the system.

Course Outcome 2 (CO2):

1. A computer system has the double integrator plant

$$\frac{Y(s)}{R(s)} = \frac{1}{s^2}$$

(i) Taking x_1=y and $x_2 = \dot{y}$ as state variables, obtain the state variable model of the plant.

(ii) Find k_1 and k_2 such that $u = -k_1x_1 - k_2x_2$ gives closed-loop characteristic roots with $\omega_n = 1$ and $\xi = 0.707$

(iii) Design a full-order observer that estimates x_1 and x_2 given measurements of x_1. Pick the characteristic roots of the state-error equations with $\omega_n = 5$ and $\xi = 0.5$

2. A servo system has the plant described by the equation

$$\dot{X} = \begin{bmatrix} -1 & -2 & -2 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \end{bmatrix} X(t) + \begin{bmatrix} 2 \\ 0 \\ 1 \end{bmatrix} u(t)$$
$$Y(t) = \begin{bmatrix} 1 & 1 & 0 \end{bmatrix} X(t)$$

Find a suitable pole placement controller to place the closed pole locations at -2,-2,-3.

3. Obtain the error equation for full order and reduced order observer.

Course Outcome 3 (CO3):

1. Consider the system shown below. Determine the optimal feedback gain matrix K such that the following performance index is minimized:

$$J = 1/2\int_0^\infty (x^T Q x + 2u^2)dt; \quad Q = \begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$$

2. Explain the working of stochastic optimal state estimators.

3. Write the expression for performance index (J) of an optimal regulator problem.

Course Outcome 4 (CO4):

1. Define singular values
2. Define transmission zero
3. Explain the frequency domain analysis of MIMO systems

Course Outcome 5 (CO5):

1. A linear second order servo is described by the equation $\ddot{y} + 2\zeta\omega_n\dot{y} + {\omega_n}^2 y = {\omega_n}^2$, where ωn = 1, y(0)=2, y (0)=0, ζ=1.5. Determine the singular point and construct the phase trajectory.
2. Determine the kind of singularity for each of the following differential equations. Also locate the singular points on the phase plane:
   $\ddot{y}$+3 $\dot{y}$+2y=0
   $\ddot{y}$+5$\dot{y}$ +6y=6
   $\ddot{y}$-8$\dot{y}$+7y=34

3.Define phase trajectory.

Course Outcome 6 (CO6):

1. Obtain the describing function of dead zone and saturation non linearity.
2. Explain in detail about different non linearity.
3. Obtain the describing function of relay with hysteresis.
4. Consider the system shown figure 3. Using the describing function analysis, investigate the possibility of a limit cycle. If a limit cycle is predicted, determine its amplitude and frequency and investigate its stability.

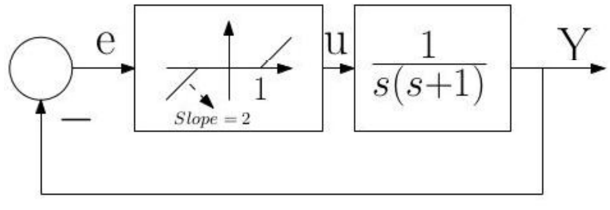


fig.3

5.Explain the stability analysis of non linear system by describing function method.

6.Investigate the stability of a relay controlled system shown in figure 4.

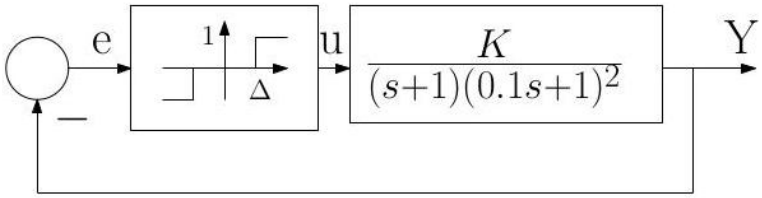


fig.4

Course Outcome 7 (CO7):

1. Consider the linear autonomous system$\dot{x}$ = $\begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} x$. Using direct method of Lyapunov, determine the stability of the equilibrium state

2. Check the stability of the equilibrium state of the system described by

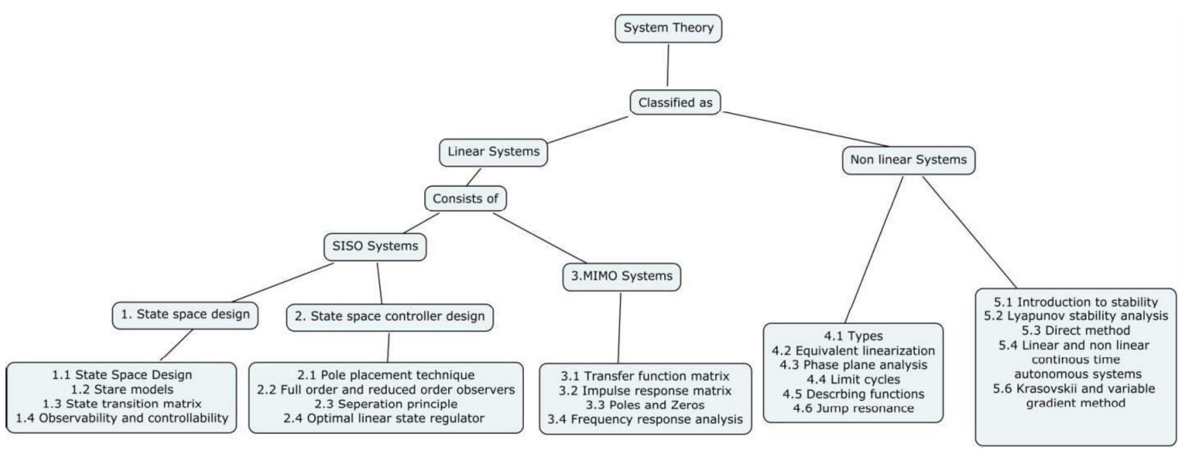
$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -x_1 - {x_1}^2 x_2$$

3. Consider a nonlinear system described by the equations

$$\dot{x}_1 = -3x_1 + x_2$$
$$\dot{x}_2 = -x_1 - x_2 - {x_2}^3$$

Using the Krasovskii method for constructing the Lyapunov function with P as identity matrix, investigate the stability of the equilibrium state

Concept Map



Syllabus

State Space Analysis

Introduction - Concept of state space model for dynamic systems – Time invariance and Linearity- Non-uniqueness - Minimal realization – Canonical state models - Solution of state equations – State transition matrix - Free and forced responses – Controllability and observability

State Space Controller Design

Introduction – State Feedback control – Pole Placement by State Feedback – Full Order and Reduced Order Observers – Separation principle –Optimal linear state regulator – Stochastic optimal linear estimator.

MIMO Systems

Properties of transfer functions Matrix – Impulse response matrices – Poles and zeros of transfer function matrices – Critical frequencies – Resonance – Steady state and dynamic response – Bandwidth- Nyquist plots – Singular value analysis.

Non-Linear Systems

Types of non-linearity – Typical examples – Equivalent linearization – Phase plane analysis – Limit cycles – Describing functions- Analysis using Describing functions – Jump resonance.

Stability

Introduction – Equilibrium Points – Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems-Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems – The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems – Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems – Lashalle Invariance principle, Barbalat Lemma, Krasovskii and Variable-Gradient Method.

Reference Books

1. M. Gopal, ―Modern Control System Theory‖, New Age International Publications, revised 2nd edition, 2005.
2. K. Ogatta, ―Modern Control Engineering‖, PHI Publications, 2002.
3. I.J.Nagarath , M. Gopal, ―Control Systems Engineering‖, New Age International Publications, 4th edition, New Delhi, 2006.
4. M.Gopal, ―Digital Control and state variable methods – conventional and intelligent control systems‖, Tata Mcgraw Hill 3rd edition, New Delhi, 2008.
5. Stanley M. Shinners, ―Modern control system theory and design‖ Wiley-IEEE 2nd edition, 1998.

Course Contents and Lecture Schedule

Sl.No.	Topic	No. of Lecture Hours
1.0	**State Space Analysis**	
1.1	Introduction - Concept of state space model for dynamic systems	1
1.2	Time invariance and Linearity, Non-uniqueness, Minimal realization, Canonical state models	2
1.3	Solution of state equations – State transition matrix	2
1.4	Free and forced responses	1
1.5	Controllability and Observability	1
2.0	**State Space Controller Design**	
2.1	Introduction – State Feedback control	1
2.2	Pole Placement by State Feedback	2
2.3	Full Order and Reduced Order Observers	1
2.4	Separation principle	1
2.5	Optimal linear state regulator	1
2.6	Stochastic optimal linear estimator	1
3.0	**MIMO Systems**	
3.1	Properties of transfer functions Matrix	1
3.2	Impulse response matrices	1
3.3	Poles and zeros of transfer function matrices	1
3.4	Critical frequencies, Resonance, Steady state and dynamic response, Bandwidth	1
3.5	Nyquist plots	1
3.6	Singular value analysis	1
4.0	**Non-Linear Systems**	

4.1	Types of non-linearity – Typical examples	1
4.2	Equivalent linearization	1
4.3	Phase plane analysis	2
4.4	Limit cycles	1
4.5	Describing functions- Analysis using Describing functions	2
4.6	Jump resonance	1
5.0	**Stability**	
5.1	Introduction – Equilibrium Points	1
5.2	Stability in the sense of Lyapunov – BIBO Stability – Stability of LTI Systems	1
5.3	Equilibrium Stability of Nonlinear Continuous Time Autonomous Systems	1
5.4	The Direct Method of Lyapunov and the Linear Continuous Time Autonomous Systems	1
5.5	Finding Lyapunov Functions for Nonlinear Continuous Time Autonomous Systems Lashalle Invariance principle, Barbalat Lemma	2
5.6	Krasovskii and Variable-Gradient Method	2
	Total	**36**

Course Designers:

1 Dr.S.Baskar sbeee@tce.edu
2 Prof. S.Sivakumar siva@tce.edu
3 Dr.S.Latha sleee@tce.edu

18CI130	PROCESS CONTROL	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Process control is an important area of control theory. It enables mass production with desired quality, safe operation of many industries. Objective of the course is to introduce the concepts of modelling, analysis & control of SISO/MIMO processes and recent trends in process instrumentation.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcomes	Blooms level
CO1	Develop transfer function and state space model of interconnected tank level processes, CSTH, CSTR, Mixing process and Tubular Heat exchanger	Apply
CO2	Analyse the open loop and closed loop response of a given process in time domain and frequency domain	Analyse
CO3	Calculate PID parameters for a given process using Direct synthesis, Ziegler Nichols, Cohen coon, relay feedback,Tyreus Luyben methods and IMC methods	Apply
CO4	Design Cascade andFeedforward controller for a given process	Apply
CO5	Explain the operation of Dead time compensation, inverse response compensation, selective control split range control, ratio control, inferential control and adaptive control methods	Understand
CO6	Design decentralized controller for a given MIMO process.	Apply
CO7	Explain the principle of operation of Dynamic Matrix Control and Generalized Predictive Control	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO3.	**S**	**M**	**M**	**M**							**M**
CO4.	**S**	**S**	**M**	**M**							**M**
CO3.	**S**	**M**	**M**	**M**							**M**
CO4.	**S**	**M**	**M**	**M**							**M**
CO5.	**M**	**S**	**S**								**M**
CO6.	**S**	**M**	**M**	**M**							**M**
CO7.	**M**	**S**	**S**								**M**

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	20	40	30	30
Apply	40	50	40	40
Analyse	30		20	20

Course Level Assessment Questions

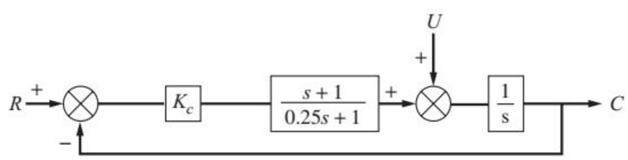
Course Outcome 1 (CO1):

1. Develop the state space model of continuously stirred tank heater.
2. Develop the state space model of isothermal mixing process.
3. Develop the transfer function matrix for quadruple tank level system.

Course Outcome 2 (CO2):

1. Consider a liquid level control process with transfer function $G(s) = \frac{1}{5s+1}e^{-2s}$. It is controlled in closed loop using a proportional controller. Average velocity of water in inlet pipe is 0.5m/s.
   a) Find the range of Kc for which the process will be stable.
   b) Because of some constraint, the control valve has to be moved far away from the tank. Assuming controller gain Kc is fixed at 2, calculate the maximum distance at which the control valve can be placed, in such a way the closed loop operation is stable.

2. For the system shown below



   a) Find the closed loop transfer function C(s)/U(s) and C(s)/R(s).
   b) Calculate the value of Kc for which the closed loop response has damping ratio of 2.3
   c) When Kc=4, calculate the offset for simultaneous unit step change in U and R.
3. How Amplitude ratio (AR) and Phase (Φ) changes, when gain, time delay, time constant changes. ?

Course Outcome 3(CO3):

1. Using the Direct synthesis method. Find the controller with PI/PID structure with only one tuning parameter (λ) , for the below transfer functions

$$G_1(S) = \frac{K_P}{\tau_P S+1} \text{b) } G_2(S) = \frac{2e^{-3S}}{5S+1} \quad \text{c)} G_3(S) = \frac{-9S+1}{(15S+1)(3S+1)}$$

2. Find the ultimate gain and ultimate period for the Transfer function below $G(s) = \frac{-5 * e^{-0.5S}}{(2.5S+1)}$ Calculate the P, PI, PID setting by using the ZN- closed loop tuning method.

3. Design a structure and implementation of the PID- control scheme with the following features: Bump-less auto-manual transfer, Proportional – kick elimination, Derivative – kicks elimination.

Course Outcome 4(CO4):

1. Design the cascade controller for the system with primary transfer function $G_{p1}(s) = \frac{1}{10s+1}$ And with the secondary transfer function $G_{p2}(s) = \frac{1}{(5s+1)(2s+1)}$. The Measurement sensor for the inner loop with dynamics of $G_{m2}(s) = \frac{1}{s+1}$.
   Design the proportional controller for inner loop and PI controller for the outer loop.

2. The Distillation column has the following transfer function model: $\frac{Y'(s)}{D'(s)} = \frac{2\,e^{-20s}}{95s+1}$; $\frac{Y'(s)}{F'(s)} = \frac{0.5\,e^{-30s}}{60s+1}$, where $G_v = G_m = G_t = 1$. Design a feed forward controller based on a steady-state analysis. Design a PI Feed controller based on the Direct Synthesis approach with closed loop time constant of 30.
3. Consider the following transfer functions.
   $G_v = \frac{5}{s+1}$; $G_{p1} = \frac{4}{(4s+1)(2s+1)}$; $G_{p2} = 1$; $G_{d2} = 1$; $G_{m1} = 0.05$; $G_{m2} = 0.2$; $G_{d1} = \frac{1}{3s+1}$,where the time constants have units of minutes and the gains have consistent units. Determine the stability limits for a conventional proportional controller as well as for a cascade control system consisting of two proportional controllers. Assume $K_{c2} = 4$ for the secondary controller. Calculate the resulting offset for a unit step change in the secondary disturbance variable D_2.

Course Outcome 5(CO5):

1. **Explain about the ratio and split range control for a particular application**
2. **A smith predictor is to be used with an integrator-plus-time-delay process,** $\boldsymbol{G(s)} = \frac{2}{s}e^{-3s}$. For a unit step disturbance and $G_d = G$, show that PI control will not eliminate offset even when the model is known perfectly.
3. Explain any two adaptive control strategy.

Course Outcome 6(CO6):

1. Consider the MIMO process with transfer function matrix,

$$G_p(s) = \begin{bmatrix} \frac{s+4}{(s+2)(s+3)} & \frac{2}{(s+2)(s+3)} \\ \frac{3}{(s+2)(s+3)} & \frac{1}{(s+2)(s+3)} \end{bmatrix}.$$

   Develop a multivariable Internal Model Controller for the process.
2. Consider a process ("the shower problem") where a cold water stream at 15°C is mixed with a hot water stream of 50°C. The outputs are the total mixed stream flow rate and temperature. Assume steady-state flow rates of 0.19 and 0.13 litres/sec for the cold and hot streams respectively. The steady-state outputs are then 0.32 litres/sec and 29°C. Scale the inputs and outputs to cover appropriate ranges, find the scaled gain matrix and perform an SVD analysis. What is the condition number? What are the most sensitive input and output directions (provide a physical interpretation of this result)? For a rectangular input space where the cold water flow can range from 0 to 0.25 litres/second and the hot water flow can range from 0 to 0.19 litres/sec, construct the output operating window. Given those input flow limits, is it possible to operate over a mixed stream flow rate of 0.19 to 0.44 litres/sec, with a mixed stream temperature between 23 and 34°C?
3. Consider the MIMO Process given below.

$$G_p(s) = \begin{bmatrix} \frac{2.6}{62s+1} & \frac{1.5}{(62s+1)(23s+1)} \\ \frac{1.4}{(30s+1)(90s+1)} & \frac{2.8}{90s+1} \end{bmatrix}$$

a) Calculate transmission zeros of the process.
b) Using relative gain array choose suitable I/O pair and design decentralized proportional controller to increase the speed of response by 2 times the open loop response.
c) Design static and simplified decouplers to reduce the effect of interaction.

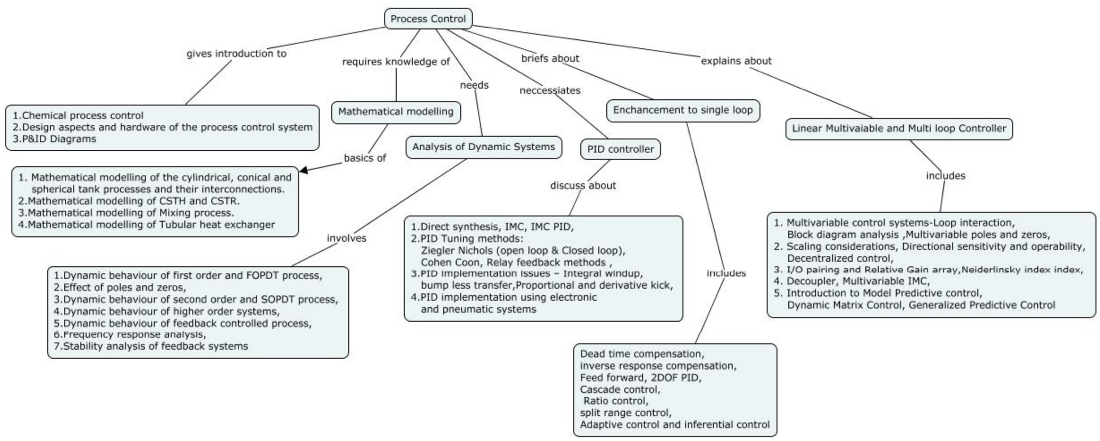
Course Outcome 7(CO7):

1. Compare the features of various MPC packages.
2. A chemical process is to be controlled by Dynamic Matrix controller. Initially, input to the process and the output of the process are zero. Finite Step response coefficients of a process are S = {0.18, 0.3, 0.45, 0.55, 0.63, 0.72, 0.75}. Assuming prediction horizon

=3, control horizon =1, and unit step reference, calculate the first output of Dynamic Matrix controller. Assume control input weight =0.

3. Discuss about the Generalized Predictive Control

Concept Map



Syllabus

Introduction

Incentives for chemical process control, Design aspects of process control systems, Hardware for a process control system, P&ID diagrams

Mathematical Modelling of Chemical process

Need for mathematical model, modelling of cylindrical, conical and spherical tank processes and their interconnections, Modelling of CSTH and CSTR, Modelling of Mixing process, Modelling of Tubular heat exchanger

Analysis of Dynamic Systems: Dynamic behaviour of first order and FOPDT process, Effect of poles and zeros, Dynamic behaviour of second order and SOPDT process, Dynamic behaviour of higher order systems, Dynamic behaviour of feedback controlled process, Frequency response analysis, Stability analysis of feedback systems

PID Control: Direct synthesis, IMC, IMC PID, PID Tuning methods: Ziegler Nichols (open loop & Closed loop), Cohen Coon, Relay feedback methods , PID implementation issues – Integral windup, bump less transfer, Proportional and derivative kick, PID implementation using electronic and pneumatic systems

Extension of Single loop control systems:

Dead time compensation, inverse response compensation, Feed forward, 2DOF PID, Cascade control, Ratio control, split range control, Adaptive control and inferential control

Multivariable Control

Multivariable control systems, Loop interaction, Block diagram analysis , Multivariable poles and zeros, Scaling considerations, Directional sensitivity and operability, Decentralized control, I/O pairing and Relative Gain array, Neiderlinsky index index, Decoupler, Multivariable IMC, Introduction to Model Predictive control, Dynamic Matrix Control, Generalized Predictive Control

Reference Books

1. B.WayneBequette, “Process Control: Modeling, Design, and Simulation”, Prentice Hall ofIndia, 2004
2. Dale E. Seborg , Duncan A. Mellichamp , Thomas F. Edgar, and Francis J. Doyle, III, “Process Dynamics and Control”, John Wiley and Sons, 3rd Edition, 2010.
3. George Stephanopolus, "Chemical Process Control", Prentice Hall India,2000
4. Donald R Coughanowr and Steven LeBlanc, “Process System Analysis and Control”, 3^{rd} edition, Mc Graw Hill Education, 2017.
5. Instrumentation symbols and identification ANSI/ISA-S5.1-1984 (R 1992), Instrument Society of America, 1992
6. Friedtich Frohr & F Orttenburer, "Introduction to Electronic Control Engineering", New Age International publishers, 2010.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.	**Introduction**	
1.1	Incentives for chemical process control	1
1.2	Design aspects of process control systems, Hardware for a process control system	1
1.3	P&ID Diagrams	1
2.	**Mathematical Modelling of Chemical process**	
2.1	Need for mathematical model	1
2.2	Modelling of cylindrical, conical and spherical tank processes and their interconnections	2
2.3	Modelling of CSTH and CSTR	2
2.4	Modelling of Mixing process	1
2.5	Modelling of Tubular heat exchanger	1
3	**Analysis of Dynamic Systems**	
3.1	Dynamic behaviour of first order and FOPDT process, Effect of poles and zeros	2
3.2	Dynamic behaviour of second order and SOPDT process	2
3.3	Dynamic behaviour of higher order systems	
3.4	Dynamic behaviour of feedback controlled process	2
3.5	Frequency response analysis	2
3.6	Stability analysis of feedback systems	2
4	**PID Control**	
4.1	Direct synthesis, IMC, IMC PID	2
4.2	PID Tuning methods: Ziegler Nichols (openloop & Closed loop), Cohen Coon, Relay feedback methods	2
4.3	PID implementation issues – Integral windup, bump less transfer, Proportional and derivative kick	1
4.4	PID implementation using electronic and pneumatic systems	1
5	**Extension of single loop control systems**	
5.1	Dead time compensation, inverse response compensation	1
5.2	Feed forward, 2DOF PID	1
5.3	Cascade control	1
5.4	Ratio control, split range control	1
5.5	Adaptive control and inferential control	1
6	**Multivariable Control**	
6.1	Multivariable control systems, Loop interaction	1
6.2	Block diagram analysis , Multivariable poles and zeros, Scaling considerations, Directional sensitivity and operability	2

No.	Topic	No. of Lectures
6.3	Decentralized control, I/O pairing and Relative Gain array, Neiderlinsky index	2
6.4	Decoupler	1
6.5	Multivariable IMC	1
6.6	Introduction to Model Predictive control	1
6.7	Dynamic Matrix Control	1
6.8	Generalized Predictive Control	1
Total		**40**

Course Designers:

1.	M.Varatharajan	varatharajan@tce.edu
2.	S.Surendhar	ssreee@tce.edu
3.	R.Suganya	rsaeee@tce.edu

18CI160 TRANSDUCER ENGINEERING

Category	L	T	P	Credit
PC	2	0	2	3

Preamble

Sensor and Transducer are used in automation, in industries, transport, construction, domestic appliances, health services, and other applications. Advances in processing and computation have opened up opportunities for very accurate control of plants, processes, and systems. Sensors/Transducers have helped achieve substantial accuracy and control as automation of any kind begins with the measurement of certain system parameters of which sensors and transducers form an essential and indispensable part. Industrial process monitoring has become possible by appropriate and accurate sensing of the relevant variables. This course deals with different sensors and transducers their characteristics, operation and applications.

Course Outcomes

On the successful completion of the course, students will be able to

(CO)	Course Outcome	Bloom's Level
(CO1)	Appreciate the significance of static and dynamic characteristics of transducers	Understand
(CO2)	Illustrate the mathematical model for resistive, inductive capacitive transducers	Understand
(CO3)	Appreciate the importance of cold junction compensation of thermocouple	Understand
(CO4)	Explain the Characteristics of Piezo-electric, hall effect, magnetostrictive and encoding transducers	Understand
(CO5)	Choose suitable signal conditioning methods for specific transducers	Apply
(CO6)	Explain the functionalities of smart sensors	Understand
(CO7)	Determine the static characteristics of various transducers.	Apply
(CO8)	Determine the dynamic characteristics of various temperature measuring transducers	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S										
CO2.	S										
CO3	S	M									
CO4	S	M	M								
CO5	S										
CO6	S										
CO7	S				S						L
CO8	S				S						L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Practical test	Terminal Examination
	1	2	3		
Remember	20	20	20	0	20
Understand	80	60	60	0	60
Apply	0	20	20	100	20
Analyse	0	0	0	0	0
Evaluate	0	0	0	0	0
Create	0	0	0	0	0

Practical test should be conducted for assessing the attainment of C07 & C08.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define the term Resolution
2. Distinguish between Accuracy and Precision.
3. List the causes for hysteresis in transducers.
4. For every 10.06 meters you go down the sea level, the pressure increases by 14.5 psi. A first order pressure transducer used to measure the pressure. The pressure transducer is within a submarine which descends at the rate of 0.5 meters per minute. Find the response at a depth of 100 feet. The static gain of the sensor is 1. The time constant of the transducer is 2ms.

Course Outcome 2 (CO2):

1. Express the relationship between temperature and resistance of conductor in RTD.
2. What is the significance of phase sensitive demodulation with respect to LVDT?
3. Explain the mathematical model for resistive transducer.
4. Which of the resistance based temperature sensors with two wires does not require lead wire compensation. Why?
5. A voltage dividing potentiometer is used to measure an angular displacement. The angle of displacement is 60° and total angle of travel of the potentiometer is 355°. (i) Calculate the voltage output on open circuit if the potentiometer is excited by a 60 V source. (ii) Calculate the actual output voltage at this setting if a voltmeter of 1 MΩ resistance is connected across the output. The resistance of the potentiometer is 1 KΩ. The turns are uniformly distributed (iii) Calculate the percentage error.

Course Outcome 3 (CO3):

1. What are thermocouple tables?
2. Explain the process of Cold junction compensation of thermocouples using thermocouple tables.
3. When a high impedance voltmeter was used, type T thermocouple gave an output of 13.019mV. The actual thermocouple reference junction temperature is 20ºC. Interpolating from the type T table, 20ºC will yeald 0.787 mV with the reference junction at 0ºC. Find the unknown junction temperature.The values derived from type T thermocouple tables are given below:

Thermocouple output (mV)	Temperature(ºC)
-2.525	-72
0.787	20
13.806	282

Course Outcome 4 (CO4):

1. A piezo electric transducer has a capacitance of 1000 pF and a charge sensitivity of 4 X 10^{-6} Coulomb/cm. The connecting cable has a capacitance of 400 pF. The display device has an input impedance of 1 M ohm resistance and 50 pF capacitance connected in parallel. What is the lowest frequency that can be measured with 2 percent error?
2. Write some Natural and artificial piezoelectric crystals
3. A Hall element made out of Sn-Ge with co-efficient of 8 X 10^{-6}V-m^3/ (Wb-Amp) is subjected to a magnetic flux density of 0.75 Wb/sq.m. The thickness of this element is 2 mm. When a current of 1.5 A is flowing through the element, what is the voltage output.
4. A piezo electric transducer has a capacitance of 1200 pF. The connecting cable has a capacitance of 350 pF. The display device has an input impedance of 1 M Ω resistance and 50 pF capacitance connected in parallel. What is the lowest frequency that can be measured with 1 percent error?

Course Outcome (CO5):

1. A 2 wire RTD (100 ohms at 0ºC) is connected to a Wheatstone bridge circuit. The resistance of the 100 ohm RTD element will change by 0.385 ohms for each degree Centigrade change in temperature. The maximum allowable increase in indicated process temperature due to lead wire resistance is 1ºC. 20 SWG copper wire is used as the lead wire to connect the RTD to the bridge circuit. A 20 Gauge copper lead wire of 7.6m length has a resistance of 0.5 ohms. Calculate the maximum distance at which the RTD can be placed from the wheat stone bridge.
2. Specify the concept that is necessary for determining the direction of travel in a LVDT. Explain how this can be realized by a Cost effective circuit. List disadvantages of it, if any.
3. Derive the output of a Half bridge configuration of Wheatstone bridge with Strain gauge as active elements. Identify in which possible position combinations the active elements may be mounted.
4. Strain gauges of gauge resistances 1000-Ω and a gauge factor of 2.4 each is wound on a cantilever beam on the top and bottom sides and connected in full bridge configuration. The bridge is supplied by a 5 V source. The detector has a resistance of 1000 Ω. What is the Current through the detector for 0.18% strain.
5. In a Hall Wattmeter, a voltage of 250 V is applied. This voltage is connected to the Hall element of Bismuth with 2.5 mm thickness with a series resistance of 500 ohms. The current coil produces a flux of 0.5 Wb/ m^2, when a current of 200 mA is passed through and it is linear up to a current of 2 Ampere. When the Hall voltage is 0.5mV, what is the power consumed by the load circuit. The Hall coefficient for Bismuth is – 1 X 10^{-6}V-m^3/ (Wb-Amp)

Course Outcome (CO6):

1. Elaborate about TEDs.
2. Appreciate the significance of Plug and Play capability of Smart sensors
3. Mention the instrumentation Current Standard
4. Specify the instrumentation Pressure Standard
5. What is NIST?

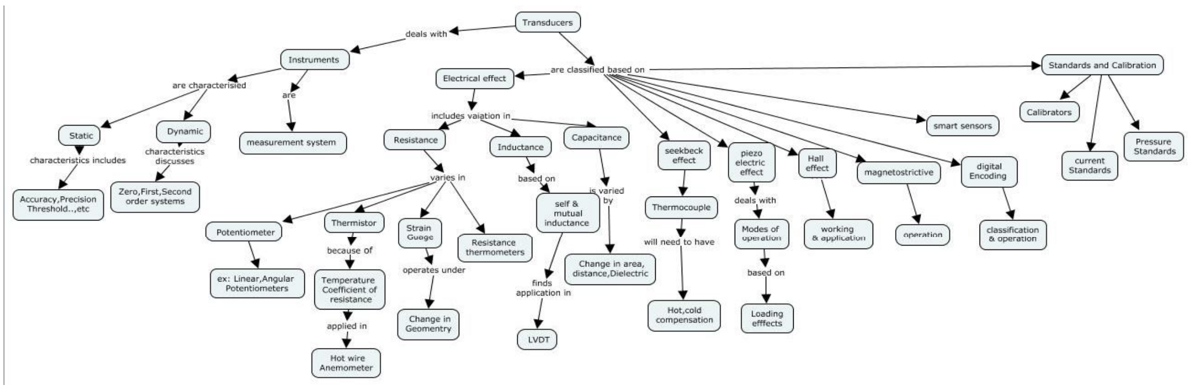
Laboratory Session (CO7 & CO8)

1. Determine the sensitivities in Quarter Bridge, Half Bridge and Full Bridge based strain measurement.
2. Determine the dynamic characteristics of various temperature measuring transducers
3. Appreciate the Sensitivity vs Power dissipation in a potentiometer used as a

displacement transducer

4. Demonstrate the various errors occurring in 2 Wire RTD, 3 Wire RTD and 4 Wire RTD
5. Use Hot Wire Anemometer to determine air flow and compare it with wane type anemometer
6. Perform cold junction compensation of the given thermocouple by experimentation and with the aid of relevant thermocouple tables
7. Develop a wattmeter using Hall Effect Sensor
8. Analyze the directional and magnitude characteristics of displacement using LVDT.
9. Analyze the characteristics of variable capacitance sensor for measurement of linear and angular displacement and level measurement.
10. Determine the speed of motor using Encoder

Concept Map



Syllabus

Introduction to measurement systems: Elements of a measurement system – Definition of Sensor/ Transducer

Performance Characteristics of Transducers

Static characteristics: Meaning of static calibration, Accuracy, Precision, bias, Linearity, Threshold, Resolution, Hysteresis and Dead space, Scale readability and span
Dynamic characteristics: Sinusoidal transfer function, zero order transducer, First order transducer, Step, Ramp, Frequency and Impulse response, Second order transducer, Step, Ramp Frequency and Impulse response

Variable Resistance Transducers

Potentiometers: Loading effect, Power rating of potentiometers, Linearity and Sensitivity, Construction of potentiometers, Non-linear potentiometers - **Strain gauges**
Theory of Strain gauges, Types of strain gauges, Characteristics of strain gauges - **Resistance thermometers:** Characteristics, Linear approximation, Quadratic approximation, 2 wire RTD, 3 wire RTD – **Thermistors:** Resistance vs. Temperature characteristics - **Hot wire anemometers:** Constant current mode and Constant temperature mode

Variable Inductance transducers
Variable Inductance sensor - Linear Variable Differential Transformer Construction, Working principle, Auxiliary circuits

Variable capacitance transducers

Change in area of plates, Change in distance between the plates, Differential arrangement, Variation of dielectric constant, Frequency response.

Thermocouples - Construction, Measurement of thermocouple output, Law of Thermocouples, Compensating circuits, Reference junction compensation, Lead Compensation
Piezoelectric transducers -Modes of operation of piezoelectric crystals, Properties, Equivalent circuit of piezoelectric transducers, Loading effects and frequency response
Hall effect transducers- working principle, application, **Magnetostrictive transducers-** principle of operation

Digital encoding transducers – Classification of encoders, Construction of encoders – Signal generation - Brush type, Optical type, Magnetic type, Eddy current type
Smart sensors: Introduction, primary sensors, Excitation, Amplification, Filters, Convertors, Compensation, Information coding process, Data communication
Introduction to MEMS sensors
Standards and Calibration: Instrumentation current Standards, Instrumentation Pressure Standards, Calibrators

Reference Books

1. E.O.Doubelin, Measurement Systems, McGraw Hill Book Company, 2008
2. Tony R. Kuphaldt , Lessons In Industrial Instrumentation ,Version 1.0 – Released September 28, 2009
3. D. Patranabis, Sensors and Transducers, Wheeler Publishing, 2006
4. Hermann, K.P. Neubert, Instrument Transducers, Oxford University Press, 1988
5. D.V.S. Murthy, Transducers and Instrumentation, Prentice Hall of India Pvt. Ltd., 2008

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.1	**Introduction to measurement systems:** Elements of a measurement system – Definition of Sensor/ Transducer	1
1.2	**Performance Characteristics of Transducers** **Static characteristics:** Meaning of static calibration, Accuracy, Precision, bias, Linearity, Threshold, Resolution, Hysteresis and Dead space, Scale readability and span	2
1.3	**Dynamic characteristics:** Sinusoidal transfer function, zero order transducer, First order transducer, Step, Ramp, Frequency and Impulse response, Second order transducer, Step, Ramp Frequency and Impulse response	2
2.0	**Variable Resistance transducers**	
2.1	**Potentiometers:** Loading effect, Power rating of potentiometers, Linearity and Sensitivity, Construction of potentiometers, Non-linear potentiometers	2
2.2	**Strain gauges** Theory of Strain gauges, Types of strain gauges, Characteristics of strain gauges	2
2.3	**Resistance thermometers:** Characteristics, Linear approximation, Quadratic approximation, 2 wire RTD, 3 wire RTD **Thermistors:** Resistance vs. Temperature characteristics	2
2.4	**Hot wire anemometers:** Constant current mode and Constant temperature mode	1
3.0	**Variable Inductance transducers**	
3.1	Variable Inductance sensor -	1

3.2	Linear Variable Differential Transformer Construction, Working principle, Auxiliary circuits	2
4.0	**Variable capacitance transducers**	
4.1	Change in area of plates, Change in distance between the plates, Differential arrangement, Variation of dielectric constant, Frequency response.	2
5.0	**Thermocouples** Compensating circuits, Reference junction compensation, Lead Compensation	1
5.1	Construction, Measurement of thermocouple output	
5.2	Law of Thermocouples, Compensating circuits, Reference junction compensation, Lead compensation	1
6.0	**Piezoelectric transducers**	
6.1	Modes of operation of piezoelectric crystals, Properties, Equivalent circuit of piezoelectric transducers	1
6.2	Loading effects and frequency response	2
7.0.	**Hall effect transducers**	
7.1	working principle, application	2
8.0	**Magnetostrictive transducers**	
8.1	Principle of operation	1
9.0	**Digital encoding transducers**	
9.1	Classification of encoders, Construction of encoders – Signal generation - Brush type, Optical type, Magnetic type, Eddy current type	2
10.	**Smart sensors**	
10.1	Introduction, primary sensors, Excitation, Amplification, Filters, Convertors, Compensation, Information coding process, Data communication, Introduction to MEMS sensors	2
11.	**Standards and Calibration:** Instrumentation current Standards, Instrumentation Pressure Standards, Calibration	1
	Total	**30**

Course Designers:

1. Dr.V.Prakash vpeee@tce.edu
2. Dr.B.Ashok kumar ashokudt@tce.edu
3. Mrs. R. Suganya rsaeee@tce.edu

18CI170	CONTROL AND INSTRUMENTATION LAB	Category	L	T	P	Credit
		PC	0	0	4	2

Preamble

Hands-on experience of the components present in any control system is a must for a control and instrumentation engineer. This helps to develop precise control systems. In this context, this laboratory course aims at providing hands-on training to the students in the fields of instrumentation and control.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcomes	Blooms level
CO1	Determine the characteristics of control valves	Apply
CO2	Determine the static characteristics of orifice and venturi meter	Apply,
CO3	Determine the characteristics of capacitance based level transducer	Apply
CO4	Calibrate the pressure gauge using dead weight pressure tester	Apply
CO5	Develop Labview based instrumentation system using data acquisition devices	Apply
CO6	Analyze the performance of P,PI and PID controllers tuned using ZN, Cohen-Coon and relay oscillation method in a process control system	Analyze
CO7	Analyze the performance of Euler method and Runge-Kutta method for simulation of nonlinear systems	Analyze,
CO8	Analyze the effect of compensator for a servo mechanism to achieve desired specifications	Analyze
CO9	Analyze the effect of state feedback controller with observer for a servo mechanism to achieve desired specifications	Analyze
CO10	Analyze the stability of limit cycles for a different types of hard nonlinear system by simulation in matlab/scilab	Analyze

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO	**S**	**M**	**M**	**M**							**M**
CO2.	**S**	**M**	**M**	**M**							**M**
CO3	**S**	**M**	**M**	**M**							**M**
CO4	**S**	**M**	**M**	**M**							**M**
CO5	**S**	**M**	**M**	**M**							**M**
CO6	**S**	**S**	**M**	**M**							**M**
CO7	**S**	**S**	**M**	**M**							**M**
CO8	**S**	**S**	**M**	**M**							**M**

CO9	**S**	**S**	**M**	**M**							**M**
CO10	**S**	**S**	**M**	**M**							**M**

S- Strong; M-Medium; L-Low

Experiments

Instrumentation:

1. Determination of Characteristics of control valves
2. Flow measurement using rotameter, orifice and venturi meter
3. Level measurement using Capacitance based level transmitter
4. Calibration of pressure gauge
5. PC based data acquisition

Control:

6. Analysis of closed loop performance of PID tuning methods in tank level control process
7. Simulation of nonlinear systems
8. Design and implementation of compensators in Quanser servo system
9. Design and implementation of state feedback controller with observer in Quanser servo system
10. Analysis of stability of limit cycle on a simulated hard nonlinear system

Course Designers:

1.	V.Prakash	vpeee@tce.edu
2.	M.Varatharajan	varatharajan@tce.edu

18CI210	INDUSTRIAL AUTOMATION	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Automation has become a backbone of present day industrial improvements. Industrial automation along with industrial Information technology play a huge role in implementation of Industry 4.0. Objective of this course is to introduce the fundamental components of industrial automation. This course also introduces basics of industrial automation, hydraulic and pneumatic actuators, Programmable logic controllers, DCS, SCADA and common industrial data network standards and buses.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcomes	Blooms level
CO1	Explain the architecture of Industrial automation systems	Understand
CO2	Explain the principle of operation of flow control valves, hydraulic and pneumatic actuators	Understand
CO3	Develop PLC program for a given sequential process using digital i/o timers and counters	Apply
CO4	Develop PLC program for a given sequential process using special function modules, sequencers and shift registers	Apply
CO5	Explain the features of industrial data networks	Understand
CO6	Explain the architecture of Distributed control systems and SCADA	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO	**M**	**S**	**S**								**M**
CO2.	**M**	**S**	**S**								**M**
CO3.	**S**	**M**	**M**	**M**							**M**
CO4.	**S**	**M**	**M**	**M**							**M**
CO5.	**M**	**S**	**S**								**M**
CO6.	**M**	**S**	**S**								**M**

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	50	50	50	50
Apply	30	30	30	30

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Illustrate the architecture of Industrial Automation Systems.
2. Differentiate industrial automation and industrial information technology.
3. List a few final control elements in Industries.

Course Outcome 2 (CO2):

1. Differentiate cavitation and flashing.
2. With a neat diagram explain the components and the working of pneumatic actuated flow control valves
3. List the difference between hydraulic and pneumatic systems.
4. With suitable diagram explain the construction and working of servo valves

Course Outcome 3 (CO3)

1. When the lights are turned off in a building (assume 2 lights inside the building), an exit door light is to remain ON for additional 2 minutes. Then parking lot lights should remain on for additional 3 minutes after the door light goes out. Develop a PLC program to implement this process

2. A pump is to be used to fill two storage tanks. The pump is manually started by the operator from a station. When the first tank is full, the control logic must be able to automatically stop flow to the first tank and direct flow to the second tank through the use of sensors and electric solenoid valves. When the second tank is full, the pump must shut down automatically. Indicator lamps are to be included to signal when each tank is full. Develop a PLC program to implement this process

3. Write a program to operate a light according to the following sequence:
    a. A momentary pushbutton is pressed to start the sequence.
    b. The light is switched on and remains on for 2 s.
    c. The light is then switched off and remains off for 2 s.
    d. A counter is incremented by 1 after this sequence.
    e. The sequence then repeats for a total of 4 counts.
    f. After the fourth count, the sequence will stop and the counter will be reset to zero.

Course Outcome 4 (CO4)

1. Two part conveyor lines, A and B, feed a main conveyor line M. A third conveyor line, R, removes rejected parts a short distance away from the main conveyor. Conveyors A, B, and R have parts counters connected to them. Construct a PLC program to obtain the total parts

2. Write a program that uses the COP instruction to copy 128 bits of data from the memory area, starting at 83:0, to the memory area, starting at 83:8.

3. The temperature reading from a thermocouple is to be read and stored in a memory location every 5 min for 4 h. The temperature reading is brought in continuously and stored in address N7:150. File #7:200 is to contain the data from the last full 4-hour period.

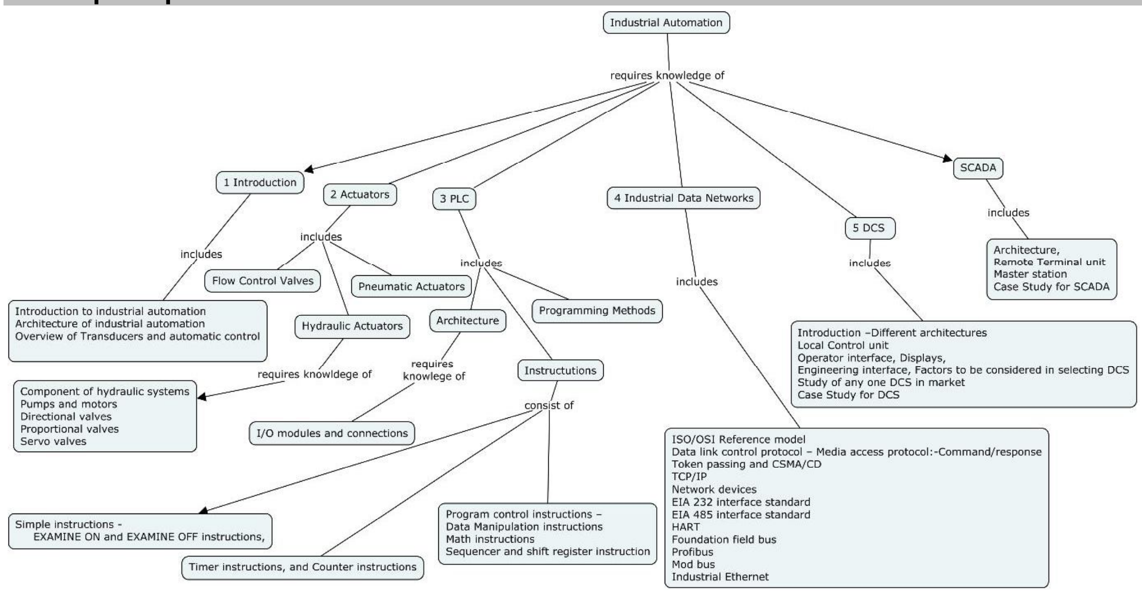
Course Outcome 5 (CO5)

1. Explain the role of various layers in ISO reference model
2. Explain the half duplex operation of EIA 232 interface
3. With suitable diagram explain fieldbus message specification.

Course Outcome 6(CO6)

1. List the advantages of distributed control architecture over centralized control architecture
2. Define control complexity ratio
3. Explain about various types of approaches in designing a LCU control architecture
4. Discuss about the input and output devices used for high level operator interface.
5. With a neat diagram explain the architecture of SCADA

Concept Map



Syllabus

Introduction

Introduction to industrial automation, Architecture of industrial automation, overview of Transducers and automatic control,

Actuators:

Flow control valves - Hydraulic actuators: - Component of hydraulic systems, pumps and motors, directional valves, Proportional valves, servo valves, - Pneumatic actuators

PLC:

Architecture of PLC, I/O modules and connections, PLC programming methods-Ladder logic, Functional block programming, Sequential function chart, Instruction list and Structured text programming,

Simple instructions - EXAMINE ON and EXAMINE OFF instructions, Timer instructions, and Counter instructions- program control instructions – Data Manipulation instructions - math instructions, Sequencer and shift register instruction,

Industrial Data Networks

ISO/OSI Reference model – Data link control protocol – Media access protocol:-Command/response, Token passing and CSMA/CD - TCP/IP – Network devices

EIA 232 interface standard – EIA 485 interface standard – HART, Foundation field bus, Profibus, Mod bus, Industrial Ethernet, Wireless HART, CAN bus, ISA 100

Distributed Control system
Introduction –Different architectures – Local Control unit, Operator interface, Displays, Engineering interface, Factors to be considered in selecting DCS, Study of any one DCS in market, DCS implementation case study

SCADA: Architecture, Remote Terminal unit, Master station, Communication, Open SCADA Protocols, SCADA implementation case study

Reference Books

1. W.Buchanan, "Computer Busses: Design and Application", CRC Press, 2000
2. F.D.Petruzella, "Programmable Logic Controllers", Third Edition, Tata McGraw-Hill, 2010
3. S.Mackay, E.Wright, D.Reynders, and J.Park, "Practical Industrial Data Networks: Design,Installation and Troubleshooting", Newnes Publication, Elsevier, 2004
4. M.P.Lucas, "Distributed Control System", Van Nostrand Reinhold Company, New York, 1986.
5. G.K.McMillan, "Process/Industrial Instrument and Controls Handbook", Fifth Edition, McGraw-Hill handbook, New York, 1999.
6. Mukkhopadhyay, Sen and Deb, "Industrial Instrumentation , Control and Automation, JAICO Publishing House, 2013.
7. G.Clarke, D.Reynders and E.Wright, "Practical Modern SCADA Protocols: DNP3, IEC 60870.5 and Related Systems", Newnes, First Edition, 2004.
8. Liptak, B.C., Instrumentation Engineers Handbook (Measurement), CRC Press, 2005.
9. R.Bowden, "HART Application Guide", HART Communication Foundation, 1999

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.	**Introduction**	
1.1	Introduction to industrial automation , Architecture of industrial automation	1
1.2	Overview of Transducers and automatic control	1
	Actuators	
2.1	Flow Control Valve -	2
2,2	Hydraulic actuators: - Component of hydraulic systems, pumps and motors, directional valves, Proportional valves, servo valves,	3
2.3	Pneumatic actuators	1
3.0	**PLC**	
3.1	Architecture of PLC, I/O modules and connections, ,	1
3.2	Simple instructions - EXAMINE ON and EXAMINE OFF instructions,	2
3.3	Timer instructions, and Counter instructions,	2
3.4	Program control instructions – Data Manipulation instructions - math instructions	2
3.5	Sequencer and shift register instruction	2
3.6	PLC programming methods-Ladder logic, Functional block programming, Sequentialfunction chart, Instruction list and Structured text programming	3
4	**Industrial Data Networks**	

No.	Topic	No. of Lectures
4.1	ISO/OSI Reference model	1
4.2	Data link control protocol – Media accessprotocol:- Command/response	1
4.3	Token passing and CSMA/CD	1
4.4	TCP/IP	1
4.5	Network devices	1
4.6	EIA 232 interface standard	2
4.7	EIA 485 interface standard	1
4.8	HART	1
4.9	Foundation field bus	2
4.10	Profibus	2
4.11	Mod bus	1
4.12	Industrial Ethernet	1
	Wireless HART	1
	CAN bus	1
	ISA 100	1
5.0	**Distributed Control system**	
5.1	Introduction –Different architectures	1
5.2	Local Control unit	1
5.3	Operator interface, Displays,	1
5.4	Engineering interface, Factors to be considered inselecting DCS	1
5.5	Study of any one DCS in market	1
5.6	Case Study for DCS	1
6.0	**SCADA:**	
6.1	Architecture,	1
6.2	Remote Terminal unit. Master station	1
6.3	Open SCADA Protocols	1
6.4	Case Study for SCADA	1
Total		**40**

Course Designers:

1.	M.Varatharajan	varatharajan@tce.edu
2.	S.Surendhar	ssreee@tce.edu
3.	R.Suganya	rsaeee@tce.edu

18CI260	DIGITAL CONTROL SYSTEM DESIGN	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

Modern embedded solutions allow for better performance and lower costs of dynamic systems such as servomechanisms, chemical processes, and vehicles that move over water, land, air, or space. Digital control theory is here an enabling factor as it can exploit steadily increasing computational capabilities to shift emphasis from hardware to software and thus to take full advantage of modern embedded solutions. This course illustrates the main issues related to digital control theory. The aim is to provide basic notions required for the design and implementation of a digital control system. This knowledge is necessary for the selection of an appropriate microprocessor/DSP or for the correct design of a dedicated component

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

No	Course Outcome	Blooms Level
CO1	Explain the process of sampling performance of digital control system	Understand
CO2	Calculate the response of a given pulse transfer function in time domain and frequency domain	Apply
CO3	Analyze the effect of controllers/compensators in the closed loop performance of a given Linear Time Invariant sampled data system	Analyze
CO4	Design pole placement controller for a given transfer function	Apply
CO5	Analyze the effect of state feedback with observers for a given Linear Time Invariant sampled data system	Analyze
CO6	Design LQR and LQG controller for a given LTI sampled data system	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**									**M**
CO2	**S**	**M**	**L**	**L**							**M**
CO3	**S**	**S**	**M**	**M**							**M**
CO4	**S**	**M**	**L**	**L**							**M**
CO5	**S**	**S**	**M**	**M**							**M**
CO6	**S**	**M**	**L**	**L**							**M**

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Analyze level of CO will be evaluated through assignment and lab experiments

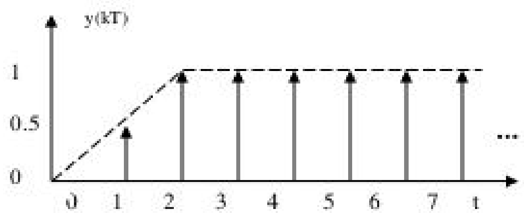
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State sampling theorem
2. With a neat block diagram explain about various elements of digital control system
3. Derive the mathematical model of zero order hold

Course Outcome 2 (CO2):

1. A unit step sequence $u(k)$ is applied to a system and the output is obtained as below.
    a. Find the z transform of signal y(kT)
    b. Find the discrete transfer function of the system $G(z) = Y(z)/U(z)$
    c. Rewrite the system in difference equation form and find the first five output sequence(i.e. k={0,1,2,3,4}) for unit ramp sequence



2. Derive the discrete transfer function from the discrete state model of the system
3. Using Jury's stability criterion determine the stability of the system with characteristic equation $\Delta(z) = z^4 + 1.7z^3 + 0.92z^2 + 0.172z + 0.0096 = 0$

Course Outcome 3 (CO3)

1. Derive the control law for discrete PID controller.
2. Consider the system G(s)=1/s+1. It is to be sampled at the rate of 0.2s through a zero order hold. Design suitable compensator using discrete root locus to achieve dead beat response.
3. Consider a continuous system G(s)=1/s(s+2). It is to be sampled through a ZOH. Find which of the following sampling period is preferred.
   T=1s, 0.1s and 1ms

Course Outcome 4 (CO4)

1. Determine the pole placement controller for the non-minimum phase oscillator with transfer function $G(z) = \frac{(-1+2z^{-1})}{1-1.7z^{-1}+z^{-2}} z^{-2}$. The controller should satisfy the following requirements
    a. Closed loop characteristic polynomial is $(1-0.6z^{-1})$

b. There should be an integral term $1/(1-z^{-1})$ present in the loop.

2. Develop 2 DOF pole placement controller for the plant $G(z)=\frac{z+2}{z^2+z+1}$ so as to have a rise time of 5 samples i.e., Nr=5, and overshoot of 10%. The controller should track the step changes in the reference signal, even if the plant parameters change.
3. Explain internal model principle with an example.

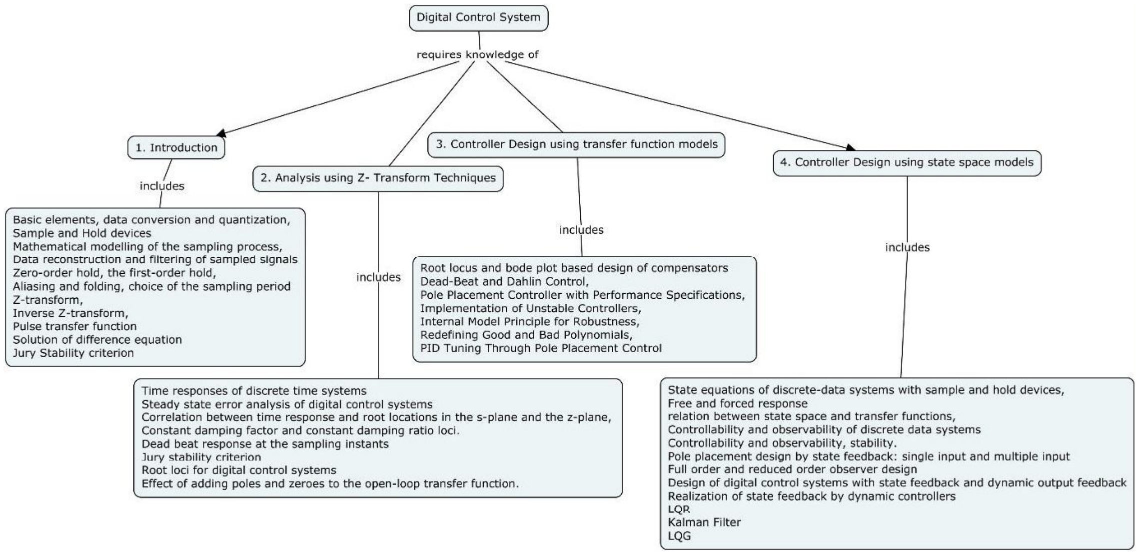
Course Outcome 5 (CO5)

1. Consider the position control of separately exited DC servomotor fed by a buck converter. Assume the armature inductance of DC motor and viscous friction coefficient are negligible. Manipulated variable is duty cycle. Let the sampling time T=1/26 s.
   a. Obtain the discrete state model of the system
   b. Design a state feedback controller such that motor position attains desired reference at 2 sampling instants.
   c. If a constant load torque is to applied check whether the disturbance is eliminated as $k \rightarrow \infty$
   d. Assuming position alone is measured, design an output feedback regulator to achieve $\varsigma = 0.5$ and $\omega_n = 4$
2. A continuous plant is described by the equation $\dot{y} = -y + u + w$ is to be controlled by a digital computer. y is the output, u is the input and w is the disturbance signal. Let sampling interval T=1s.
   a. Obtain discrete time state variable model of the plant. Compute K and N such that control law $u(k) = -Ky(t) + Nr$, result in a response y(t) with time constant 0.5s and $y(\infty) = r$ (r is the constant reference)
   b. Show that steady state error to constant disturbance input w, is not zero
   c. Add to the plant equation an integrator equation, $v(k) = v(k-1) + y(k) - r$ and select gains K1 and K2 such that the control law $u = -K_1 y(k) - K_2 v(k)$ results in a response $\zeta = 0.5\ and\ \omega_n = 4$
   d. Show that steady state error to constant disturbance w is zero for the above control law
3. For the system $X_{k+1} = \begin{bmatrix} 0 & 1 \\ -1 & 1 \end{bmatrix} X_k + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u_k$ and $Y_k = \begin{bmatrix} 1 & 0 \end{bmatrix} X_k$
   a. Design full order observer for the system with dead beat response
   b. Design reduced order observer to with eigen value at z=0.1

Course Outcome 5 (CO5)

4. Consider the unstable discrete time system, $X_{k+1} = \begin{bmatrix} 2 & 0 \\ 1 & 0 \end{bmatrix} X_k + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u_k$. Design steady state LQR with weighting matrix $Q = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ and R=1
5. Explain the assumptions involved in Kalman Filter
6. It is desired to control a system having two states x1 and x2 using two control variables u1 and u2. It is necessary to control the first state only. The second state could take any value. The first control variable is ten times more expensive than the second control variable. Pose this as an optimal control problem familiar to you.

Concept Map



Syllabus

Introduction to digital control systems and Z- Transform Techniques
Basic elements, data conversion and quantization, sample and Hold devices, mathematical modelling of the sampling process, data reconstruction and filtering of sampled signals, pulse transfer function

Analysis using Z- Transform Techniques
Time responses of discrete data systems, steady state error analysis, stability, root loci and frequency domain analysis of discrete time systems.

Controller design using transfer function models:
Root locus and bode plot based design of compensators, Dead-Beat and Dahlin Control, Pole Placement Controller with Performance Specifications, Implementation of Unstable Controllers, Internal Model Principle for Robustness, Redefining Good and Bad Polynomials, PID Tuning Through Pole Placement Control

Controller Design using state space models:
State equations of discrete-data systems with sample and hold devices, Free and forced response, Relation between transfer function and state space models, Controllability and observability, stability, Pole placement design by state feedback and output feedback, Full order and reduced order observer design, LQR, Kalman Filter, LQG

Reference Books

1. Ogata, Discrete-time Control Systems, Prentice hall, Second edition, 2005.
2. M. Gopal, Digital Control and State Variable Methods, Tata McGraw Hill Publication Limited, 2008
3. Kannan Moudgalya, “Digital Control”, Wiley India Ltd, Wiley India, 2007
4. Benjamin C. Kuo, Digital control systems, Second edition (Indian),2007, Oxford University Press.
5. Franklin, Powell, Workman, Digital Control of Dynamic Systems, Pearson Education Third edition, 2006.

Course Contents and Lecture Schedule

Module No.	Topic	No of Lecture Hours
1	**Introduction to digital control systems and Z- Transform Techniques**	
1.1	Basic elements, data conversion and quantization, sample and Hold devices	2
1.2	Pulse transfer function	1
2	**Analysis using Z- Transform Techniques**	
2.1	Time responses of discrete data systems	2
2.2	Steady state error analysis of digital control systems	1
2.3	Stability	1
2.6	Root loci for digital control systems	1
2.7	Frequency domain analysis of discrete time systems	1
3.0	**Controller design using transfer function models**	
3.1	Root locus and bode plot based design of compensators	2
3.2	Dead-Beat and Dahlin Control, Pole Placement Controller with Performance Specifications, Implementation of Unstable Controllers,	1
3.4	Internal Model Principle for Robustness,	1
3.5	Redefining Good and Bad Polynomials,	1
3.6	PID Tuning Through Pole Placement Control	1
4	**Controller Design using state space models**	
4.1	State equations of discrete-data systems with sample and hold devices,	1
4.2	Free and forced response, Relation between state space and transfer functions, Controllability and observability of discrete data systems	1
4.4	Controllability and observability, stability.	1
4.5	Pole placement design by state feedback: single input and multiple input	1
4.6	Full order and reduced order observer design	1
4.9	LQR	1
4.10	Kalman Filter	2
4.11	LQG	1
	Total	**24**

Lab Experiments:

1. Analysis of effect of sampling period and finite word length by simulation in computer
2. Discrete Rootlocus based Design and implementation of compensators on simulated and real time servo system
3. Bode plot based Design and implementation of compensators on simulated and real time servo system
4. Design and implementation of PID in microcontroller/embedded system for control of experimental tank level control process
5. Closed loop control of a system with State feedback controller and observer implementation in an embedded platform

6. Implementation of Kalman filter in microcontroller/miniature computer for estimating the states of a process.

Project: Students should design and develop embedded system/microcontroller based closed loop system and demonstrate its operation.

Course Designers:

1.	Mr.M.Varatharajan	varatharajan@tce.edu
2.	Mr.V.Mahesh	vmahesh@tce.edu

		Category	L	T	P	Credit
18CI1270	**CONTROL AND AUTOMATION LAB**	PC	0	0	4	2

Preamble

This course introduces programming of automation systems using PLC and DCS environment along implementation of advanced control techniques for control of real time processes. A project is also included with a focus on digital instrumentation system development.

Prerequisite

18CI140 Process Control
18CI170 Control and Instrumentation Lab

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcomes	Blooms level
CO1	Develop PLC programs for closed loop control of given sequential and continuous processes	Apply
CO2	Develop DCS for control of sequential and continuous processes using Siemens S7-1400 DCS controller	Apply
CO3	Analyze the effect of Q and R matrices LQR controller for stabilizing the Quanser single rotary inverted pendulum	Analyze
CO4	Analyze the closed loop performance of decentralized PID controller and LQI controller for controlling twin rotor helicopter system	Analyze
CO5	Compute the closed loop performance of model predictive controller for tank level process by simulation in MATLAB/Scilab	Apply
CO6	Develop LabVIEW based automatic circuit testing system using networked instrumentation and instrument control	Apply
CO7	Develop microprocessor/arudino based instrumentation system with IOT	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**S**	**M**	**L**	**L**							**M**
CO2	**S**	**M**	**L**	**L**							**M**
CO3	**S**	**S**	**M**	**M**							**M**
CO4	**S**	**S**	**M**	**M**							**M**
CO5	**S**	**M**	**L**	**L**							**M**
CO6	**S**	**M**	**L**	**L**							**M**
CO7	**S**	**M**	**L**	**L**							**M**

S- Strong; M-Medium; L-Low

Experiments

1. Monitoring and control of sequential process using PLC

2 Control of continuous process using PLC

3.Online monitoring and control of sequential processes using Distributed control system

4.Online monitoring and control of continuous process using Distributed Control System

5. Design and implementation of Linear quadratic regulator for Stabilization of rotary inverted pendulum

6. Design and implementation of Linear quadratic integral and decentralized PID for control of Twin rotor Helicopter

8. Design and implementation of model predictive controller on simulated model of tank level control process

9. Development of automatic test setup using Instrument Control and Networked Instrumentation

Project:

. Each student will be given a transducer using which he has to develop an Instrumentation System using the relevant components.

- Design of Signal conditioning circuit- Power Supply, filters (including Aliasing, Anti-Aliasing filter), amplification, cold junction compensation, V/I, I/V, P/I, I/P
- Display unit
- Arduino/ESP/other embedded boards with IOT access

Course Designers:

1.	V.Prakash	vpeee@tce.edu
2.	M.Varatharajan	varatharajan@tce.edu

18PG250	RESEARCH METHODOLOGY AND IPR	Category	L	T	P	Credit
		CC	2	0	0	2

Preamble

The course on the Research Methodology and IPR is offered as common Core course. The objective of this course is to understand and analyze Research Methodology and IPR protection.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

1. Understand research problem formulation.
2. Analyze research related information
3. Follow research ethics
4. Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
5. Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.
6. Understand that IPR protection provides an incentive to inventors for further research work and investment in R&D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Syllabus

Module 1: Meaning of research problem, Sources of research problem, Criteria, Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem, Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Module 2: Effective literature studies approaches, analysis Plagiarism, Research ethics

Module 3: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Module 4: Nature of Intellectual Property: Patents, Designs, Trade and Copyright, Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Module 5: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Module 6: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs

Reference Books

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'" 2nd Edition,
2. "Research Methodology: A Step by Step Guide for beginners"
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
4. Mayall, "Industrial Design", McGraw Hill, 1992.
5. Niebel, "Product Design", McGraw Hill, 1974.
6. Asimov, "Introduction to Design", Prentice Hall, 1962.
7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Designers:

1. Adapted from AICTE Model Curriculum for Postgraduate Degree Courses in Engineering & Technology, Volume-I, January 2018.

18CIPA0	INDUSTRIAL INSTRUMENTATION	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

For all real time process related operations in industries, the entire system has to be controlled properly for achieving more economical, efficient, and reliable operations. Hence, some devices are used for measuring the physical quantities such as temperature, pressure and so on , which are called as instruments. The process in which assembly of several electrical, measuring and control instruments interconnected for measuring, analyzing and controlling the electrical and non-electrical physical quantities is called as Instrumentation. The process of measuring and controlling various quantities in industries by utilizing various industrial instruments is known as industrial instrumentation.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcome	Blooms category
CO1	Explain the principle and operating characteristics of Mass, Force and torque measuring techniques for industrial applications	Understand
CO2	Choose appropriate pressure sensors for the given industrial applications.	Apply
CO3	Select a suitable level measurement sensor for the given industrial applications.	Apply
CO4	Choose the appropriate temperature sensor for the given industrial applications.	Apply
CO5	Choose the common flow-measuring devices and instruments for the given industrial applications.	Apply
CO6	Explain the principle of Measurement of viscosity, humidity and moisture	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO3.	**M**	**L**						**M**		**M**	
CO4.	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**S**	**M**	**L**	**L**				**M**		**M**	
CO5	**M**	**L**						**M**		**M**	
CO6	**M**	**L**						**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	50	50	50	50
Apply	40	40	40	40
Analyse				
Evaluate				
Create				

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Write the difference between mass and weight.
2. List the four main methods used to measuring torque
3. Draw the schematic of a Prony brake and explain its operation.

Course Outcome 2 (CO2):

1. Explain the difference among absolute pressure, gauge pressure, and differential pressure.
2. A differential pressure can be measured by subtracting the readings from two separate pressure transducers. Predict the problem with this and suggest a better way of measuring differential pressures.
3. Discuss the range of instruments available for measuring very low pressures (pressures below atmospheric pressure)

Course Outcome 3 (CO3):

1. List the advantages and disadvantages of dipsticks in level measurement.
2. Illustrate the main things to consider when choosing a liquid level sensor for a particular application?
3. Explain the mode of operation of the capacitive level sensor using suitable sketch.

Course Outcome 4 (CO4):

1. Write the main differences between base metal and noble metal thermocouples.
2. The temperature of a fluid is measured by immersing a type K thermocouple in it. The reference junction of the thermocouple is maintained at 0_C in an ice bath and an output e.m.f. of 6.435 mV is measured. Estimate the fluid temperature.
3. Name three kinds of temperature-measuring devices that work on the principle of thermal expansion

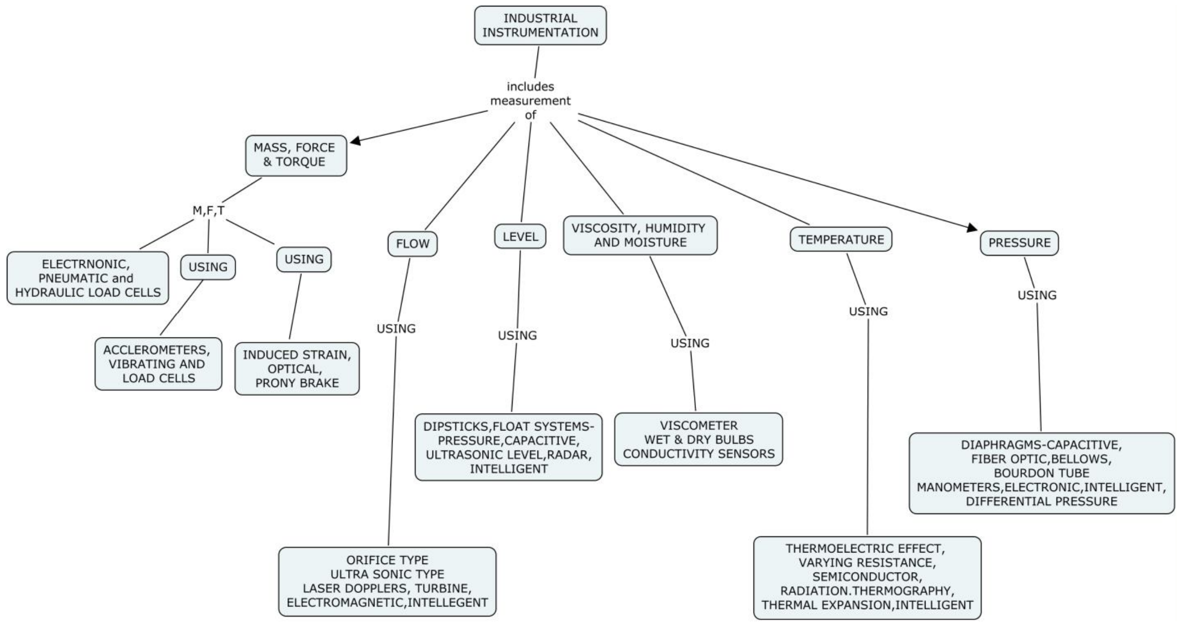
Course Outcome 5(CO5):

1. Name and discuss three different kinds of instruments used for measuring the mass flow rate of substances (mass flowing in unit time)
2. Explain the working principle of rotary piston meter.
3. Name four different kinds of differential pressure meters.

Course Outcome 6(CO6):

1. Define viscosity.
2. List the methods of measuring the relative humidity.
3. Draw and explain the operation of moisture measurement using IR.

Concept Map



Syllabus

MEASUREMENT OF MASS, FORCE, TORQUE

Introduction- Mass (Weight) Measurement- Electronic Load Cell (Electronic Balance)- Pneumatic and Hydraulic Load Cells- Intelligent Load Cells- Mass Balance (Weighing) Instruments- Force Measurement- Use of Accelerometers- Vibrating Wire Sensor- Use of Load Cells- Torque Measurement- Measurement of Induced Strain- Optical Torque Measurement- Prony Brake

PRESSURE MEASUREMENT

Introduction- diaphragms-capacitive pressure sensor-fiber-optic pressure sensors- bellows-bourdon tube-manometers-electronic pressure gauges-special measurement devices for low pressures-high-pressure measurement (greater than 7000 bar)- intelligent pressure transducers-differential pressure-measuring devices-selection of pressure sensors

LEVEL MEASUREMENT

Introduction-dipsticks-float systems-pressure-measuring devices (hydrostatic systems)-capacitive devices-ultrasonic level gauge-radar (microwave) sensors-nucleonic (or radiometric) sensors-intelligent level-measuring instruments-choice between different level sensors

TEMPERATURE MEASUREMENTS

Introduction- thermoelectric effect sensors - varying resistance devices- semiconductor devices-radiation thermometers- thermography- thermal expansion methods- intelligent temperature-measuring instruments- choice between temperature transducers

FLOW MEASUREMENTS

Introduction-mass flow rate- conveyor-based methods- thermal mass flow measurement-volume flow rate- differential pressure (obstruction-type) meters - variable area flowmeters (rotameters) - positive displacement flowmeters - turbine meters - electromagnetic flowmeters - ultrasonic flowmeters - open channel flowmeters intelligent flowmeters-choice between flowmeters for particular applications

MEASUREMENT OF VISCOSITY, HUMIDITY AND MOISTURE

Viscosity — Saybolt viscometer-Rotameter type viscometer Humidity-- Dry and wet bulb psychrometers — Resistive and capacitive type hygrometers — Dew cell — Commercial type dew meter — Moisture measurement in solids-Conductivity sensor-Microwave and IR sensors.

Case Studies on application of above discussed measurement in temperature, level, pressure process.

Reference Books

1. Measurement and Instrumentation, Theory and application, Alan S. Morris, Reza Langari, Elsevier Publications , 2012
2. Patranabis, D. Principles of Industrial Instrumentation, 3rd Edition, Tata McGraw Hill, New Delhi, 2010.
3. Liptak, B.C., Instrumentation Engineers Handbook (Measurement), CRC Press, 2005.
4. Singh,S.K., Industrial Instrumentation and Control, Tata McGrawHill Education Pvt. Ltd., New Delhi, 2009.
5. Jain, R.K., Mechanical and Industrial Measurements, Khanna Publishers, Delhi, 1999.
6. A. K. Sawhney, Puneet Sawhney Course in Mechanical Measurements and Instrumentation and Control Dhanpat Rai & Sons, New Delhi, 1997.
7. Doebelin, E.O.and Manik,D.N., Measurement Systems Application and Design, Special Indan Edition, Tata McGraw Hill Education Pvt. Ltd., 2007

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**MEASUREMENT OF MASS, FORCE, TORQUE**	
1.1	Introduction- Mass (Weight) Measurement	1
1.2	Electronic Load Cell (Electronic Balance)- Pneumatic and Hydraulic Load Cells	1
1.3	Intelligent Load Cells- Mass Balance (Weighing) Instruments- Force Measurement- Use of Accelerometers-	2
1.4	Vibrating Wire Sensor- Use of Load Cells- Torque Measurement- Measurement of Induced Strain- Optical Torque Measurement- Prony Brake	2
2	**PRESSURE MEASUREMENT**	

2.1	Introduction- Diaphragms-Capacitive Pressure Sensor-Fiber-Optic Pressure Sensors	2
2.2	Bellows-Bourdon Tube-Manometers-Electronic Pressure Gauges-Special Measurement Devices for Low Pressures-High	2
2.3	Pressure Measurement (Greater than 7000 bar)- Intelligent Pressure Transducers-	1
2.4	Differential Pressure-Measuring Devices-Selection of Pressure Sensors	1
3	**LEVEL MEASUREMENT**	
3.1	Introduction-Dipsticks-Float Systems-Pressure-Measuring Devices (Hydrostatic Systems)	1
3.2	Capacitive Devices-Ultrasonic Level Gauge-Radar (Microwave) Sensors-Nucleonic (or Radiometric) Sensors-	2
3.3	Intelligent Level-Measuring Instruments-	2
3.4	Choice between Different Level Sensors	1
4	**TEMPERATURE MEASUREMENT**	
4.1	Introduction- Thermoelectric Effect Sensors -	1
4.2	Varying Resistance Devices- Semiconductor Devices-Radiation Thermometers- Thermography	2
4.3	Thermal Expansion Methods- Intelligent Temperature-Measuring Instruments	2
4.4	Choice between Temperature Transducers	1
5	**FLOW MEASUREMENTS**	
5.1	Introduction-Mass Flow Rate- Conveyor-Based Methods-Thermal Mass Flow Measurement-	1
5.2	Volume Flow Rate- Differential Pressure (Obstruction-Type) Meters - Variable Area Flowmeters (Rotameters) -	2
5.3	Positive Displacement Flowmeters - Turbine Meters - Electromagnetic Flowmeters	1
5.4	Ultrasonic Flowmeters - Open Channel Flowmeters Intelligent Flowmeters-Choice between Flowmeters for Particular Applications	2
6	**MEASUREMENT OF VISCOSITY, HUMIDITY AND MOISTURE:**	
6.1	Viscosity — Saybolt viscometer-Rotameter type viscometer	2
6.2	Humidity-- Dry and wet bulb psychrometers — Resistive and capacitive type hygrometers	2
6.3	Dew cell — Commercial type dew meter — Moisture measurement in solids	2
6.4	Conductivity sensor-Microwave and IR sensors	2
	Total	38

Course Designers:

1.	Dr.V.Prakash	vpeee@tce.edu
2.	Dr.B.Ashok Kumar	ashokudt@tce.edu

		Category	L	T	P	Credit
18CIPB0	**EMBEDDED SYSTEMS DESIGN**	PE	2	0	2	3

Preamble

An embedded system is a computer system with a dedicated function within a larger electrical or mechanical system, often with real-time computing constraints. An embedded system is some combination of computer hardware and software, either fixed in capability or programmable, that is specifically designed for a particular function. Industrial machines, automobiles, medical equipments, digital cameras, household appliances, airplanes, vending machines, toys, cellular phone and PDA are among the numerous possible hosts of an embedded system. Embedded systems that are programmable are provided with programming interfaces. In order to meet real time constraints, most of the embedded systems use a real-time operating system (RTOS). This course introduces the architecture, design and development process of embedded systems. The architecture and programming of ARM Cortex M4 microcontroller is covered in this course.

Prerequisite

- Basics of microcontroller

Course Outcomes

On the successful completion of the course, students will be able to:

COs No.	**Course outcomes**	Blooms level
CO1	Explain embedded system architecture and its building blocks.	Understand
CO2	Select proper microcontroller, memory and peripherals for given engineering applications	Apply
CO3	Explain the embedded system software development tools and Cortex-M programming	Understand
CO4	Explain the architecture and function of on-chip peripherals of ARM Cortex Microcontroller	Understand
CO5	Develop Embedded-C program for Interfacing I/O devices ARM Cortex microcontroller	Apply
CO6	Develop Embedded-C programs for various applications using ARM Cortex microcontroller	Analyse

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**					**M**		**M**	
CO3	**M**	**L**						**M**		**M**	
CO4	**M**	**L**						**M**		**M**	
C05	**S**	**M**	**L**					**M**		**M**	
C06	**S**	**S**	**M**	**L**	**S**			**M**		**M**	

S- Strong; **M**-Medium; **L**-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Practical test	Terminal Examination**
	1	2	3		
Remember	40	20	20	0	20
Understand	40	30	30	0	30
Apply	20	50	50	0	50
Analyse	0	0	0	100	0
Evaluate	0	0	0	0	0
Create	0	0	0	0	0

***Assignment and practical test are compulsory and are based on laboratory performance.
**Terminal examination covers theory part only.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Discuss the selection of processor and memory in embedded application.
2. Explain the challenges in building IOT.
3. How the embedded systems are classified ?
4. Describe the design process in embedded system.

Course Outcome 2 (CO2):

1. Explain the selection of microcontroller for a particular application.
2. An embedded application is required for speed control of DC motor. Select suitable microcontroller and other peripherals for the application and justify your answer.
3. Illustrate the effects of improper selection of microcontroller for an embedded application.

Course Outcome 3 (CO3):

1. Demonstrate the layers of an embedded system.
2. Demonstrate the process of converting C program into the file for ROM image.
3. Compare C vs. Assembly language programming.
4. Discuss the methods to control the flow of the program.

Course Outcome 4 (CO3):

1. Explain the architecture of ARM Cortex Microcontroller.
2. Explain the different interrupts in ARM Cortex Microcontroller.
3. Explain the operation of USB interface in ARM Cortex Microcontroller.
4. With neat diagram, explain the working of CAN interface in ARM Cortex Microcontroller.

Course Outcome 5 (CO4):

1. Interface display device with microcontroller and develop a embedded C code to display your name.
2. **Write a embedded C program to blink two LEDs alternatively such that each glow for 2 seconds using** ARM Cortex Microcontroller.

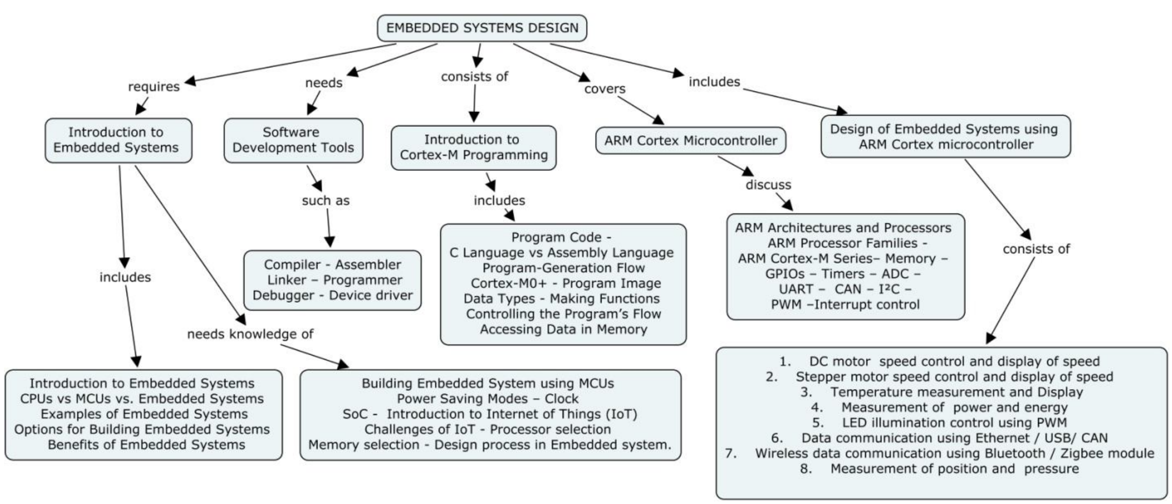
3. **Develop embedded C program to initiate serial transmission using** ARM Cortex Microcontroller.

Course Outcomes 6 (C05):

The evaluation is based on the design and development of the following embedded systems using ARM Cortex Microcontroller in the laboratory:

1. DC motor speed control and display of speed
2. Stepper motor speed control and display of speed
3. Temperature measurement and Display
4. Measurement of power and energy
5. LED illumination control using PWM
6. Data communication using Ethernet / USB/ CAN
7. Wireless data communication using Bluetooth / Zigbee module
8. Measurement of position and pressure

Concept Map



Syllabus

Introduction to Embedded Systems: Introduction to Embedded Systems - CPUs vs MCUs vs. Embedded Systems - Examples of Embedded Systems - Options for Building Embedded Systems - Benefits of Embedded Systems - Building Embedded System using MCUs - Power Saving Modes – Clock – SoC - Introduction to Internet of Things (IoT) - Challenges of IoT - Processor selection - Memory selection - Design process in Embedded system.

Software Development Tools: Compiler - Assembler - Linker – Programmer - Debugger - Device driver

Introduction to Cortex-M Programming: Program Code - C Language vs Assembly Language - Program-Generation Flow - Cortex-M0+ - Program Image - Data Types - Making Functions - Controlling the Program's Flow - Accessing Data in Memory.

ARM Cortex Microcontroller: ARM Architectures and Processors - ARM Processor Families - ARM Cortex-M Series - Memory – GPIOs – Timers – ADC – UART – CAN – I²C – PWM – Interrupt control.

Reference Books

1. ARM University Program- Rapid embedded system design and programming
2. Alexander G Dean ,Embedded Systems Fundamentals with ARM Cortex-M based Microcontrollers: A Practical Approach, ARM Education Media
3. Raj Kamal, 'Embedded Systems, Architecture, Programming and Design', Tata McGraw-Hill, second edition 2010.
4. D.P.Kothari, Shriram K.Vasudevan, Embedded Systems, New Age International Publishers, 2012.
5. ARM Cortex M4 Data sheet, Texas Instruments.
5. Shibu K V, 'Introduction to Embedded Systems', Tata McGraw Hill Education Pvt. Ltd.,2010
6. Tammy Noergaard, Embedded systems Architecture, Second edition, Newnes – Elsevier,2013.
7. Frank Vahid and Tony Givargis, 'Embedded System Design: A Unified Hardware/Software Introduction', John Wiley & Sons, Inc. 2002.
8 Steve Heath, Embedded Systems Design, Second Edition, Elsevier, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.	**Introduction to Embedded Systems**	
1.1	Introduction to Embedded Systems, CPUs vs. MCUs vs. Embedded Systems	1
1.2	Examples of Embedded Systems	1
1.3	Options for Building Embedded Systems, Benefits of Embedded Systems	1
1.4	Building Embedded System using MCUs, Power Saving Modes, Clock, SoC,	1
1.5	Introduction to Internet of Things (IoT), Challenges of IoT	1
1.6	Processor selection	1
1.7	Memory selection, Design process in Embedded system.	1
2	**Software Development Tools**	
2.1	Compiler - Assembler - Linker	1
2.2	Programmer - Debugger - Device driver	1
3.	**Introduction to Cortex-M Programming**	
3.1	Program Code, C Language vs. Assembly Language	1
3.2	Program-Generation Flow, Cortex-M0+	1
3.3	Program Image, Data Types	1
3.4	Making Functions	1
3.5	Controlling the Program's Flow	1
3.6	Accessing Data in Memory.	1
4	**ARM Cortex Microcontroller**	
4.1	ARM Architectures and Processors	1
4.2	ARM Processor Families, ARM Cortex-M Series	1
4.4	Memory	1

4.5	GPIOs, Timers	1
4.6	ADC	1
4.7	UART, CAN	1
4.8	I²C, PWM	1
4.9	Interrupt control	1
	Total	**24**

Tentative List of Experiments (24 Hours)

Design of Embedded Systems using ARM Cortex microcontroller:

1. DC motor speed control and display of speed
2. Stepper motor speed control and display of speed
3. Temperature measurement and Display
4. Measurement of power and energy
5. LED illumination control using PWM
6. Data communication using Ethernet / USB/ CAN
7. Wireless data communication using Bluetooth / Zigbee module
8. Measurement of position and pressure

Course Designers:

1. Dr.M.Saravanan mseee@tce.edu
2. Dr.P.S.Manoharan psmeee@tce.edu
3. Dr.D.Kavitha dkavitha@tce.edu

18CIPC0 **ADAPTIVE CONTROL**

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Adaptive control is an area of control theory, where the controller parameters are adapted based on the variation in the system parameters. This adaptation mechanism helps in maintaining the closed loop response same, irrespective of the variation in the operating point. Adaptive control extensively uses system identification to identify the plant model in real time and to calculate the controller parameters. This course introduces the concept of parametric and non-parametric methods. Adaptive control methods like Gain scheduling, MRAS and Self tuned regulators are covered

Prerequisite

18CI130 Process Control
18CI120 System Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcome	Blooms Level
CO1	Compute the parametric model of a system from I/O data	Apply
CO2	Design deterministic self-tuned regulators for a given system	Apply
CO3	Design stochastic and predictive self-tuned regulators for a given system	Apply
CO4	Design gain scheduling controller for a given system	Apply
CO5	Design MRAS for a given system using MIT rule and Lyapunov methods	Apply
CO6	Explain about the properties and practical implementation issues associated with the adaptive control algorithms	Understand
CO7	Analyze the effect of adaptive controllers by computer simulations	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**S**	**M**	**L**	**L**				**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**S**	**M**	**L**	**L**				**M**		**M**	
CO5	**S**	**M**	**L**	**L**				**M**		**M**	
CO6	**M**	**L**						**M**		**M**	

CO7	**S**	**S**	**M**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	**2**	**3**	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60

- **CO7 WILL BE EVALUATED THROUGH ASSIGNMENTS**

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compute the performance parameters of the given system using continuous time parameter estimation. $\frac{k}{s(s+a)}$
2. Consider the system $\frac{dx_1}{dt} = x_2 + \theta f(x_1)$&$\frac{dx_2}{dt} = u$, where θ is an unknown parameter and f is a known differential function. Compute the control law using the certainty equivalence principle.
3. Consider data generated by the discrete-time system
   $y(t) = b_0 u(t) + b_1 u(t-1) + e(t)$
   Where $e(t)$ is a sequence of independent N(0,1) random variables. Assume that the parameter b of the model $y(t) = bu(t)$is determined by least squares. Compute the estimates obtained for large observation sets when the input u is a step

Course Outcome 2 (CO2):

1. Consider the process with $G(s) = \frac{1}{s(s+a)}$where a is an unknown parameter. Assume that the desired closed-loopsystem is$G_m(s) = \frac{\omega^2}{s^2+2\zeta\omega s+\omega^2}$. Construct the continuous and discrete time indirect self-tuning algorithms for the system.
2. In sampling a continuous-time process model with h = 1 the following pulse transfer function is obtained: $(z) = \frac{z+1.2}{z^2-z+0.25}$. The design specification states that the discrete-time closed-loop poles should correspond to the continuous-time characteristic polynomial $s^2 + 2s + 1$Design a minimal-order discrete-time indirect self-tuning regulator. The controller should have integral action and give a closed-loop system having unit gain in stationary. Determine the Diophantine equation that solves the design problem.

3. In sampling a continuous-time process model with h = 1 the following pulse transfer function is obtained: $(z) = \frac{z+1.2}{z^2-z+0.25}$. The design specification states that the discrete-time closed-loop poles should correspond to the continuous-time characteristic polynomial $s^2 + 2s + 1$Suggest a design that includes direct estimation of the controller parameters. Discuss why a well-working direct self-tuning regulator is more difficult to design for this process than is an indirect self-tuning regulator.

Course Outcome 3(CO3):

1. Consider an integrator with a time delayτ. For the sampling period $h > \tau$ thesystem is described by$(q) = q(q-1)$; $B(q) = (h-\tau)q + \tau = (h-\tau)(q+b)$ where $b = \frac{\tau}{h-\tau}$ and $d_0 = 1$. The noise is assumed to be characterized by $C(q) = q(q+c)$and $|c| < 1$.
   Assume that the process is known and controller structure is $u(t) = -\hat{s}_0(t)y(t) - \hat{r}_1(t)u(t-1)$.Compute the optimal minimum-variance controller and the least attain- able output variance when (a)$\tau = 0.4$ (the minimum-phase case) and (b) $\tau = 0.6$ (the nonminimum-phase case).
2. Compute the closed-loop characteristic equation. Discuss when the de- sign method may give an unstable closed-loop system. For instance, is it useful for the process in the Problem no.1 when t = 0.6?
3. Consider the system with e(t)=0 and equation as $A^*(q^{-1}) = 1 - 4q^{-1} + 4q^{-2}$; $B^*(q^{-1}) = q^{-1} - 1.999q^{-2}$. The open loop process is unstable. Compute the generalized predictive controller that minimizes the loss function for different values of N.

Course Outcome 4 (CO4):

1. Consider the conical tank with variable cross section area $A(h)$, Volume V, input flow q_i, nominal input q_0 , nominal output h_0 and output h. Design the PI controller structure for the above system.
2. Simulate the above conical tank system. Let the tank area vary as $A(h) = A_0 + h^2$. Further assume that $a = 0.1\,A_0$. (a) Study the behaviour of the closed-loop system when the full gain schedule is used and when the modified gain schedule is used. (b) Study the sensitivity of the system to changes in the parameters of the process. (c) Study the sensitivity of the closed-loop system to noise in the measurement of the level.
3. Discuss the various methods in implementation of the scheduling of controller parameter over the more than one operating region and also discuss with respect to the single region linear controller structure.

Course Outcome 5 (CO5):

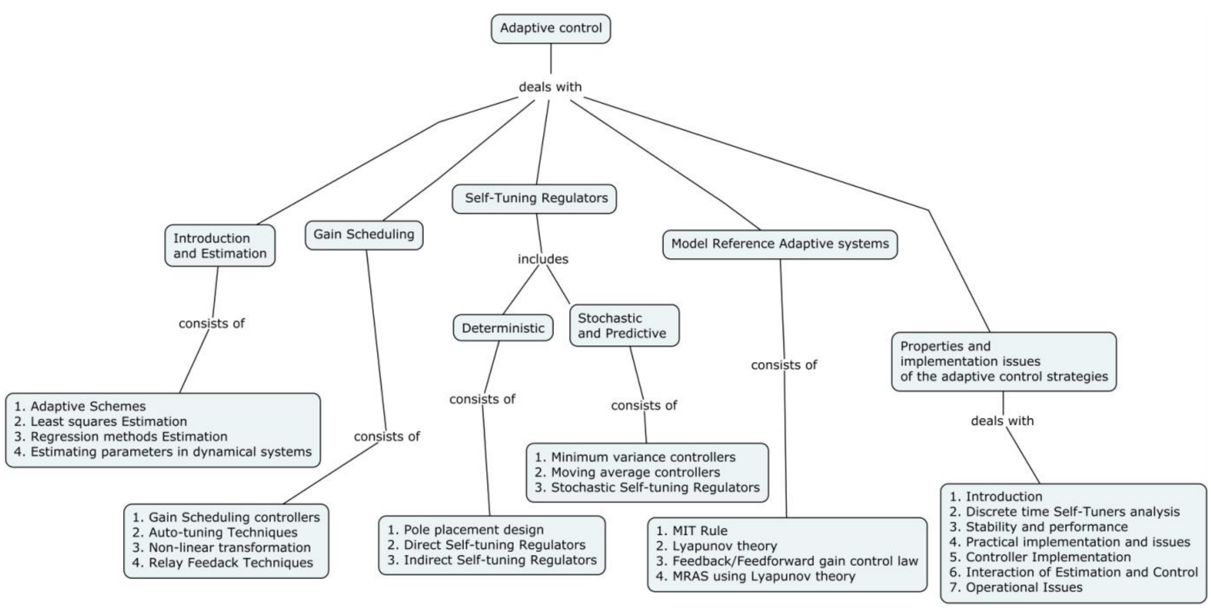
1. Consider the process with $G(s) = \frac{1}{s(s+a)}$ where a is an unknown parameter. Assume that the desired closed-loop system is $G_m(s) = \frac{\omega^2}{s^2+2\zeta\omega s+\omega^2}$. Construct the MRAC based on gradient and stability theory for the system.

2. Consider a position servo described by $\frac{dv}{dt} = -av + bu$; $\frac{dy}{dt} = v$ where parameters a and b are unknown. Assume that the control law is $u = \theta_1(u_c - y) - \theta_2 v$ is used and with the TF of y wrt u is given by $G_m(s) = \frac{\omega^2}{s^2+2\zeta\omega s+\omega^2}$. Determine the adaptive control law that adjusts parameter θ_1 ; θ_2 so that the desired objective is obtained.
3. Consider the problem of adaptation of a feed forward gain $\theta = \frac{k_0}{k}$ where $G_m(s) = k_0 G(s)$ and $G(s) = \frac{k}{(s+1)(s+2)}$. a) Introduce the augmented error, and determine an MRAS based stability theory. b) Show that the derived adaptation law in part (a) gives a stable closed loop system.

Course Outcome 6 (CO6):

1. Explain about the various implementation issues in the adaptive control strategies.
2. State the condition to guarantee that the parameter convergence.
3. How should the disturbance annihilation filter Hf (q) be chosen if v(t) in the equation y(t) = G0(q)u(t) + v(t) is a sinusoidal?

Concept Map



Syllabus

Introduction:

Introduction - Adaptive Schemes - The adaptive Control Problem – Applications - Real-time parameter estimation: - Least squares and regression methods- Estimating parameters in dynamical systems

Deterministic Self-Tuning Regulators

Introduction- Pole Placement design - Indirect Self-tuning regulators - direct self-tuning regulators – Disturbances with known characteristics

Stochastic and Predictive Self-Tuning Regulators
Introduction – Design of minimum variance controller - Design of moving average controller - stochastic self-tuning regulators

Model – Reference Adaptive Systems
Introduction- MIT rule – Determination of adaptation gain - Lyapunov theory –Design of MRAS using Lyapunov theory – Relations between MRAS and STR

Gain Scheduling
Introduction- The principle - Design of gain scheduling controllers- Nonlinear transformations - application of gain scheduling - Auto-tuning techniques: Methods based on Relay feedback

Properties and implementation issues of the adaptive control strategies
Introduction - Discrete time Self-Tuners analysis - Stability and performance - Practical implementation and issues - Controller Implementation - Interaction of Estimation and Control - Operational Issues

Reference Books

1. Astrom .K, Adaptive Control, Second Edition, Pearson Education Asia Pte Ltd, 2002.
2. T. Soderstorm and PetreStoica, “System Identification”, Prentice Hall International(UK) Ltd., 1989.
3. Ljung.L, System Identification :Theory for the user, Prentice Hall, EnglewoodCliffs,1987.
4. Chang C. Hong, Tong H. Lee and Weng K. Ho, Adaptive Control, ISA press, Research Triangle Park, 1993.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**Introduction**	
1.1	Adaptive Schemes - The adaptive Control Problem – Applications	3
1.2	Real-time parameter estimation: - Least squares	1
1.3	Real-time parameter estimation: - Regression methods	1
1.4	Estimating parameters in dynamical systems	2
2	**Gain Scheduling**	
2.1	Introduction- The principle	1
2.2	Design of gain scheduling controllers	2
2.3	Nonlinear transformations	2
2.4	Application of gain scheduling	1
2.5	Auto-tuning techniques: Methods based on Relay feedback	2
3	**Deterministic Self-Tuning Regulators**	
3.1	Introduction- Pole Placement design	2
3.2	Indirect Self-tuning regulators	1
3.3	Direct self-tuning regulators	2
3.4	Disturbances with known characteristics	1

4	**Stochastic and Predictive Self-Tuning Regulators**	
4.1	Introduction	3
4.2	Design of minimum variance controller	1
4.3	Design of moving average controller	1
4.4	Stochastic self-tuning regulators	2
5	**Model – Reference Adaptive Control**	
5.1	Introduction- MIT rule	2
5.2	Determination of adaptation gain	2
5.3	Lyapunov theory	1
5.4	Design of MRAC using Lyapunov theory	2
5.5	Relations between MRAC and STR	1
	Total	**36**

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mr.S.Surendhar ssreee@tce.edu

18CIPD0	SYSTEM IDENTIFICATION	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

System identification is a process of developing models of a plant from the experimental data. Even though first principle models are widely covered in the fundamental courses, they can be used only for the purpose of initial study and analysis. Assumptions involved in the first principle models make them irrelevant in practices. Hence data based model development is extensively used in all the industries. This course introduces basic concepts of linear system identification.

Prerequisite

18CI110 Calculus of Variation & Applied Mathematics
18CI120 System Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcome	Blooms Level
CO1	Explain the need and the steps in system identification.	Understand
CO2	Compute the non-parametric model of a system from I/O data	Apply
CO3	Compute the parametric model of a system from I/O data	Apply
CO4	Explain about identification of state space models	Understand
CO5	Compute FOPDT and SOPDT model for a given process using rely feedback methods	Apply
CO6	Explain about statistical and practical aspects of system identification	Understand
CO7	Analyze the features of parametric, non-parametric models developed for a given I/O data using computer tools	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**M**	**L**						**M**		**M**	
CO5	**S**	**M**	**L**	**L**				**M**		**M**	
CO6	**M**	**L**						**M**		**M**	
CO7	**S**	**S**	**M**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	50	50	50

- CO7 WILL BE EVALUATED THROUGH ASSIGNMENTS

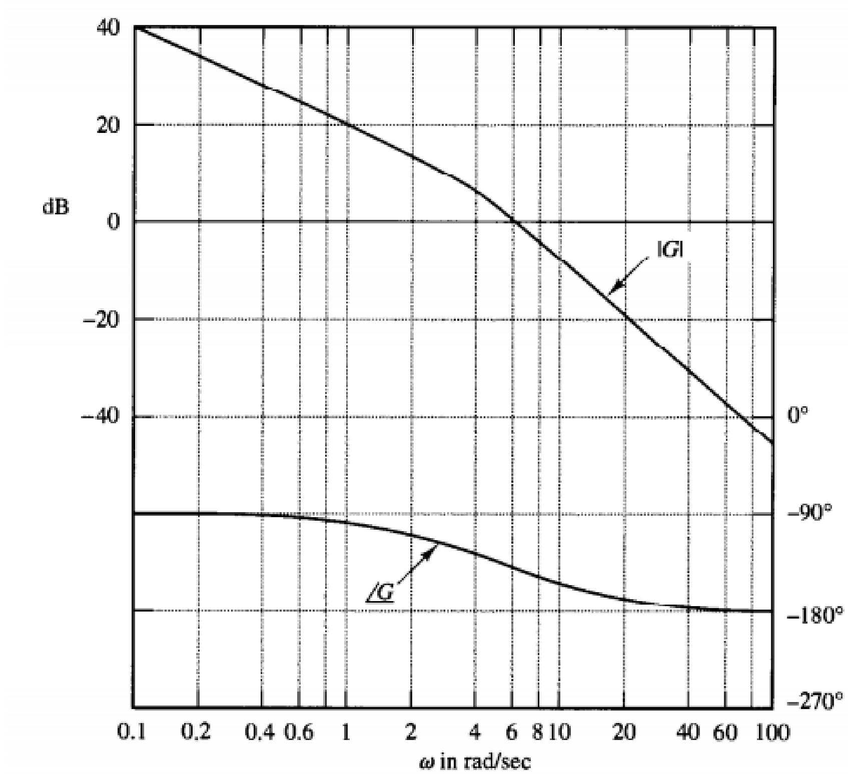
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the need for system identification
2. Explain the characteristics of AR process.
3. Draw the flow chart of the system identification

Course Outcome 2 (CO2):

1. Define the generalized expectation operator. In what sense is it generalized?
2. Explain impulse response identification using correlation analysis.
3. Frequency response of a process is given below. Determine the transfer function of the system.



Course Outcome 3 (CO3):

1.Would you prefer an MA or an AR model when estimation effort is the criterion?
I/O data of a system identification experiment is shown below.

	K=0	K=1	K=2	K=3
Y	0.28	1.53	1.58	0.8
U	1	1	0	1

Fit the models (Assume e[k] as zero mean white noise with variance 1)

a. y[k]=-a0*y[k-1]+b0*u[k-1]+e[k]
b. y[k]=-a0*y[k-1]+b1*u[k-1]+b0*u[k]+e[k]
c. Based on the covariance choose the best model.

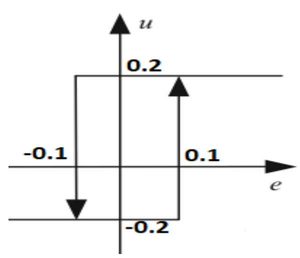
2.Derive the Y-W equations and explain how it can be used for estimating an AR

Course Outcome 4 (CO4):

1. Describe at least two potential advantages of identifying state-space models over the classical input-output forms.
2. What is extended observability matrix? Explain the identification of state space model from extended observability matrix
3. Explain the role of Kalman filter in identification of state space models.

Course Outcome 5 (CO5)

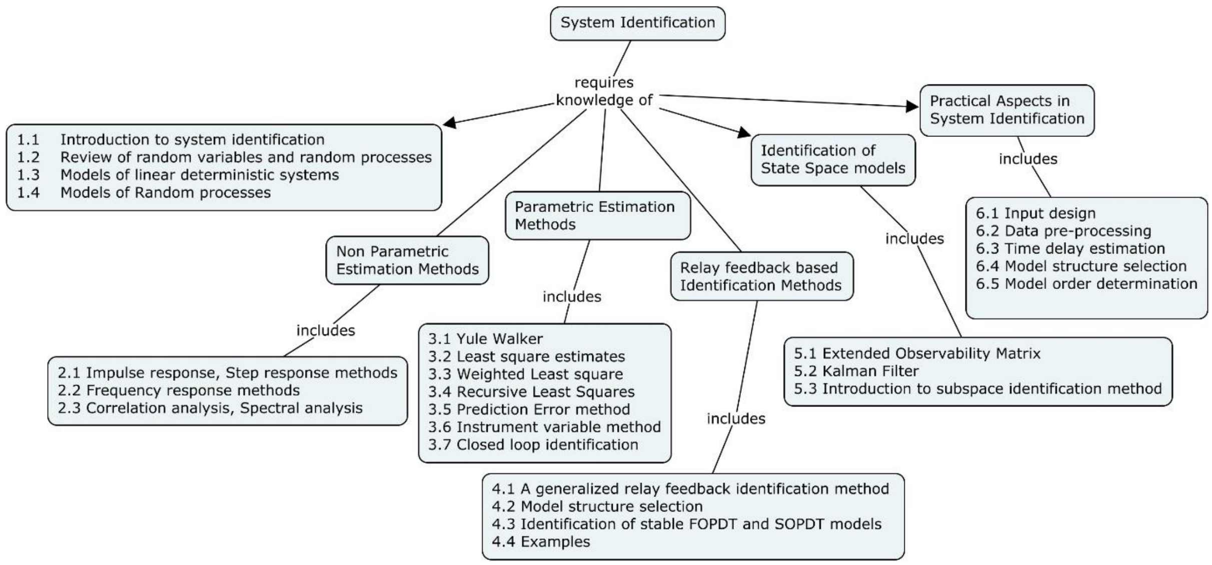
1. Define describing function
2. Explain the concept of relay feedback based identification
3. In a relay feedback test, output oscillates between +5.15 and -4.85 with a time period of 1.5s. Characteristics of the relay is given below. Assuming gain =1, Calculate first order + dead time model of the process



Course Outcome 6 (CO6)

1.Define persistent excitation
2. Explain the process of the selecting a model using residual analysis
3. Explain the features PRBS signal and its role in system identification.

Concept Map



Syllabus

Introduction:
Introduction to system identification, Review of random variables and random processes, Models of linear deterministic systems, Models of Random processes

Non Parametric Methods:
Impulse response, step response and Frequency response methods, correlation and spectral analysis methods.

Parametric Methods:
YW, Least Square, Weighted Least square methods, Recursive Least square methods, Prediction Error Method, Instrument Variable Method, Closed loop identification

Relay feedback based closed loop Identification:
A generalized relay feedback identification method – model; structure selection - relay feedback identification of stable processes: FOPDT and SOPDT model. Illustrative examples

Identification of State Space models,
Extended Observability Matrix, Kalman Filter, Introduction to subspace identification method

Statistical and Practical Aspects of System Identification:
Input design, data pre-processing, Time delay estimation, Model structure selection, model order determination, System identification using MATLAB

Reference Books

1. Arun.K.Tangirala, “Principles of System Identification: Theory and Practice” , CRC Press, 2014
2. Karel J. Keesman, “System Identification an Introduction ”,Springer, 2011
3. Liu, Tao & Gao, Furong, Identification and Control Design, Step-test and Relay experiment based methods, Springer-Verlag, London 2012
4. T. Soderstorm and Petre Stoica, “System Identification”, Prentice Hall International(UK)

Ltd., 1989.
5. Ljung.L, System Identification :Theory for the user, Prentice Hall, EnglewoodCliffs,1987.

Course Contents and Lecture Schedule

Module. No.	Topic	No. of Lecture Hours
1	**System Identification**	
1.1	Introduction to system identification	1
1.2	Review of random variables and random processes	2
1.3	Models of linear deterministic systems	1
1.4	Models of Random processes	2
2	**Non Parametric estimation methods**	
2.1	Impulse response, Step response methods	1
2.2	Frequency response methods	2
2.3	Correlation analysis, Spectral analysis	2
3	**Parametric estimation methods:**	
3.1	Yule Walker	1
3.2	Least square estimates	2
3.3	Weighted Least square	1
3.4	Recursive Least Squares	1
3.5	Prediction Error method	2
3.6	Instrument variable method	1
3.7	Closed loop identification	2
4	**Relay feedback based closed loop Identification**	
4.1	A generalized relay feedback identification method	1
4.2	Model structure selection	1
4.3	Identification of stable FOPDT and SOPDT models	2
4.4	Examples	1
5	**Identification of State Space models**	
5.1	Extended Observability Matrix	1
5.2	Kalman Filter	1
5.3	Introduction to subspace identification method	1
6	**Practical Aspects in system identification:**	
6.1	Input design	1
6.2	Data pre-processing	1
6.3	Time delay estimation	1
6.4	Model structure selection	2
6.5	Model order determination	1
6.6	System identification using MATLAB	1
	Total	**36**

Course Designers:

1. M.Varatharajan varatharajan@tce.edu
2. R.Suganya rsaeee@tce.edu

18CIPE0	NON - LINEAR CONTROL	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Physical systems are inherently nonlinear. So non-linear control systems have gained importance in many industrial areas and research has undergone significant developments recently. Nonlinear control theory studies how to apply existing linear methods to these more general nonlinear control systems. Additionally, it provides novel control methods that cannot be analyzed using LTI system theory. This course aims at giving an adequate exposure in perturbation theory, singular perturbations, gain scheduling and feedback linearization, sliding mode and back-stepping control.

Prerequisite

- 18CI110 - Calculus of Variation & Applied Mathematics
- 18CI120 - Systems Theory

Course Outcomes

On the successful completion of the course, students will be able to

COs	Course Outcome	Blooms Level
CO1	Use perturbation theory to solve nonlinear systems	Apply
CO2	Explain the stability of non-autonomous systems using Lyapunov theory	Understand
CO3	Apply gain scheduling approach to control non-linear systems for different operating points	Apply
CO4	Use feedback linearization to transform a given nonlinear system to linear system	Apply
CO5	Apply sliding mode control to alter the dynamics of the nonlinear system	Apply
CO6	Use Lyapunov based control schemes to stabilize a class of nonlinear systems	Apply
CO7	Analyze the effect of nonlinear controllers designed for a given system using computer tools	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	L				M		M	
CO2	M	L						M		M	
CO3	S	M	L	L				M		M	
CO4	S	M	L	L				M		M	
CO5	S	M	L	L				M		M	
CO6	S	M	L	L				M		M	

CO7	**S**	**S**	**M**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CO7 will be evaluated through assignments

Course Level Assessment Questions

Course Outcome 1 (CO1)**:**

1. Explain standard singular perturbation model
2. Consider the singularly perturbed system given by the equations $\dot{x} = -\eta(x) + az$ and $\in \dot{z} = -\frac{x}{a} - z$. Where "a" is a positive constant and $\eta(x)$ is a smooth nonlinear function which satisfies the condition $\eta(0) = 0$ and $x\eta(x) > 0$ for $x \in (-\infty, b) - \{0\}$.Find the stability of origin for small $\in$ using singular perturbation method
3. Consider the singularly perturbed system

$$\dot{x}_1 = x_2$$
$$\dot{x}_2 = -x_2 + z$$
$$\in \dot{z} = \tan^{-1}(1 - x_1 - z)$$

a) Find the reduced and boundary layer models

b) For x1(0) =x2(0) =z (0) =0 find $O(\in)$ approximation of the solution

Course Outcome 2 (CO2)**:**

1. Explain the role of Arbalat's lemma in analyzing the stability of systems
2. State Lyapunov theorem
3. Explain the extension of Lyapunov like stability analysis for non autonomous systems

Course Outcome 3(CO3)

1. Explain about regulation via integral control
2. Consider the tank level control problem with tank cross sectional area β varying with height h. Its model is given by the equation $\frac{d}{dt}\left(\int_0^h \beta(y)dy\right) = q - c\sqrt{2h}$. Where q is the inflow rate, h is the liquid height in tank and c is a positive constant. Design gain scheduling controller to track the reference h_{ref} with same dynamics (i.e. same $\varsigma \,\&\, \omega_n$) for all operating points

3. Consider the pendulum equation $\ddot{\theta} = -a\sin(\theta) - b\dot{\theta} + cT$ where a, b>0 are constants. T is the torque applied to the pendulum. θ is the angle subtended by vertical axis and rod? Derive suitable control law to stabilize the pendulum around $\theta = \theta_{ref}$

Course Outcome 4(CO4):

1. Explain internal dynamics and zero dynamics
2. Consider the second-order system $\dot{x}_1 = -x_1 - x_2 + \psi(x_2)$, $\dot{x}_2 = x_1 + \psi(x_2) + u$, $y = x_2$ where Ψ is a continuously differentiable function such that $\Psi(0)=0$, $\Psi'(0)=1$, and $0< \Psi'(x_2)<1$ for all $x_2 \neq 0$.
   (a) Is the system input-output linearizable?

   (b) Is it minimum phase?

   (c) Is it feedback linearizable?

3. Consider the first-order system $\dot{y} = u - k_1 - k_2 y - k_3 y^2$ where k_1, k_2, and k_3 are positive constants. Using linearization, design a feedback control law to (locally) stabilize the system at $y = y_{ss} > 0$.

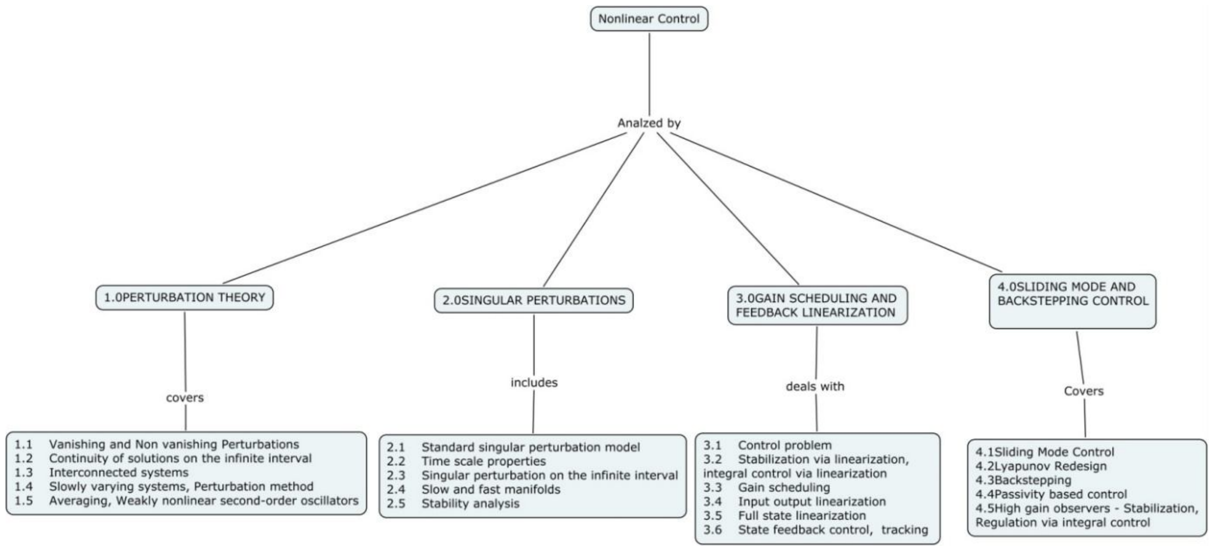
Course Outcome 5(CO5):

1. Explain the methods to reduce the effects of chattering in sliding mode control
2. Consider the second-order system $\dot{x}_1 = x_2$, $\dot{x}_2 = \psi(x_1, x_2) + u$ where Ψ is an unknown function that satisfies $|\psi(x_1, x_2)| < {x_1}^2 + {x_2}^2$ for all x. Design a state feedback, continuous, sliding mode control to globally stabilize the origin.
3. Consider the system $\ddot{y} = -{y_1}^3 + \sin(x_1)u$ .Design sliding mode controller with PID sliding surface to track the reference $y_{ref}(t) = 10*\sin(0.1t)$

Course Outcome 6 (CO6):

1. Explain the basic mechanism of back stepping control.
2. Consider the system $\ddot{x} = -x - \dot{x}^2 + u$. Design back stepping controller to stabilize the system at origin.
3. Consider the second-order system $\dot{x}_1 = x_1 + \dfrac{x_2}{1 + x_1^2}$, $\dot{x}_2 = -x_2 + u$ Using backstepping, design a globally stabilizing state feedback control law.

Concept Map



Syllabus

PERTURBATION THEORY

Vanishing and Non vanishing Perturbations – Continuity of solutions on the infinite interval – Interconnected systems – Slowly varying systems – Perturbation method – Averaging - Weakly nonlinear second-order oscillators , chaos and bifurcation analysis.

SINGULAR PERTURBATIONS

Standard singular perturbation model – Time scale properties – Singular perturbation on the infinite interval – Slow and fast manifolds – stability analysis – exercises.

Stability Analysis:

Review of Lyapunov theorem, Stability of non-autonomous systems, Lyapunov like analysis using Barbalat’s lemma, Positive linear system, Passivity, Absolute stability, Establishing boundedness of signals

FEEDBACK LINEARIZATION

Control problem – stabilization via linearization – integral control via linearization – gain scheduling – Input output linearization – Full state linearization – state feedback control – tracking.

SLIDING MODE AND BACKSTEPPING CONTROL

Sliding Mode Control - Lyapunov Redesign - Backstepping - Passivity based control – High gain observers – stabilization – Regulation via integral control – exercises.

Reference Books

1. Hasan Khalil," Nonlinear systems and control", 3rd edition, Prentice Hall of India Publisher, 2002.
2. Slotine, J A E Slotine and W Li, "Applied Nonlinear control", 1st edition Prentice Hall of India Publisher, 1991.
3. S.H. Zak," Systems and control", 1st edition, Oxford University Press 2003

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**PERTURBATION THEORY**	**10**
1.1	Vanishing and Non vanishing Perturbations	2
1.2	Continuity of solutions on the infinite interval	1
1.3	Interconnected systems	2
1.4	Slowly varying systems, Perturbation method	2
1.5	Averaging, Weakly nonlinear second-order oscillators,	2
1.6	Chaos and bifurcation analysis	3
2.0	**SINGULAR PERTURBATIONS**	**10**
2.1	Standard singular perturbation model	2
2.2	Time scale properties	2
2.3	Singular perturbation on the infinite interval	1
2.4	Slow and fast manifolds	1
2.5	Stability analysis	2
3.0	**GAIN SCHEDULING AND FEEDBACK LINEARIZATION**	**10**
3.1	Control problem	1
3.2	Stabilization via linearization, integral control via linearization	2
3.3	Gain scheduling	2
3.4	Input output linearization	2
3.5	Full state linearization	1
3.6	State feedback control, tracking	1
3.7	Exercises	1
4.0	**SLIDING MODE AND BACKSTEPPING CONTROL**	**10**
4.1	Sliding Mode Control	2
4.2	Lyapunov Redesign	1
4.3	Backstepping	2
4.4	Passivity based control	1
4.5	High gain observers - Stabilization, Regulation via integral control	2
4.6	Exercises	2
	Total	**40**

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mr.S.Surendhar ssreee@tce.edu

18CIPF0 **MODEL PREDICTIVE CONTROL**

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Model predictive control is the class of advanced control techniques most widely applied in the process industries. A primary advantage to the approach is the explicit handling of constraints. In addition, the formulation for multivariable systems with time-delays is straightforward. The basic principle is to solve an open-loop optimal control problem at each time step. The decision variables are a set of future manipulated variable moves and the objective function is to minimize deviations from a desired trajectory; constraints on manipulated, state and output variables are naturally handled in this formulation. This course introduces the basically Discrete and continuous time MPC and methods for MPC with constraints.

Prerequisite

18CI260 Digital Control System
18CI130 Process Control
18CI120 System Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcome	Blooms Level
CO1	Calculate the global optimal input for the given system and specified horizon specifications.	Apply
CO2	Calculate the optimal control law solution for the given system with equality/inequality constraints.	Apply
CO3	Design DMPC using Laguerre Function for the given system and specifications.	Apply
CO4	Analyse the effect of prediction horizon and exponential weight in the closed loop stability of system controlled by discrete MPC	Apply
CO5	Calculate the MPC gains using the Kautz functions for the given specifications and system.	Apply
CO6	Explain the features of commercially available MPC packages.	Understand

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**S**	**M**	**L**	**L**				**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**S**	**S**	**M**	**M**				**M**		**M**	
CO5	**S**	**M**	**L**	**L**				**M**		**M**	

CO6	**M**	**L**						**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60

*CO4 - Analyze level will be assessed with the assignments of the relevant topics using simulation tools.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Assume the augmented model as $A = \begin{bmatrix} 0.6 & 0 \\ 0.6 & 1 \end{bmatrix}$; $B = \begin{bmatrix} 0.3 \\ 0.3 \end{bmatrix}$; $C = \begin{bmatrix} 0 \\ 1 \end{bmatrix}^T$. Consider initial condition of x as 0.1, 0.2 . Assume Nc=4, Np=10. Find the 2 step ahead of the prediction for the unconstrained control law.
2. Find the optimal control del_U and min_J. $J = Y^T Y + \Delta U^T \bar{R} \Delta U$, where $\bar{R} = r_w I, r_w = 3$, $r(k_i) = 0$.
3. Explain the features of MPC for a multivariable system.

Course Outcome 2 (CO2):

1. Describe the effect of unconstrained control inputs on the process response.
2. Consider the system matrices as $A = \begin{bmatrix} 0.9048 & 0 \\ 0.0952 & 1 \end{bmatrix}$; $B = \begin{bmatrix} 0.0952 \\ 0.0048 \end{bmatrix}$; $C = \begin{bmatrix} 0 \\ 1 \end{bmatrix}^T$. Assume that the reference is unit step. Closed loop observer poles is located at 0.1,0.2,0.3. Constraints are $0 \leq u(k) \leq 0.6, -0.2 \leq \Delta u(k) \leq 0.2$. Assume Np=60, Nc=5, R=I. Initial conditions are zero. Find the control input u(4).
3. Find the unconstrained minimum of J. Consider the objective function as $J = \frac{1}{2} x^T E x + x^T F$. Given that $E = \begin{bmatrix} 3 & 1 \\ 1 & 1 \end{bmatrix}$ and $F = [-15 \quad -7]$. Constraints are $x_1 \geq 0$, $x_2 \geq 0$, $x_1 + x_2 \leq 3$, $2x_1 - x_2 \leq 4, x_2 \leq 2$.

Course Outcome 3(CO3):

1. For the system with $G(z) = \frac{0.3(z-1.1)}{(z-0.3)(z-1.5)}$. Verify that for Np=28 and N=3, the system produces the stable response. Let $Q = C^T C$, R=0.1, scaling factor=1/1.5.

2. Consider the continuous system with $G(s) = \frac{1}{s^2+0.6s+9}$ with delt=0.1, $Q = C^TC$, R=0.3, $C = [0 \quad 0 \quad 1], \alpha = 0.7$, N=8 . $x(10) = [0.1 \quad 0.2 \quad 0.3]^T$. Within one optimization window find the optimal η with constraints $-1 \leq \Delta u_m(k_i + m) \leq 1$.
3. Describe the Laguerre functions with examples.

Course Outcome 4 (CO4):

1. Design the discrete time predictive control system for $G(z) = \frac{0.1(z-0.3)}{(z-1.25)(z-0.6)} z^{-6}$ with the design parameters are specified as a=0.5, N=5, $Q = C^TC$, R=1, $J = \eta^T\Omega\eta + 2\eta^T\psi x(k_i)$. For any two tuning of N_p and R, calculate the Ω, ψmatrices.
2. Consider the augmented matrices as $A = \begin{bmatrix} 0.5 & 0 \\ 0.5 & 1 \end{bmatrix}; B = \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix}; C = \begin{bmatrix} 0 \\ 1 \end{bmatrix}^T$. Choose $Q = C^TC$, R=0.1, $\alpha = 1.5, Q_\alpha, R_\alpha, a = 0.3, N = 4, N_p = 20$. Calculate the K_{mpc}
3. Design a predictive control system with integral action, which also has the closed loop poles inside a circle of radius 0.8. The rest of the design specifications are a1 = a2 = 0.5, N1 = N2 = 12, $Q = C^TC$ and R = 0.3, α = 1.2, Np = 60. Observer specifications are $Q_{ob} = I, R_{ob} = 0.1I$. Constraints are $-1 \leq \Delta u_1(k) \leq 1, -1 \leq \Delta u_2(k) \leq 1, \ 8 \leq u_1(k) \leq 16, -2 \leq u_2(k) \leq 2$. with system transfer function

$$G(z) = \begin{bmatrix} \dfrac{0.1(z-0.5)}{(z-0.7+j0.8)(z-0.7-j0.8)} & \dfrac{0.001}{z-0.3} \\ -0.1/z^2 & \dfrac{1.1(z-0.8)}{(z-1)^2} \end{bmatrix}$$

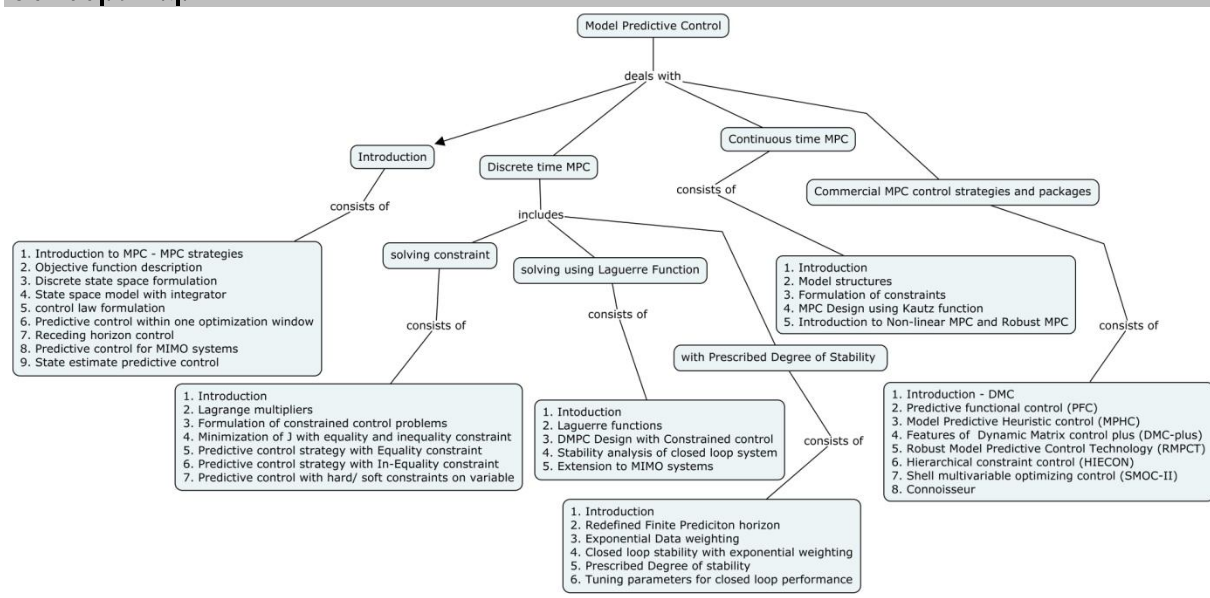
Course Outcome 5 (CO5):

1. Suppose that an augmented state-space model for a continuous time system is described by
   $\dot{x}(t) = Ax(t) + Bu(t)$; $y(t) = Cx(t)$where the matrices are
   $$A = \begin{bmatrix} -1 & -1 & 0 & 0 & 0 & 0 \\ -2 & -3 & 0 & 0 & 0 & 0 \\ -1 & -2 & -5 & 0 & 0 & 0 \\ 1 & 2 & 3 & -5 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \end{bmatrix}; B = \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 1 \\ 0 & 1 \\ 0 & 0 \\ 0 & 0 \end{bmatrix}; C = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 1 \\ 1 & 0 \end{bmatrix}^T$$ choose $Q = C^TC$ and $R = \begin{bmatrix} 0.2 & 0 \\ 0 & 0.2 \end{bmatrix}$, calculate the K_{mpc} with minimizing the with minimizing the $J = \eta^T\Omega\eta + 2\eta^T\psi x(t_i)$ with the prediction horizon as 8.
2. Consider the system $G(s) = \frac{(1-3s)}{(s^2+0.4s+1)(1+3s)}$. Find the Augmented State space,ψ, Ω matrices given that = C^TC , R = [0.1] , N=5, p=1, , $T_p = 6$, $J = \eta^T\Omega\eta + 2\eta^T\psi x(t_i)$.
3. Discuss about the various constraints to be considered for find the optimal control signal.

Course Outcome 6 (CO6):

1. Discuss about the control strategies involved in the Predictive functional control.
2. Discuss about the features in various commercial MPC packages.
3. A chemical process is to be controlled by Dynamic Matrix controller. Initially, input to the process and the output of the process are zero. Finite Step response coefficients of a process are S = {0.18, 0.3, 0.45, 0.55, 0.63, 0.72, 0.75}. Assuming prediction horizon =3, control horizon =1, and unit step reference, calculate the first output of Dynamic Matrix controller. Assume control input weight =0.

Concept Map



Syllabus

Introduction:

Introduction to MPC - MPC strategies – Objective function description - Discrete state space formulation - state space model with integrator - control law formulation - Predictive control within one optimization window - Receding horizon control - Predictive control for MIMO systems - State estimate predictive control, Dynamic Matrix control, Generalized Predictive Control

Discrete-time MPC with constraints

Introduction - Equality and Inequality constraint - Lagrange multipliers - Formulation of constrained control problems - Minimization with equality constraint and inequality constraint - Predictive control with constraints on input variable

Discrete-time MPC using Laguerre Functions

Introduction - Laguerre functions and DMPC - DMPC Design - Constrained control using Laguerre functions - Stability analysis - Extension to MIMO systems

Discrete-time MPC with Prescribed Degree of Stability

Introduction - Finite Prediction horizon - Exponential Data weighting - Closed loop stability with exponential weighting - Prescribed Degree of stability - Tuning parameters for closed loop performance , Distributed MPC

Continuous time MPC
Introduction - Model structures - optimal control strategy - MPC using Kautz functions - Formulation of constraints - Introduction to Non-linear MPC and Robust MPC

Commercial MPC control strategies and packages
Introduction - Model Predictive Heuristic control (MPHC) - Dynamic Matrix control plus (DMC-plus) - Hierarchical constraint control (HIECON) - Predictive functional control (PFC) - Robust Model Predictive Control Technology (RMPCT) - Shell multivariable optimizing control (SMOC-II) - Connoisseur

Reference Books

1. by E.F.Camacho and C.Bordons, Model Predictive control, 2nd Edition, springer- verlog London 2007.
2. Liuping Wang, Model Predictive Control system Design and Implementation using MATLAB, springer - verlog London, 2009.
3. Qin, S.J., Badgwell, T.A., 2003. A survey of industrial model predictive control technology. Control Eng. Pract. 11, 733–764.
4. J A Rossiter, Model based Predictive Control - A Practical Approach, 2nd Edition, CRC Press LLC Publication.
5. James B.Rawlings David Q.Mayne, Model Predictive Control - Theory, computation and Design by, 2nd Edition, Nob Hill Publications, New York., 2016.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**Introduction**	
1.1	Introduction to MPC - MPC strategies	1
1.2	Objective function description - Discrete state space formulation	1
1.3	state space model with integrator - control law formulation	1
1.4	Predictive control within one optimization window - Receding horizon control	1
1.5	Predictive control for MIMO systems	1
1.6	State estimate predictive control	1
1.7	Dynamic Matrix Control	1
1.8	Generalized Predictive Control	1
2	**Discrete-time MPC with constraints**	
2.1	Introduction - various constrained variables	1
2.2	Lagrange multipliers - Formulation of constrained control problems	1
2.3	Minimization of J with equality constraint and inequality constraint	1
2.4	Predictive control strategy with Equality constraint	1
2.5	Predictive control strategy with In-Equality constraint	2
2.6	Predictive control with hard/ soft constraints on variable	2

3	**Discrete-time MPC using Laguerre Functions**	
3.1	Introduction - Laguerre functions	1
3.2	DMPC Design with Constrained control using Laguerre functions	2
3.3	Stability analysis of closed loop system with observer	1
3.4	Extension to MIMO systems, Distributed MPC	2
4	**Discrete-time MPC with Prescribed Degree of Stability**	
4.1	Introduction - Redefined Finite Prediction horizon	1
4.2	Exponential Data weighting - Closed loop stability with exponential weighting	2
4.3	Prescribed Degree of stability	1
4.4	Tuning parameters for closed loop performance	2
5	**Continuous time MPC**	
5.1	Introduction - Model structures	1
5.2	Formulation of constraints	1
5.3	MPC Design using Kautz function	2
5.4	Introduction to Non-linear MPC and Robust MPC	1
6	**Commercial MPC control strategies and packages**	
6.1	Introduction - DMC	1
6.2	Predictive functional control (PFC)	1
6.3	Model Predictive Heuristic control (MPHC)	1
6.4	Features of Dynamic Matrix control plus (DMC-plus), Robust Model Predictive Control Technology (RMPCT), Hierarchical constraint control (HIECON), Shell multivariable optimizing control (SMOC-II), Connoisseur	2
	Total	**36**

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mr.S.Surendhar ssreee@tce.edu

		Category	L	T	P	Credit
18CIPG0	**ROBOTICS**	PE	3	0	0	3

Preamble

Robotics is a multidisciplinary field involving mechanics, control, instrumentation, artificial intelligence, computer science etc. Applications of robotics range from routine pick and place jobs in industries to intelligent remote operated vehicles in space research. This course mainly discusses about robot anatomy, coordinate frames, mapping and transforms, direct kinematic modelling of robots and inverse kinematics, dynamic modelling, trajectory planning, linear and nonlinear control of manipulators.

Prerequisite

18CI120 System Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the components of robot	Understand
CO2	Develop forward and inverse kinematics of a given manipulator	Apply
CO3	Develop dynamic model of a given manipulator	Apply
CO4	Calculate trajectories of end effectors and joints for a given set of via points	Apply
CO5	Apply linear and nonlinear control schemes for a given manipulator	Apply
CO6	Implement forward and inverse kinematics and trajectory planning algorithm using software and hardware tools.	Apply

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**S**	**M**	**L**	**L**				**M**		**M**	
CO5	**S**	**M**	**L**	**L**				**M**		**M**	
CO6	**S**	**M**	**L**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60

Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CO6 is assessed based on the assignments submitted on the following experiments:
1. Simulation of Forward and Inverse Kinematics using suitable software.
2. Simulation of Closed loop control of two degree of freedom R-R manipulator.
3. Implementation of trajectory planning algorithm for straight line and parabolic motion.
4. Path planning and Obstacle Avoidance using QBot 2

Course Level Assessment Questions

Course Outcome 1 (CO1)**:**
1. Illustrate the role of degree of freedom in selection of robots
2. With suitable diagram describe the working principle of any one tactile and touch sensor used in robotics
3. Explain various components of robots

Course Outcome 2 (CO2)**:**
1. A vector OP defined in the reference frame {0} is [1 2 3] ^{T}. Origin of frame is displaced by +2units along y axis and +3 units along z axis. Frame {0} is then rotated about z axis by 90^o and about x axis by $-90^{o.}$ Find the vector OP w.r.t the transformed frame.
2. Compute the manipulator transformation matrix for 3DOF manipulator arm with Cartesian Arm (PPP) configuration.
3. Compute the manipulator transformation matrix and inverse kinematics for 3DOF manipulator arm with Polar (RRP) configuration.

Course Outcome 3 (CO3)**:**
1. Explain the method of static force analysis of manipulators
2. Using Euler Lagrange equation derive the dynamic model of 2 DOF planar manipulator
3. Derive the dynamic model of 3DOF manipulator arm with Cartesian configuration

Course Outcome 4 (CO4)**:**
1. It is desired to have the first joint of a six-axis robot go from initial angle of 30 degree to final angle of 60 degree in 5 seconds. Using fifth order polynomial calculate the joint angle at 1^{st}, 2^{nd}, 3^{rd}, and 4^{th} second. Assume initial acceleration and final retardation be 5 degree/sec^2
2. Determine the trajectory of pick and place robot which has to pass through three via-points using piecewise linear interpolation with parabolic blends for each segment. The path points are [0 10 45 30 5] degrees and travel times for the segments are [0.5 1.5 2.0 1.0] seconds respectively. Assume the magnitude of acceleration at each parabolic blend is 25 degree / sec^2
3. Derive the cubic polynomial trajectory model of point to point motion without via points

Course Outcome 5 (CO5)**:**
1. Consider the servo motor driven joint-link with dynamic model $\tau = I\ddot{\theta}_a$. It is driven by a armature controlled servo motor. Dynamic model of servo motor model is $e_a = K_b\dot{\theta}_a + i_a R_a$, and $\tau_a = K_t i_a$, where,

$e_a \rightarrow$ Control voltage(V)

$K_b \rightarrow$ Back emf constant (V/rad/s)

$i_a \rightarrow$ Armature current(A)

$R_a \rightarrow$ Armature resistance(Ω)

$K_t \rightarrow$ Torque Constant(Nm/A)

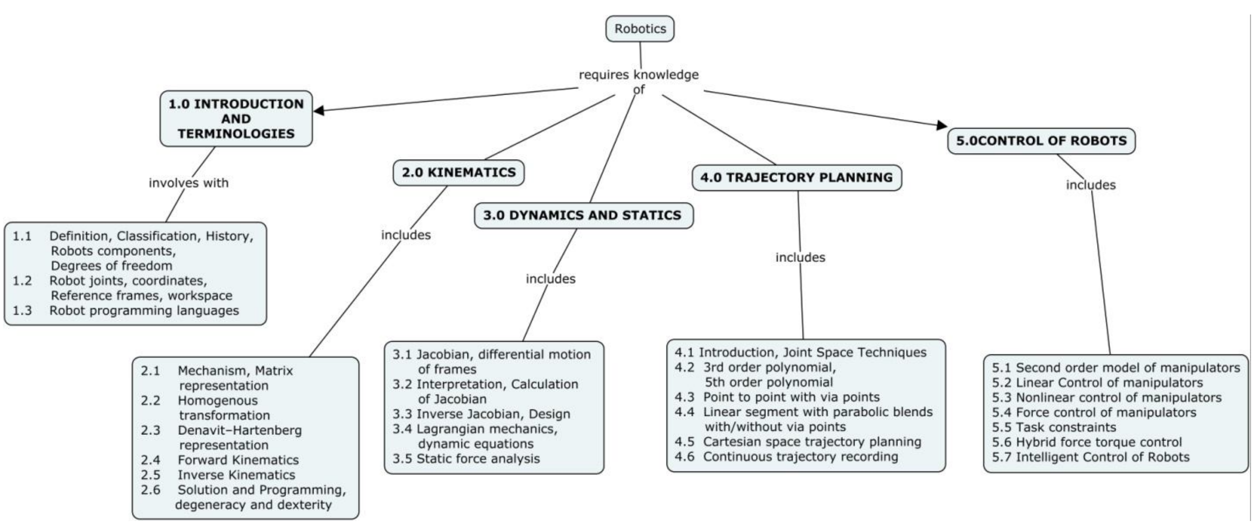
$\tau_a \rightarrow$ Torque produced by servo motor (Nm)

This setup is to be controlled by a PID controller with partitioning scheme to track the reference trajectory. Find the closed loop error dynamics of the system and the condition for critically damped response.

2. Consider a manipulator with linear, second order dynamic model $\tau = I\ddot{\theta} + B\theta$, where I is the total inertia and B is the total friction.
   a. Design suitable partitioned control scheme to achieve the error dynamics $\ddot{e} + 4\dot{e} + 4e = 0$
   b. Assuming that there is a constant disturbance torque τ_d, design suitable control scheme to eliminate the effect of disturbance and achieve the error dynamics $\dddot{e} + 3\ddot{e} + 4\dot{e} + 4e = 0$
3. With suitable diagram illustrate hybrid position /force control scheme.

Course Outcome 6 (CO6)**:**
1. Create robot joint trajectories using Roboanalyzer software
2. Simulate Forward and Inverse Kinematics using RoboAnalyzer.
3. Implement trajectory planning algorithm for straight line motion using Matlab
4. Implement Forward and inverse kinematics using robot.

Concept Map



Syllabus

INTRODUCTION AND TERMINOLOGIES
Definition, Classification, History, Robot components, Degrees of freedom, Robot joints, coordinates, Reference frames, workspace, Robot programming languages, Robotic Sensors and actuators

KINEMATICS(limited to 3-DOF manipulators)
Mechanism-matrix representation, Homogenous transformation, DH representation, Forward Kinematics, Inverse kinematics, Solution and programming, degeneracy and dexterity,

DYNAMICS AND STATICS (limited to 3-DOF manipulators)
Jacobian, differential motion of frames, Interpretation, Calculation of Jacobian, Inverse Jacobian, Design, Lagrangian mechanics, dynamic equations, static force analysis

TRAJECTORY PLANNING
Introduction, Joint Space Techniques, 3rd order polynomial, 5th order polynomial, Point to point with via points, Linear segment with parabolic blends with/without via points, and Cartesian space trajectory planning, Continuous trajectory recording

CONTROL OF ROBOTS
Second order model of manipulators, Linear Control of manipulators – Nonlinear control of manipulators, Force control of manipulators, Task constraints, Hybrid force torque control, Intelligent Control of Robots

Reference Books

1. Saeed B. Niku ,''Introduction to Robotics '', Pearson Education, 2002
2. John J.Craig, “Introduction to Robotics, Mechanics and control”, third edition, Pearson education, 2005
3. R.K. Mittal, I.J. Nagrath, Robotics and control, Tata McGraw-Hill, 2003.
4. R.D. Klafter, TA Chmielewski and Michael Negin, "Robotic Engineering, An Integrated approach", Prentice Hall of India, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**INTRODUCTION AND TERMINOLOGIES**	
1.1	Definition, Classification, History, Robots components, Degrees of freedom	1
1.2	Robot joints, coordinates, Reference frames, workspace	1
1.3	Robot programming languages, Robotic Sensors and actuators	1
2.0	**KINEMATICS**	
2.1	Mechanism, Matrix representation	1
2.2	Homogenous transformation	1

2.3	DH representation	1
2.4	Forward Kinematics	2
2.5	Inverse Kinematics	2
2.6	Solution and Programming, degeneracy and dexterity	1
3.0	**DYNAMICS AND STATICS**	
3.1	Jacobian, differential motion of frames	1
3.2	Interpretation, Calculation of Jacobian	1
3.3	Inverse Jacobian, Design	2
3.4	Lagrangian mechanics, dynamic equations	2
3.5	Static force analysis	2
4.0	**TRAJECTORY PLANNING**	1
4.1	Introduction, Joint Space Techniques	1
4.2	3rd order polynomial, 5th order polynomial	1
4.3	Point to point with via points	1
4.4	Linear segment with parabolic blends with/without via points	2
4.5	Cartesian space trajectory planning	1
4.6	Continuous trajectory recording	1
5.0	**CONTROL OF ROBOTS**	
5.1	Second order model of manipulators	1
5.2	Linear Control of manipulators	2
5.3	Nonlinear control of manipulators	2
5.4	Force control of manipulators	1
5.5	Task constraints	1
5.6	Hybrid force torque control	1
5.7	Intelligent Control of Robots	1
	Total	**36**

Course Designers:

1. Dr.M.Saravanan mseee@tce.edu
2. Mr.M.Varatharajan varatharajan@tce.edu
3. Dr.P.S.Manoharan psmeee@tce.edu

		Category	L	T	P	Credit
18CIPH0	**INTELLIGENT CONTROLLERS**	PE	2	0	2	3

Preamble

Intelligent control achieves automation via the emulation of biological intelligence. It either seeks to replace a human who performs a control task (e.g., a chemical process operator) or it borrows ideas from how biological systems solve problems and applies them to the solution of control problems. This course provides an overview of several techniques used for intelligent control and discusses challenging industrial application domains where these methods may provide particularly useful solutions. The subject begins with a brief overview of the main areas in intelligent control, which are fuzzy control and neural networks

Prerequisite

18CI130 - Process control

Course Outcomes

On the successful completion of the course, students will be able to:

CO1	Apply multi layered networks, radial basis function, recurrent networks and self organizing map networks for nonlinear function approximations	Apply
CO2	Design a various adaptive neural control scheme for controlling nonlinear systems	Apply
CO3	Analyze the performance of Neural network controller for optimal control of the given system using MATLAB	Analyze
CO4	Explain the fundamentals of Fuzzy logic system	Understand
CO5	Develop Fuzzy PD, PI and Model based controller	Apply
CO6	Analyze the performance of Fuzzy logic controller for control of the given system using MATLAB	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	S	M	L	M			M		M	
CO2	S	S	M	L	M			M		M	
CO3	S	S	S	M	M			M		M	
CO4	M	M	L					M		M	
CO5	S	S	M	L	M			M		M	
CO6	S	S	S	M	M			M		M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Practical test	Terminal Examination
	1	2	3		
Remember	20	20	20	0	20
Understand	20	20	20	0	20
Apply	60	60	60	40	60
Analyze	0	0	0	60	0
Evaluate	0	0	0	0	0

Create	0	0	0	0	0

CO3 and CO6 are tested through practical test.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Derive the back propagation algorithm for an MLN with three layers using generalized delta rule.
2. Realize XOR function using radial basis function network
3. Explain the applications of self organizing maps in control engineering.

Course Outcome 2 (CO2):

1. Explain indirect adaptive control using schematic structure.
2. The first order plant is represented as x(k+1)=ax(k) + bu(k). It is assumed that the plant parameters a and b are unknown. Design an indirect adaptive control scheme for the above system.
3. Design a direct adaptive controller for the following linear plant: y' =2y+5u

Course Outcome 3 (CO3):

1. Design Neural Network based indirect adaptive control scheme for a first order linear system.
2. Design direct adaptive controller for a ball and beam system.
3. Design of Neural Network based back stepping control of Rigid Link Electrically Driven Robot Manipulator (RLED).

Course Outcome 4 (CO4):

1. What are the different methods of De-fuzzification?
2. Explain Sugeno type fuzzy model
3. Explain the construction of fuzzy model for a nonlinear equation

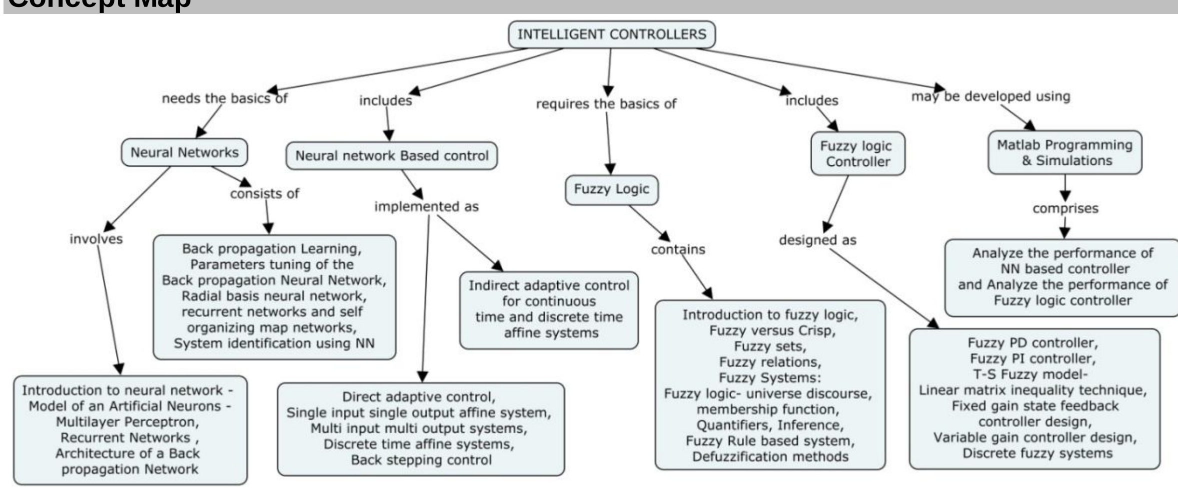
Course Outcome 5 (CO5):

1. Design a fuzzy PI controller for a series DC motor.
2. Explain variable gain controller design.
3. Consider the following dynamical equations of a VanderPol Oscillator.
   x1'=x2;
   x2'=-x1 +μ (1-x12)x2 +u. Design a T-S fuzzy model of the above system.

Course Outcome 6 (CO6):

1. Design Fuzzy PI controller to control DC motor.
2. Design Fuzzy controller to control the dynamics of an automobile.
3. Design inversion based control design for a cart – pole system.

Concept Map



Syllabus

Neural Networks: Introduction to neural network - Model of an Artificial Neurons -Multilayer Perceptron, Recurrent Networks ,Architecture of a Back propagation Network, Back propagation Learning, Parameters tuning of the Back propagation Neural Network, Radial basis neural network, recurrent networks and self organizing map networks, System identification using NN

Neural network Based control: Direct adaptive control, Single input single output affine system, Multi input multi output systems, Discrete time affine systems, Back stepping control, Indirect adaptive control for continuous time and discrete time affine systems, Introduction to machine learning.

Fuzzy Logic: Introduction to fuzzy logic, Fuzzy versus Crisp, Fuzzy sets, Fuzzy relations, universe of discourse, membership function, Quantifiers, Inference, Fuzzy Rule based system, Defuzzification methods

Fuzzy logic Controller: Fuzzy PD controller, Fuzzy PI controller, T-S Fuzzy model- Linear matrix inequality technique, Fixed gain state feedback controller design, Variable gain controller design, Discrete fuzzy systems

Matlab Programming & Simulations: Analyze the performance of NN based controller and Analyze the performance of Fuzzy logic controller.

Reference Books

1. Intelligent Systems and Control- Principles and applications, Laxmidhar Behera, Indrani Kar, Oxford university press, First edition, 2009, Fifth impression, 2014
2. A.E. Ruano, 'Intelligent Control Systems using computational Intelligence technique', IET, 2008.
3. Simon Haykin, 'Neural Networks', Pearson Education, 2003.
4. John Yen Timothy J. Ross, 'Fuzzy Logic with Engineering Applications', Tata McGraw Hill, 1997.
5. John Yen and Reza Langari, 'Fuzzy Logic – Intelligence Control & Information', Pearson Education, New Delhi, 2003

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**Neural Networks**	
1.1	Introduction to neural network -Model of an Artificial Neurons	1
1.2	Multilayer Perceptron, Recurrent Networks	1
1.3	Architecture of a Back propagation Network, Back propagation Learning	2
1.4	Parameters tuning of the Back propagation Neural Network	1
1.5	Radial basis neural network, recurrent networks	2
1.6	self organizing map networks	1
1.7	System identification using NN	2
2	**Neural network Based control**	

2.1	Direct adaptive control	2
2.2	Single input single output affine system	1
2.3	Multi input multi output systems	1
2.4	Discrete time affine systems	2
2.5	Back stepping control	2
2.6	Indirect adaptive control for continuous time and discrete time affine systems	3
3	**Fuzzy Logic**	
3.1	Introduction to fuzzy logic, Fuzzy versus Crisp, Fuzzy sets, Fuzzy relations	2
3.2	Universe of discourse, membership function, Quantifiers	1
3.3	Inference, Fuzzy Rule based system	1
3.4	Defuzzification methods	1
4	**Fuzzy logic Controller**	
4.1	Fuzzy PD controller, Fuzzy PI controller	2
4.2	T-S Fuzzy model- Linear matrix inequality technique	2
4.3	Fixed gain state feedback controller design	2
4.4	Variable gain controller design	2
4.5	Discrete fuzzy systems	2
5	**Matlab Programming & Simulations**	
5.1	Analyze the performance of NN based controller	6
5.2	Analyze the performance of Fuzzy logic controller	6
	Total	48

Tentative list of experiments: (Using MATLAB)

1. Modelling of discrete time dynamical system using multi layered network.
2. Realization of XOR function using radial basis function network.
3. Design of NN based indirect adaptive control scheme for a first order linear system.
4. Design of direct adaptive controller for a ball and beam system.
5. Design of NN based back stepping control of Rigid Link Electrically Driven Robot Manipulator (RLED)
6. Simulation of Fuzzy PI controller to control DC motor.
7. Designing of Fuzzy controller to control the dynamics of an automobile.
8. Simulation of inversion based control design for a cart – pole system.

Course Designers:

1. Dr.S. Baskar sbeee@tce.edu
2. Dr.D.Kavitha dkeee@tce.edu

		Category	L	T	P	Credit
14CIPJ0	**OPTIMAL CONTROL AND FILTERING**	**PE**	2	1	0	3

Preamble

Optimal control theory, which is playing an increasingly important role in the design of modern systems, has maximizing the returns while minimizing the operational efforts as its objectives. Often the optimal control is described by a feedback law. Such a law determines the optimal control. This subject deals with deriving optimal control laws for control systems, as functions of time, and decisions that must be made as time proceeds.

Prerequisite

- 18CI110 Calculus of Variation & Applied Mathematics
- 18CI120 System Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain various optimal control formulations and necessary conditions of optimal control	Understand
CO2	Design optimal controller using calculus of variations	Apply
CO3	Use dynamic programming to design optimal controller for a given system	Apply
CO4	Explain various optimal filtering/estimation methods	understand
CO5	Implement Kalman filter and Extended Kalman filter for a given linear /nonlinear system	Apply
CO6	Analyze the implementation of optimal controller and observers using MATLAB	Analyze

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**M**	**L**						**M**		**M**	
CO5	**S**	**M**	**L**	**L**				**M**		**M**	
CO6	**S**	**S**	**M**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

*CO6 will be evaluated using assignments

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	20	20	20	20
Understand	45	35	40	30
Apply	35	45	45	50
Analyse	0	0	0	0

Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Using simple diagram, state the condition for optimality for dynamic programming.
2. What is linear tracking problem?
3. State any two properties of optimal solution

Course Outcome 2(CO2)

1. Explain the principle of optimality
2. Derive Hamiltonian Jacobi equation
3. Using dynamic programming, find the control law for the performance measure to be minimized for the equation X(k+1)=-0.5 X(k+1)+u (k) ,J=1/2/o∞(x2+u2)with limits zero to infinity.

Course Outcome 3 (CO3)

1. Derive the necessary conditions of optimal control
2. Explain any one algorithm used for solving split boundary value problems
3. Consider the system $\dot{x} = \begin{bmatrix} 0 & 1 \\ -3 & -2 \end{bmatrix} x + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$. Design a regulator for the system which reaches the final state in minimum time.

Course Outcome 4 (CO4)

1. Derive the Least square estimation for a first order ARMA process
2. Explain the advantages of recursive estimation over least square estimation
3. The measured output of a simple moving average process is $y_k = w_k + w_{k-1}$, where $\{w_k\}$ is zero mean white noise with variance 1
   a. Generate a state-space description for this system with the first element of state, x_k equal to w_{k-1} and second element equal to w_k.
   b. Suppose that the initial estimation-error covariance is equal to the identity matrix. Show that the a posteriori estimation-error covariance is given by $P_{k^+} = \frac{1}{k+1}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$.

Course Outcome 5 (CO5)

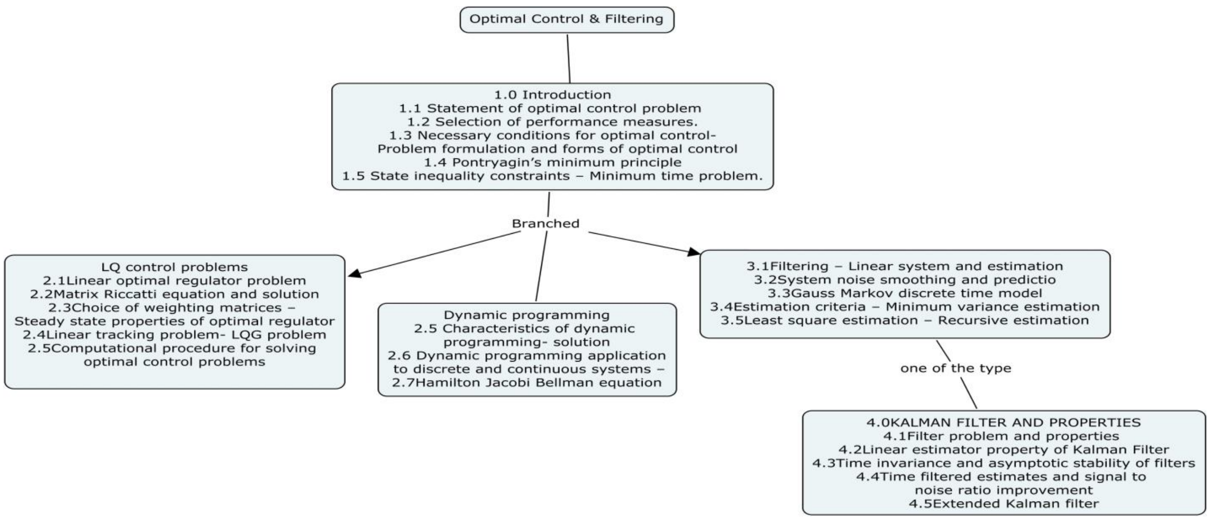
1. Explain the properties of Kalman filter
2. Consider the system given below. $\{w_k\}$ & $\{v_k\}$ are zero mean process noise with variance Q and R respectively?

   $x_{k+1} = x_k + w_k$

   $y_k = x_k + v_k^{\,2}$

   a. What is the mean of the a posteriori estimation error of discrete EKF?
   b. Modify the measurement equation by subtracting the known bias of the measurement noise so that modified measurement noise is zero-mean. What is the variance of modified measurement noise?
3. Consider a nonlinear system $x_{k+1} = -x_k - x_k^{\,3} + w_k$ & $y_k = x_k^{\,2} + v_k$ where u is the input, w_k and v_k are zero mean white process and measurement noises with covariance 5 and 10 respectively. Design Extended Kalman filter to estimates the state x_k of the system.

Concept Map



Syllabus

Introduction

Statement of optimal control problem – Problem formulation and forms of optimal control – Selection of performance measures. Necessary conditions for optimal control – Pontryagin’s minimum principle – State inequality constraints – Minimum time problem.

LQ Control Problems and Dynamic Programming

Linear optimal regulator problem – Matrix Riccatti equation and solution method – Choice of weighting matrices – Steady state properties of optimal regulator – Linear tracking problem – LQG problem – Computational procedure for solving optimal control problems – Characteristics of dynamic programming solution – Dynamic programming application to discrete and continuous systems– Hamilton Jacobi Bellman equation, Approximate Dynamic Programming – Case Studies using MATLAB

Filtering and estimation

Filtering – Linear system and estimation – System noise smoothing and prediction – Gauss Markov discrete time model – Estimation criteria – Minimum variance estimation – Least square estimation – Recursive estimation.

KALMAN Filter and properties

Filter problem and properties – Linear estimator property of Kalman Filter – Time invariance and asymptotic stability of filters – Time filtered estimates and signal to noise ratio improvement – Extended Kalman filter – Case studies using MATLAB

Reference Books

1. Kirk D.E., ‘Optimal Control Theory – An introduction’, Dover Publications, 2004.
2. D. Subbaram Naidu, “Optimal Control Systems”, CRC Press, 2002.
3. Dan Simon, “Optimal State Estimation Kalman, H-infinity and Non-linear Approaches”, John Wiley and Sons, 2006
4. B. D. O. Anderson and J. B. Moore. Linear Optimal Control., Dover Publications, New York, 2005

5. S.M. Bozic, “Digital and Kalman Filtering”, Edward Arnould, London, 1994.
6. K. J. AStrom, “Introduction to Stochastic Control Theory”, Dover, New York, 2006.
7. C.K. Chui and G. Chen,” Kalman Filtering with Real-Time Applications”, Springer Ser. Info. Sci., Vol. 17. Springer, Berlin, Heidelberg, 1987.
8. A.V.Bala Krishnan ,”Kalman filtering Theory” , Springer; 1 edition, 28, 1984

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**INTRODUCTION**	
1.1	Statement of optimal control problem	1
1.2	Selection of performance measures.	1
1.3	Necessary conditions for optimal control- Problem formulation and forms of optimal control	2
1.4	Pontryagin’s minimum principle	2
1.5	State inequality constraints – Minimum time problem.	2
2.	**LQ CONTROL PROBLEMS AND DYNAMIC PROGRAMMING**	
2.1	Linear optimal regulator problem	2
2.2	Matrix Riccatti equation and solution	2
2.3	Choice of weighting matrices – Steady state properties of optimal regulator	2
2.2	Linear tracking problem- LQG problem	3
2.4	Computational procedure for solving optimal control problems	2
2.5	Characteristics of dynamic programming- solution	1
2.6	Dynamic programming application to discrete and continuous systems,	3
2.7	Hamilton Jacobi Bellman equation, Approximate Dynamic Programming	2
2.8	Case Studies using MATLAB	1
3.	**FILTERING AND ESTIMATION**	
3.1	Filtering – Linear system and estimation	1
3.2	System noise smoothing and prediction	1
3.3	Gauss Markov discrete time model	1
3.4	Estimation criteria – Minimum variance estimation	1
3.5	Least square estimation – Recursive estimation	2
4.	**KALMAN FILTER AND PROPERTIES**	
4.1	Filter problem and properties	2
4.2	Linear estimator property of Kalman Filter	1
4.3	Time invariance and asymptotic stability of filters	2
4.4	Time filtered estimates and signal to noise ratio improvement	1
4.5	Extended Kalman filter	1
4.6	Case studies using MATLAB	1
Total		**40**

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mrs.R.Suganya rsaeee@tce.edu

18CIPK0	ROBUST CONTROL	Category	L	T	P	Credit
		PE	**3**	**0**	**0**	**3**

Preamble

.
Robust control deals with system analysis and control design for such imperfectly known process models. One of the main goals of feedback control is to maintain overall stability and system performance despite uncertainties in the plant. One of the most useful qualities of a properly designed feedback control system is robustness, i.e., the ability of the closed-loop system to continue performing satisfactorily despite large variations in the (open-loop) plant dynamics. This course will provide an introduction to the analysis and design of robust feedback control systems. The course enables the control engineer to be pioneered in designing control system. It also gives an attempt to thoroughly analyze the system for performance & stability and design robust controller for various applications.

Prerequisite

1. 18CI110 - Calculus of Variation & Applied Mathematics
2. 18CI120 – SystemsTheory
3. 18CI160 - Transducers Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Cos	Course outcomes	Blooms Level
CO1	Explain the concepts related to the Norms of Systems and Performance	Understand
CO2	Design a LQR, LQG, H_2Controllerfor the given system specifications	Apply
CO3	Design a H_∞optimal control using Riccati Equationfor the given system specifications	Apply
CO4	Design a H_∞optimal control using LMI Approach for the given system specifications	Apply
CO5	Explain the robust controller synthesis using D-K iteration method	Understand
CO6	Analyze the performance of Robust Controller for the CSTR, Distillation Column, Invented Pendulum systems by simulation in computer tools	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	

CO4	**S**	**M**	**L**	**L**				**M**		**M**	
CO5	**M**	**L**						**M**		**M**	
CO6	**S**	**S**	**M**	**M**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	10	10	10	10
Understand	60	30	30	30
Apply	30	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

* CO6 - Should be assessed with the simulations using modern tools like MATLAB

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Differentiate the two norm and infinity norm.
2. State the necessary and sufficient condition for the Robust Performance
3. State the co-prime factorization for the system matrices A,B,C,D with the gains are F,L.

Course Outcome 2 (CO2):

1. Consider the inverted pendulum system matrices as $A = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{-mg}{M} & \frac{\left(\frac{\frac{K_t * K_b}{R_a}}{r_1^2}\right)}{M} & 0 \\ 0 & \frac{(M+m)g}{Ml} & \frac{\left(\frac{\frac{K_t * K_b}{R_a}}{r_1^2}\right)}{Ml} & 0 \end{bmatrix}$

$B = \begin{bmatrix} 0 \\ 0 \\ \frac{\left(\frac{K_t}{R_a * r_1}\right)}{Ml} \\ -\left(\left(\frac{K_t}{R_a * r_1}\right)\right)\Big/ Ml \end{bmatrix}$; $C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}$; $D = 0$ with the parameter as per the figure

Parameter	Value	Units
R_a	1	Ω
K_t	0.02	$N \cdot m/A$
K_b	0.02	$V \cdot s/rad$
r_1	0.015	m
M	1	Kg
m	0.1	Kg
l	0.25	m

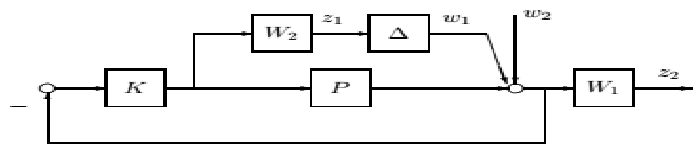
Design a LQR controller for the above system.

2. Interpret between the loop shaping design procedure and LQG control scheme.
3. Outline various robust control methods for parametric families.

Course Outcome 3 (CO3):

1. Consider the system shown below. Design a controller K such that

$$P = \frac{0.5(1-s)}{(s+2)(s+0.5)}, \quad W_1 = 50\frac{s/1.245+1}{s/0.007+1}, \quad W_2 = 0.1256\frac{s/0.502+1}{s/2+1}.$$



   a. $\underset{K \ \ stabilizing}{Infinity} \|M\|_\infty$

   b. $\underset{K \ \ stabilizing}{Infinity} \ \sup_{\omega} \mu_\Delta(M), \qquad \Delta = \begin{bmatrix} \Delta_1 & \\ & \Delta_2 \end{bmatrix}$

2. For the system with plant model $G(s) = \frac{85}{(s+1)(0.1s+2)^2}$ and the weighting function is chosen as $w_s(s) = \frac{\left(\frac{s}{M}\right)+\omega_0}{s+\omega_0 A}$; $w_t(s) = \frac{\left(\frac{\omega_0}{M}\right)+s}{As+\omega_0}$; $w_{ks} = 1$ where A=0.01,M(sensitivity peak) = 2,ω_0 = 0.1. Design the H-infinty controller using Riccati equation and find the gamma value.
3. For the system with plant model $P(s) = \frac{2\left(\frac{s-3}{s+1}\right)}{1+2\left(\frac{s-3}{s+1}\right)e^{-0.5s}}$ and the weighting function is chosen as $w_1(s) = 0.5$; $w_2(s) = \frac{1+0.1s}{0.4+s}$. Find the optimal H-infinity controller using Riccati equation and also find γ_{opt}.

Course Outcome 4 (CO4):

1. .For the system with plant model $G(s) = \frac{70}{(s+2)(0.3s+2)^1}$ and the weighting function is chosen as $w_s(s) = \frac{\left(\frac{s}{M}\right)+\omega_0}{s+\omega_0 A}$; $w_t(s) = \frac{\left(\frac{\omega_0}{M}\right)+s}{As+\omega_0}$; $w_{ks} = 1$ where A=0.02,M(sensitivity peak) = 2,ω_0 = 0.1. Design the H-infinty controller using LMI approach and find the gamma value.
2. For the system with plant model $P(s) = \frac{2\left(\frac{s-3}{s+1}\right)}{1+2\left(\frac{s-3}{s+1}\right)e^{-0.5s}}$ and the weighting function is chosen as $w_1(s) = 0.5$; $w_2(s) = \frac{1+0.1s}{0.4+s}$. Find the optimal H-infinity controller H-infinity controller using LMI approach and also find γ_{opt}.
3. State the control law for determining the input using LMI approach.

Course Outcome 5 (CO5):

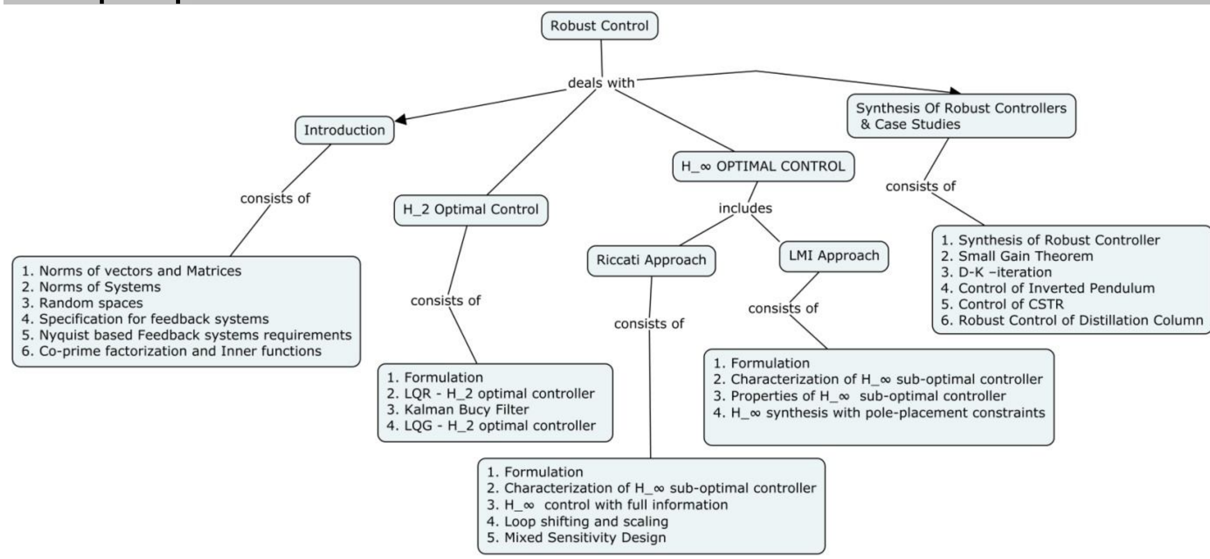
1. Differentiate the structured and unstructured uncertainties
2. Define small gain theorem and µ synthesis
3. Discuss the basic idea/steps involved in D-K Iteration method

Course Outcome 6 (CO6)

1. Simulate the rudder roll stabilization (RRS) Non-linear model with differential equation.

2. For the Benchmark wood-berry distillation column model with the model transfer $$\begin{bmatrix} y_1(s) \\ y_2(s) \end{bmatrix} = \begin{bmatrix} \frac{12.8e^{-s}}{16.7s+1} & \frac{-18.9e^{-3s}}{21s+1} \\ \frac{6.6e^{-7s}}{10.9s+1} & \frac{-19.4e^{-3s}}{14.4s+1} \end{bmatrix} \begin{bmatrix} u_1(s) \\ u_2(s) \end{bmatrix}$$ matrix, synthesis the robust controller using D-K iteration. show the performance of closed loop control in Matlab.
3. Perform the detailed study of the standard benchmark unstable process of the CSTR with robust controller.

Concept Map



Syllabus

Introduction

Norms of vectors and Matrices – Norms of Systems – Calculation of operator Norms – vector - Random spaces- Specification for feedback systems – Nyquist based Feedback systems requirements - Co-prime factorization and Inner functions – Representation of structured and unstructured uncertainty- robustness

H_2 Optimal Control

Linear Quadratic Controllers – Characterization of H_2 optimal controllers – H_2 optimal estimation-Kalman Bucy Filter – LQG Controller.

H_∞ OPTIMAL CONTROL-RICCATI APPROACH

Formulation – Characterization of H_∞sub-optimal controllers by means of Riccati equations – H_∞control with full information – Loop shifting and scaling - Mixed Sensitivity Design

H_∞OPTIMAL CONTROL- LMI APPROACH

Formulation – Characterization of H_∞sub-optimal controllers by means of LMI Approach– Properties of H_∞sub-optimal controllers – H_∞synthesis with pole-placementconstraints

SYNTHESIS OF ROBUST CONTROLLERS & CASE STUDIES

Synthesis of Robust Controllers – Small Gain Theorem – D-K –iteration- Control of Inverted Pendulum- Control of CSTR – Control of Aircraft -Robust Control of Distillation Column

Reference Books

1. U. Mackenroth “Robust Control Systems: Theory and Case Studies”, Springer International Edition, 2010.
2. J. B. Burl, “ Linear optimal control H2 and H-infinity methods”, Addison W Wesley, 1998

3. D. Xue, Y.Q. Chen, D. P. Atherton, "Linear Feedback Control Analysis and Design with MATLAB, Advances In Design and Control", Society for Industrial and Applied Mathematics, 2007.
4. I.R. Petersen, V.A. Ugrinovskii and A. V. Savkin, "Robust Control Design using H-infinity Methods", Springer, 2000.
5. M. J. Grimble, "Robust Industrial Control Systems: Optimal Design Approach for Polynomial Systems", John Wiley and Sons Ltd., Publication, 2006.

Lecture Schedule

S.No.	Topic	No. of Lectures
1.	Norms of vectors and Matrices – Norms of Systems	1
2.	Calculation of operator Norms – vector - Random spaces	1
3.	Specification for feedback systems – Nyquist based Feedback systems requirements	1
4.	Co-prime factorization and Inner functions	1
5.	White noise, General Feedback system with uncertainties representation, gamma function	2
6.	Linear Quadratic Regulator	1
7.	Linear Quadratic Controllers - Characterization of H_2 optimal controllers	2
8.	H_2 optimalestimation-Kalman Bucy Filter	2
9.	LQG Controller	1
10.	Problem Formulation – Characterization of H_∞sub-optimal controllers by means of Riccatiequations	2
11.	H_∞control with full information	2
12.	Loop shifting and scaling	1
13.	Mixed Sensitivity Design	1
14.	Problem Formulation – Characterization of H_∞sub-optimal controllers by means of LMI Approach	2
15.	Properties of H_∞sub-optimal controllers	1
16.	H_∞synthesis with pole-placement constraints	2
17.	Synthesis of Robust Controllers	2
18.	Small Gain Theorem	2
19.	Structured uncertainties analysis	1
20.	Unstructured uncertainties analysis - Mu synthesis	2
21.	D-K –iteration	2
22.	Robust Control of Inverted Pendulum- Robust Control of CSTR	2
23.	Robust Control of Second-order Plant - Robust Control of Distillation Column	2
	Total	**36**

Course Designers

1. Dr.S.Baskar sbeee@tce.edu
2. Mr.S.Surendhar ssreee@tce.edu

		Category	L	T	P	Credit
18CIPL0	**STATE ESTIMATION**	PE	3	0	0	3

Preamble

State estimation includes computational algorithms that process measurements to deduce a minimum error estimate of the state of a system by utilizing knowledge of system and measurement dynamics, assumed statistics of system noises and measurement errors, and initial condition information. This course introduces various state estimation methods for linear and nonlinear systems.

Prerequisite

18CI110 Calculus of Variation & Applied Mathematics
18CI120 Systems Theory
18CI260 Digital Control System

Course Outcomes

On the successful completion of the course, students will be able to

CO	**Course Outcome**	**Blooms Level**
CO1	Explain about various estimation concepts	Understand
CO2	Use Kalman filter to estimate the states of a given linear system	Apply
CO3	Use Extended Kalman filter to estimate the states of a given linear system	Apply
CO4	Develop an unscented Kalman filter for a given nonlinear system	Apply
CO5	Develop particle Kalman filters for a given nonlinear system	Apply
CO6	Develop robust Kalman filters using H-infinity techniques for a given uncertain linear system	Apply

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**	**L**				**M**		**M**	
CO3	**S**	**M**	**L**	**L**				**M**		**M**	
CO4	**S**	**M**	**L**	**L**	**M**			**M**		**M**	
CO5	**S**	**M**	**L**	**L**	**M**			**M**		**M**	
CO6	**S**	**M**	**L**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	20	15	15	20
Understand	45	25	25	30
Apply	35	60*	60*	50
Analyze	0	0	0	0

Evaluate	0	0	0	0
Create	0	0	0	0

*Apply level of COs 4,5 and 6 may be evaluated through assignments by simulation in MATLAB

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State Bayes theorem
2. Explain the advantages of recursive estimation over batch estimation
3. With an example illustrate explain the working principle of least square estimator

Course Outcome 2(CO2):

1. Explain the properties of Kalman filter.
2. Consider the RLC circuit with R = 3, L = 1, and C = 0.5. The input voltage is zero-mean, unity variance white noise. Suppose that the capacitor voltage is measured at 10 Hz with zero-mean, unity variance white noise. Design a Kalman filter to estimate the inductor current, with an initial covariance $P_0^+ = 0$. Also calculate the steady state value of P
3. The measured output of a simple moving average process is $y_k = w_k + w_{k-1}$, where $\{w_k\}$ is zero mean white noise with variance 1
   c. Generate a state-space description for this system with the first element of state, x_k equal to w_{k-1} and second element equal to w_k.
   d. Suppose that the initial estimation-error covariance is equal to the identity matrix. Show that the a posteriori estimation-error covariance is given by $P_{k^+} = \frac{1}{k+1}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$.
   e. Find $E\left(\|x_k - \hat{x}_k\|_2^{\,2}\right)$ as a function of k.

Course Outcome 3 (CO3)

1. With suitable derivations illustrate the working principle of extended Kalman filter
2. Consider the system given below. $\{w_k\}$ & $\{v_k\}$ are zero mean process noise with variance Q and R respectively?

   $x_{k+1} = x_k + w_k$

   $y_k = x_k + v_k^{\,2}$

   c. What is the mean of the a posteriori estimation error of discrete EKF?
   d. Modify the measurement equation by subtracting the known bias of the measurement noise so that modified measurement noise is zero-mean. What is the variance of modified measurement noise?
3. Consider a nonlinear system $x_{k+1} = -x_k - x_k^{\,3} + w_k$ & $y_k = x_k^{\,2} + v_k$ where u is the input, w_k and v_k are zero mean white process and measurement noises with covariance 5 and 10 respectively. Design Extended Kalman filter to estimates the state x_k of the system.

Course Outcome 4 (CO4)

1. Explain the role of unscented transformation in approximation of nonlinear transformation
2. A random variable x is uniformly distributed over [-1,1] and $y = e^x$. Calculate the unscented approximation to $E(y)$ and variance of y
3. Compare simplex unscented transformation and spherical unscented transformation.

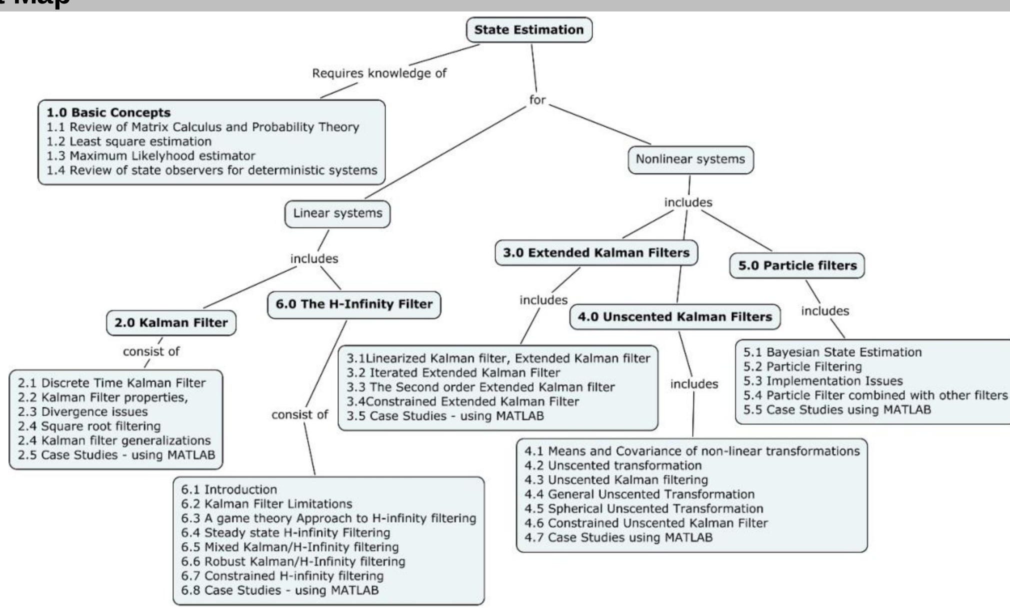
Course Outcome 5 (CO5)

1. Explain Bayesian estimation with suitable derivations
2. Explain the particle filter algorithm.
3. Consider the measurement $y_k = \frac{v_k}{x_k}$ where $v_k \sim N(9,1)$. Suppose five priori particles $x_{k,i}^-$ are given as 0.8, 0.9, 1.0, 1.1, 1.2 and the measurement obtained is $y_k = 10$. Calculate the relative likelihoods of each of the priori particles

Course Outcome 6 (CO6)

1. Explain the limitations of Kalman filter
2. Explain robust Kalman/H∞ filtering algorithm
3. Consider the system $x_k = \frac{1}{2}x_{k-1} + w_{k-1}$ and $y_k = x_k + v_k$. Calculate the steady state value of P_k for H∞ filter using variable θ and L=R=S=Q=1. Also calculate the bound on θ such that H∞ filter exists

Concept Map



Syllabus

Basic Concepts

Review of Matrix Calculus and Probability Theory, Review of state observers for deterministic systems, Least square estimation, Weighted Least square estimation, Maximum Likelihood estimation

Kalman Filter

Discrete time Kalman filter, Kalman Filter properties, Divergence issues, Square root filtering, Kalman filter generalizations – (correlated Process and measurement noise &colored process and measurement noise), Case Studies – using MATLAB

Extended Kalman Filter

Linearized Kalman filter, Extended Kalman filter, Iterated Extended Kalman Filter, The Second order Extended Kalman filter, Constrained Extended Kalman Filter, Case Studies – using MATLAB

Unscented Kalman Filter

Means and Covariance of non-linear transformations, unscented transformation, Unscented Kalman filtering, General Unscented transformation, Simplex Unscented transformation, Spherical Unscented transformation, Constrained Unscented Kalman filter, Case Studies - using MATLAB

Particle Filter

Bayesian state Estimation, Particle filtering, Implementation issues: Sample Impoverishment, Particle filter combined with other filters, Case Studies – using MATLAB

The H-Infinity Filter

Introduction, Kalman filter Limitations, A game theory Approach to H-infinity filtering, Steady state H-infinity Filtering, Mixed Kalman /H-Infinity filtering, Robust Kalman/H-infinity filtering, Constrained H-infinity filtering, Case Studies – using MATLAB

Reference Books

1. Dan Simon, “Optimal State Estimation Kalman, H-infinity and Non-linear Approaches”, John Wiley and Sons, 2006
2. Branko Ristic, Sanjeev Arulampalam, Neil Goodon, “Beyond the Kalman Filter: Particle filters for Tracking Application”, Artech House Publishers, Boston, London, 2004
3. Gelb, Arthur, ed., “Applied optimal estimation”, MIT press, Cambridge 2001

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Basic Concepts**	
1.1	Review of Matrix Calculus and Probability Theory	1
1.2	Least square estimation	1

1.3	Maximum Likelihood estimation	1
1.4	Review of state observers for deterministic systems	1
2.0	**Kalman Filter**	
2.1	Discrete time Kalman filter	2
2.2	Kalman Filter properties, Divergence issues,	2
2.3	Square root filtering	1
2.4	Kalman filter generalizations – (correlated Process and measurement noise &colored process and measurement noise)	1
2.5	Case Studies – using MATLAB	1
3.0	**Extended Kalman Filter**	
3.1	Linearized Kalman filter, Extended Kalman filter	1
3.2	Iterated Extended Kalman Filter	1
3.3	The Second order Extended Kalman filter	1
3.4	Constrained Extended Kalman Filter	1
3.5	Case Studies	1
4.0	**Unscented Kalman filter**	
4.1	Means and Covariance of non-linear transformations	1
4.2	Unscented transformation	1
4.3	Unscented Kalman filtering	1
4.4	General Unscented Transformation	1
4.5	Spherical Unscented Transformation	1
4.6	Constrained Unscented Kalman Filter	1
4.7	Case Studies – using MATLAB	1
5.0	**Particle Filter**	
5.1	Bayesian State Estimation	1
5.2	Particle Filtering	1
5.3	Implementation Issues	1
5.4	Particle Filter combined with other filters	1
5.5	Case Studies – using MATLAB	1
6.0	**The H-Infinity Filter**	
6.1	Introduction	1
6.2	Kalman Filter Limitations	1
6.3	A game theory Approach to H-infinity filtering	1
6.4	Steady state H-infinity Filtering	1
6.5	Mixed Kalman/H-Infinity filtering	1
6.6	Robust Kalman/H-Infinity filtering	1
6.7	Constrained H-infinity filtering	1
6.8	Case Studies – using MATLAB	1
Total		**36**

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mrs.R.Suganya rsaeee@tce.edu

18CIPM0	**BIOMEDICAL INSTRUMENTATION**	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Biomedical instrumentation is the application of engineering principles and design concepts to medicine and biology. This field seeks to close the gap between engineering and medicine. It combines the design and problem solving skills of engineering with medical and biological sciences to improve healthcare diagnosis, monitoring and therapy. This subject will enable the students to learn the basic principles of different instruments/equipment used in the health care industry.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO No.	COs	Bloom's Category
CO1	Describe the standards, safety and regulations of Bio medical Instruments	Understand
CO2	Design the diagnostic devices to measure the Bio electric signals like ECG, EEG, EMG.	Apply
CO3	Explain the Biomedical instrumentation system to measure Blood Flow, Blood Pressure, Heart sound, Respiratory system and Blood cell counters for specific given conditions.	Understand
CO4	Design the treatment devices like pacemakers, defibrillators, audiometer for the given specific situation.	Apply
CO5	Describe the principle and construction of medical imaging systems like MRI, CT for diagnosing applications.	Understand
CO6	Analyze real world electrophysiological signal using MATLAB.	Analyze

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	**M**	**L**						**M**		**M**		
CO2	**S**	**M**	**L**					**M**		**M**		
CO3	**M**	**L**						**M**		**M**		
CO4	**S**	**M**	**L**					**M**		**M**		
CO5	**M**	**L**						**M**		**M**		
CO6	**S**	**S**	**M**	**L**	**S**			**M**		**M**		

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	50	50	50	50
Apply	30	30	30	30
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Assignment 10 mark based on CO6 - Analyze real world electrophysiological signal using MATLAB.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define macro and micro shock.
2. Write the importance of Testing, maintaining and inspecting medical equipment.
3. Explain the impact of leakage Current in cardiac patient.

Course Outcome 2(CO2):

1. List the types of brain waves and specify its magnitude and frequency.
2. Illustrate the standard 10-20 electrode system for recording the spontaneous EEG with neat diagram.
3. Design a system to Record the Cardiac Signal.

Course Outcome 3 (CO3):

1. Explain electromagnetic blood flow meter.
2. Explain with diagram the salient features of Phonocardiography
3. Describe a method for the measurement of total lung capacity.

Course Outcome 4 (CO4):

1. Design an external pacemaker.
2. With necessary sketches explain different types of Ventilators
3. Explain the operation of the Heart Lung Machine. Give its applications..

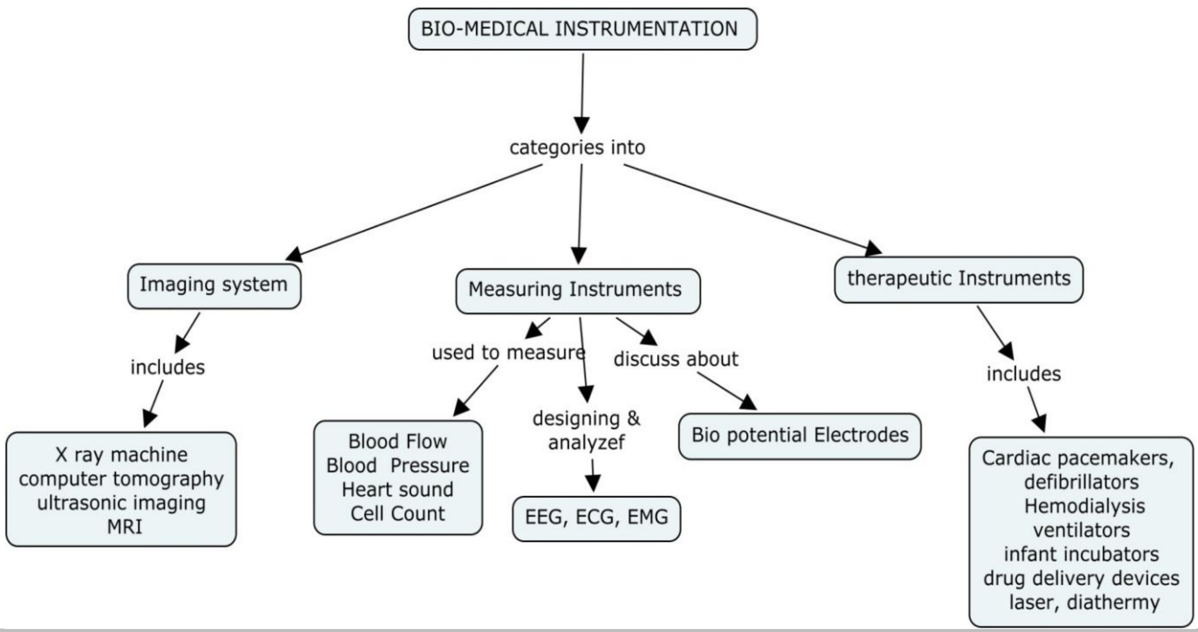
Course Outcome 5 (CO5):

1. Classify the X-rays and with neat diagram explain the function X-Ray machine.
2. Explain the principle of Magnetic Resonance imaging systems.
3. Describe the various scanning methods in ultrasonic imaging system.

Course Outcome 6 (CO6):

1. Analyze the Sleep pattern of EEG signal.
2. Using Wavelet Transform analyze the abnormalities of ECG signal.
3. Analyzes and compares distortions caused by different digital filtering techniques for noise suppression applied over the ECG signal

Concept Map



Syllabus

BASIC CONCEPTS OF BIO MEDICAL INSTRUMENTATION: Terminology – Generalized medical instrumentation system – Measurement Standards -Regulation of medical devices – Electrical safety in medical environment.

BIO POTENTIALS AND MEASUREMENTS: Electric activity and excitable cells – Functional organization of peripheral nervous system. EMG, ECG, EEG – Bio-potential electrodes-Electrodes for electric simulation of tissues – Practical hints for using electrodes.- Computer analysis of real world ECG & EEG signals using matlab.

BLOOD FLOW- Electromagnetic blood flow meter, ultrasonic blood flow meter, Doppler blood flow meter cardiac output measurement. **BLOOD PRESSURE AND HEART SOUND MEASUREMENT**: Indirect and direct Measurement of blood pressure Phonocardiograph. **BLOOD CELL COUNTERS**: Different methods for cell counting, Coulter Counters, automatic recognition and differential counting of cells. **RESPIRATORY MEASUREMENT**: Lung Volume measurement, Plethysmography

THERAPEUTIC DEVICES: Designing ofCardiac pacemakers, defibrillators, audiometer-Heart Lung Machine, Haemodialysis, ventilators, infant incubators, drug delivery devices, therapeutic applications of the laser, diathermy

MEDICAL IMAGING SYSTEMS: X ray machine, computer tomography, ultrasonic imaging system, magnetic resonance imaging system, thermal imaging system, positron emission tomography , medical image processing.

Reference Books

1. R. S. Khandpur "Handbook of Bio-Medical Instrumentation",McGraw Hill Education; Third edition (4 August 2014)
2. J.Webster, "Medical Instrumentation application and design", third edition Wiley & Sons 2001.

3. Carr & Brown, “Introduction to Biomedical Equipment Technology” Pearson Education, Asia; 4th Edition, 2001
4. Leslie Cromwell, “ Biomedical Instrumentation and Measurements” , Pearson Education India; 2 edition (2015)

Course Contents and Lecture Schedule

S. No.	Topics	No of lectures
1	**BASIC CONCEPTS OF BIO MEDICAL INSTRUMENTATION**	
1.1	Terminology – Generalized medical instrumentation system	1
1.2	Measurement Standards	1
1.3	Regulation of medical devices	1
1.4	Electrical safety in medical environment	1
2	**BIO POTENTIALS AND MEASUREMENTS :**	
2.2	Electric activity and excitable cells	1
2.3	Functional organization of peripheral nervous system.	1
2.4	EMG, ECG	2
2.5	EEG	1
2.6	Bio-potential electrodes ,Electrodes for electric simulation of tissues	2
2.7	Practical hints for using electrodes	1
2.8	Computer analysis of real world ECG & EEG signals using Matlab	2
3	**BLOOD FLOW**	
3.1	Electromagnetic blood flow meter	1
3.2	ultrasonic blood flow meter	1
3.3	Doppler blood flow meter cardiac output measurement	1
3.4	**BLOOD PRESSURE AND HEART SOUND MEASUREMENT**:	
3.4.1	Indirect Measurement of blood pressure Phonocardiograph	1
3.4.2	direct Measurement of blood pressure Phonocardiograph	1
3.5	**BLOOD CELL COUNTERS**: Different methods for cell counting, Coulter Counters	1
3.5.1	Automatic recognition and differential counting of cells.	1
3.6	**RESPIRATORY MEASUREMENT**: Lung Volume measurement,	1
3.6.1	Plethysmography	1
4	**THERAPEUTIC DEVICES**	
4.1	Designing of Cardiac pacemakers, defibrillators, Audiometer	2
4.2	Heart Lung Machine , Haemodialysis, ventilators	2
4.3	Infant incubators, drug delivery devices,	1
4.4	Therapeutic applications of the laser, Diathermy	2
5	**MEDICAL IMAGING SYSTEMS**	
5.1	X ray machine, computer tomography,	2
5.2	Ultrasonic imaging system, Magnetic Resonance Imaging system,	2
5.3	Thermal imaging system, positron emission tomography	1
5.4	Medical image processing	1
	Total	36

Course Designers:

1. Dr.R.Helen rheee@tce.edu
2. Dr. B.Ashok Kumar ashokudt@tce.edu

18CIPP0 MEMS

Category	L	T	P	Credit(s)
PE	3	0	0	3

Preamble

Micro Electro Mechanical System (MEMS) contains components of sizes less than 1 millimeter. MEMS achieve some engineering functions by electro mechanical or electro chemical means. In general a sensor, an actuator and a signal transduction unit forms the MEMS device. Automobile, Aerospace, Health care are some of the areas where MEMS found applications. Natural science, Mechanical, Electrical, Chemical, Materials and Industrial Engineering are the disciplines involved in design, Manufacture and Packaging of MEMS devices.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the characteristics and application of MEMS and Microsystems	Understand
CO2	Apply scaling laws for miniaturization of MEMS devices .	Apply
CO3	Explain the working principle of Electrostatic, Thermal, Piezo sensors	Understand
CO4	Describe the working principle of Electrostatic, Thermal, Piezo and Magnetic actuators	Understand
CO5	Select appropriate micromachining process for fabricating MEMS devices	Apply
CO6	Model MEMs device such as cantilever beam, Micro pressure sensor, and accelerometer	Apply

Mapping with Program Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L	L	**-**	-	-	-	**M**	-	**M**	-
CO2	S	M	L	M	-	-	-	**M**	-	**M**	-
CO3	M	L	L	**-**	-	-	-	**M**	-	**M**	-
CO4	M	L	L	**-**	-	-	-	**M**	-	**M**	-
CO5	S	M	L	M	-	-	-	**M**	-	**M**	-
CO6	S	M	L	M	M			**M**		**M**	

S - Strong M – Medium L – Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests	Terminal Examination

	1	**2**	**3**	
Remember	20	20	20	20
Understand	60	60	60	60
Apply	20	20	20	20
Analyze	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Define the term MEMS.
2. Define shape memory alloys.
3. Write note on the Characteristics of MEMS.
4. Explain in detail the application of MEMS in aerospace industry.
5. With neat diagram explain the functioning of micro pressure sensor.

Course Outcome 2 (CO2):
1. Explain in detail, the Trimmer matrix to represent force scaling with related acceleration, time and power density required for scaling of systems in motion.
2. Give a report on scaling in heat conduction and heat convection.
3. Estimate the associated changes in the acceleration, time and power supply to actuate a MEMS component if its weight is reduced by a factor 20.
4. Estimate the variation of the total heat flow and the time required to transmit heat in a solid with a reduction of size by factor of 10. What will happen if the solid is of sub micro meter level?

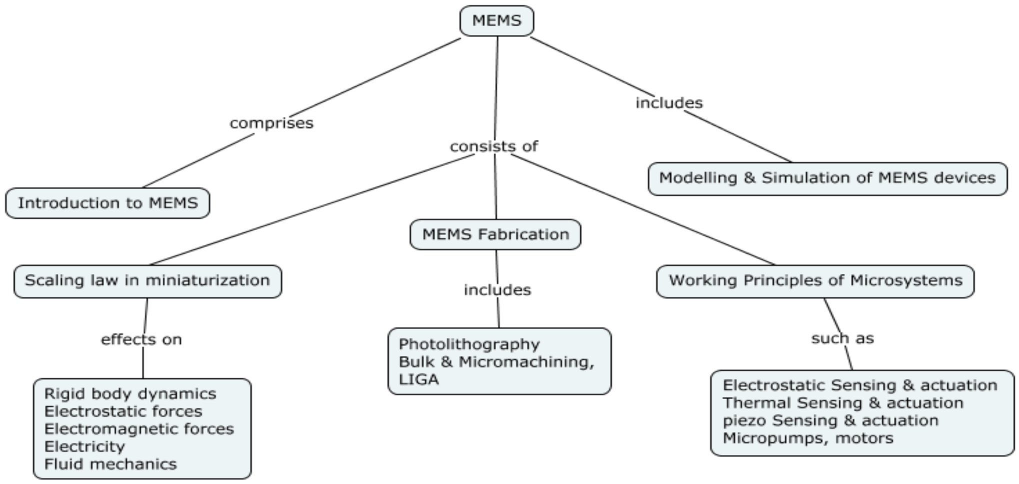
Course Outcome 4 (CO4):
1. Discuss how the Comb-drive accelerometer works.
2. Describe the working principle of resitive pressure sensor.
3. Explain Thermal Bimorph.
4. Illustrate the working principle of piezo electric force sensor.

Course Outcome 4 (CO4):
1. Discuss how the piezoelectric actuator works.
2. Illustrate the working principle of micro motor.
3. Explain about microgripper.
4. Describe about the working of Magnetic actuators.

Course Outcome 5 (CO5):
1. Explain the general procedure of photolithography. Use neat diagrams.
2. Explain the LIGA process for MEMS fabrication.
3. Discuss about bulk-micromachining process.
4. Illustrate the fabrication process for Micro channel heat sink

Course Outcome 6 (CO6):
1. Explain the modelling of Micro pressure sensor
2. Design cantilever beam using MEMs device
3. Discuss about MEMs based accelerometer.

Concept Map



Syllabus

Introduction to MEMS: Micro-Electro-Mechanical Systems (MEMS) and Microsystems, Intrinsic Characteristics of MEMS, Applications: Healthcare, Aerospace, Industrial & Consumer Products, Market for MEMS, Micro mechatronics, Overview of Micro fabrication, MEMS materials: Silicon, Silicon Dioxide, Silicon Nitride, Polysilicon, Silicon Carbide, Polymers, shape memory alloys - Clean rooms- Introduction to MOEMS & NEMS.
Scaling law in miniaturization: Introduction to scaling, scaling in rigid body dynamics, electrostatic forces, electromagnetic forces, electricity, fluid mechanics, heat transfer
Working Principles of Microsystems: Electrostatic Sensing & actuation – Resistive/Capacitive Pressure sensor, Comb-drive accelerometer, Comb-drive actuator. Thermal Sensing & actuation- Thermal Bimorph, Thermal actuator. Piezo Sensing & actuation- Force sensor, acoustic sensor, cantilever piezo electric actuator. Magnetic actuators- micro gripper- micro motor- micro valves- micro pumps
MEMS Fabrication: Photolithography, bulk micromachining, surface micromachining, LIGA process **Modelling of MEMS Devices:** cantilever beam, Micro pressure sensor, and accelerometer

Reference Book(s)

1. Chang Liu , “Foundation of MEMS”, 2nd Edition, Pearson education, 2012.
2. Tai –Ran Hsu, “MEMS and Microsystem: Design and Manufacture”, Tata McGraw Hill, First Edition, 2002.
3. Thomas M. Adams, Richard A. Layton “Introductory MEMS: Fabrication and Applications”, Springer, 2010
4. G.K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K.N. Bhat and V.K. Athrae “Micro and Smart System”, Wiley India Pvt Ltd, First edition, 2010
5. Gad El Hak (Editor), “The MEMS Hand Book”, Three volume set, 2nd revised Edition, CRC press, 2005
6. Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim “Microsensors, MEMS, and smart devices”, 1st edition, John Wiley & Sons, Ltd, 2001

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to MEMS**	
1.1	Micro-Electro-Mechanical Systems (MEMS) and Microsystems	2
1.2	Intrinsic Characteristics of MEMS, Applications: Healthcare, Aerospace, Industrial & Consumer Products	2
1.3	Market for MEMS,	1
1.4	Micro mechatronics	2
1.5	Overview of Micro fabrication	2
1.6	MEMS materials: Silicon, Silicon Dioxide, Silicon Nitride, Polysilicon, Silicon Carbide, Polymers, shape memory alloys- Clean rooms	2
1.7	Introduction to MOEMS & NEMS.	1
2	**Scaling law in miniaturization**	
2.1	Introduction to scaling,	1
2.2	scaling in rigid body dynamics,	1
2.3	electrostatic forces,	1
2.4	Electromagnetic forces, electricity	1
2.5	fluid mechanics and	2
2.6	heat transfer	2
3	**Working Principles of Microsystems**	
3.1	**Electrostatic Sensing & actuation** – Resistive/Capacitive Pressure sensor, Comb drive accelerometer, Comb drive actuator.	2
3.2	**Thermal Sensing & actuation**- Thermal Bimorph, Thermal actuator.	2
3.3	**piezoSensing & actuation**- Force sensor, acoustic sensor, cantilever piezo electric actuator.	2
3.4	Magnetic actuators	2
3.5	Microgripper	2
3.6	micro motors- micro valves- micro pumps	2
4	**MEMS Fabrication**	
4.1	Photolithography**,** bulk micromachining, surface micromachining, LIGA process	2
4.2	**Modelling & simulation of MEMS Devices:** Cantilever beam	2
4.3	Micro pressure sensor	1
4.4	Accelerometer	1
	Total	38

Course Designers:

1 Mr.M.Ramkumar mjayaramkumar@tce.edu
2 Dr.D.Kavitha dkavitha@tce.edu

		Category	L	T	P	Credit
18CIPQ0	**MULTI SENSOR DATA FUSION**	PE	3	0	0	3

Preamble

Multi Sensor data fusion is a subset of information fusion and is generally defined as the use of techniques that combine data from multiple sources and gather that information into discrete, actionable items in order to achieve inferences, which will be more efficient and narrowly tailored than if they were achieved by means of disparate sources. In this course reference has been made about the algorithms for data fusion and estimation and advanced filtering of signals from sensors. It also includes designing of optimal sensor systems. The proposed course is offered as an elective. The subject requires the fundamental knowledge of sensors, control theory, digital signal processing and mathematical knowledge of probability theory, statistical estimation and linear algebra.

Prerequisite

18CI110 Calculus of Variation & Applied Mathematics
18CI120 Systems Theory

Course Outcomes

On the successful completion of the course, students will be able to

CO	Course Outcome	Blooms Level
CO1	Explain the taxonomy of multi sensor data fusion	Understand
CO2	Explain the role of various levels in JDL model of multi sensor data fusion	Understand
CO3	Design estimators for kinematic level data fusion	Apply
CO4	Design decentralized estimators for kinematic data fusion	Apply
CO5	Explain about pre-processing used for data fusion	Understand
CO6	Implement multi sensor data fusion using software and hardware tools	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L						M		M	
CO2	M	L						M		M	
CO3	S	M	L	L				M		M	
CO4	S	M	L	L				M		M	
CO5	M	L						M		M	
CO6	S	M	L	L	S			M		M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	40	20	20	20
Understand	60	40	40	40
Apply	0	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

CO6 WILL BE EVALUATED THROUGH ASSIGNMENTS

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the JDL model of data fusion.
2. Explain how the data fusion can be used to reduce the uncertainty of measurement.

Course Outcome 2 (CO2):

1. Explain the salient features of level 2 fusion algorithms.
2. Explain the role of Bayesian inference in decision level identity fusion.

Course Outcome 3 (CO3):

1. Consider the 1 dimensional movement of an object. State model is given by
   $$x_{k+1} = x_k + 0.1v_k + w_{1k}$$
   $$v_{k+1} = v_k + w_{2k}$$. Assume the process and measurement noise are zero mean with
   $$y_k = x_k + n_k$$
   unit covariance of suitable dimensions. Calculate the steady state value of estimation error covariance matrix

2. An organization is developing a gas analyzer which measures the pressure and temperature of an effluent and gives the CO_2 content in parts per million (PPM). Experiment was carried out in three different laboratories and measurements were recorded as below. Objective is to fit a relation between PPM output (y) with pressure (P) and Temperature (T) as Y=aP+bT

	Pressure (P) in bar	Temperature (T) in Kelvin	CO2 Content Y in (PPM)	Variance in measurement of Y
Lab1	1	400	905	25
Lab2	1.2	398	920	9
Lab3	1.4	412	960	16

a) Calculate the least square estimate of the parameters a and b
b) Calculate the weighted least square estimate of parameters a and b

c) Choose the best model among the both using the covariance of the estimates

Course Outcome 4 (CO4):

1. With suitable derivations explain the operation of decentralized Kalman filter
2. Consider a first order system. It's state is estimated with two Kalman filters. The estimates of both the Kalman filters are 1, and 1.6 respectively. The estimation error variance of both the estimators are 4 and 3.2 respectively. Calculate the combined estimate of both the Kalman filters. Assume process noise variance is zero and measurement noise variance as 2 and 2.5 respectively.

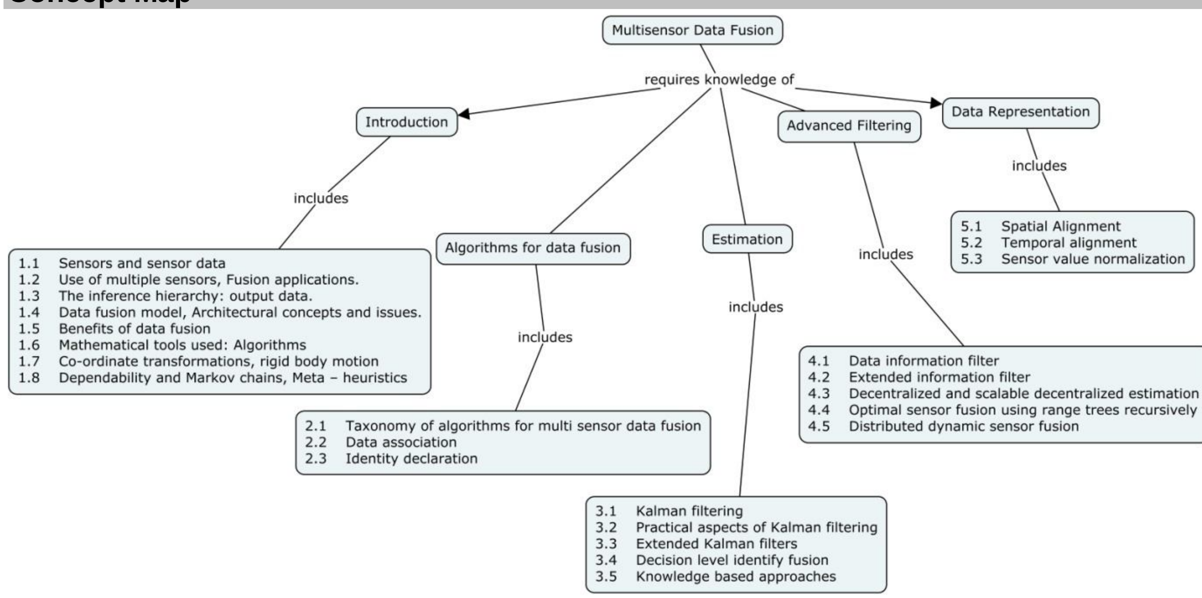
Course Outcome 5 (CO5):

1. Define spatial covariance
2. Explain the role of Principal component analysis for data fusion in common representation format

Course Outcome 6 (CO6):

1. Computer simulation of target tracking using multiple radars
2. Fusion of temperature measured from thermocouple and RTD using Arduino
3. Fusion of level from Differential pressure transmitter and Capacitance based level transmitter using LabVIEW/Arduino

Concept Map



Syllabus

INTRODUCTION: Sensors and sensor data, Use of multiple sensors, Fusion applications. The inference hierarchy: output data. Data fusion model. Architectural concepts and issues. Benefits of data fusion, Mathematical tools used: Algorithms, co-ordinate transformations, rigid body motion. Dependability and Markov chains, Meta – heuristics.

ALGORITHMS FOR DATA FUSION: Taxonomy of algorithms for multisensor data fusion. Data association. Identity declaration.

ESTIMATION:

Kalman filtering, practical aspects of Kalman filtering, extended Kalman filters. Decision level identify fusion. Knowledge based approaches.

ADVANCED FILTERING: Data information filter, extended information filter. Decentralized and scalable decentralized estimation. Sensor fusion and approximate agreement. Optimal sensor fusion using range trees recursively. Distributed dynamic sensor fusion.

DATA REPRESENTATION:
Spatial Alignment, Temporal alignment, Sensor value normalization

IMPLEMENTATION,
Target tracking, Fusion of temperature measured from thermocouple and RTD, Fusion of level from Differential pressure transmitter and Capacitance based level transmitter

Reference Books

1. David L. Hall, Mathematical techniques in Multisensor Data Fusion, Artech House, Boston, 1992.
2. David L.Hall and James Llinas, “Handbook of Multi Sensor Data Fusion”, CRC press, 2011
3. Aurthur G.O.Mutambara, “Decentralized Estimation and Control of Multi sensor Systems”, CRC Press, 1998
4. H.B.Mitchell,” Multi-Sensor Data Fusion an Introduction”, Springer-Verlag Berlin Heidelberg, 2007
5. Arthur Gelb, Applied Optimal Estimation, The M.I.T. Press, 1982.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**INTRODUCTION**	
1.1	Sensors and sensor data	1
1.2	Use of multiple sensors, Fusion applications.	1
1.3	The inference hierarchy: output data.	1
1.4	Data fusion model, Architectural concepts and issues.	1
1.5	Benefits of data fusion	1
1.6	Mathematical tools used: Algorithms	1
1.7	Co-ordinate transformations, rigid body motion	1
1.8	Dependability and Markov chains, Meta – heuristics	1
2	**ALGORITHMS FOR DATA FUSION**	
2.1	Taxonomy of algorithms for multi sensor data fusion	4
2.2	Data association	2
2.3	Identity declaration	2
3	**ESTIMATION**	
3.1	Kalman filtering	2
3.2	Practical aspects of Kalman filtering	1
3.3	Extended Kalman filters	1
3.4	Decision level identify fusion	1
3.5	Knowledge based approaches	3
4	**ADVANCED FILTERING**	
4.1	Data information filter	1

4.2	Extended information filter	1
4.3	Decentralized and scalable decentralized estimation	2
4.4	Optimal sensor fusion using range trees recursively	2
4.5	Distributed dynamic sensor fusion	1
5	**DATA REPRESENTATION:**	
5.1	Spatial Alignment	1
5.2	Temporal alignment	2
5.3	Sensor value normalization	2
Total		**36**

Course Designers:

1. Dr.V.Prakash vpeee@tce.edu
2. Mr.M.Varatharajan varatharajan@tce.edu

18CIPR0	**ADVANCED DIGITAL SIGNAL PROCESSING**	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Digital processing of a signal has major advantage over analog techniques. With digital filters, linear phase characteristics can be achieved; filters can be made to work over a wide range of frequencies. Storage of digital data is very easy. Digital processing is more suited for low frequency signals like seismic signals, bio-signals.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Design IIR and FIR filters for given specifications.	Apply
CO2	Analyze the performance of sampling methods of continuous time signals	Analyze
CO3	Apply digital signal banks and wavelet transforms to process the given DT signals.	Apply
CO4	Design Linear Prediction And Optimum Linear Filters for given specifications.	Apply
CO5	Estimate the power spectral characteristics of the Random Signals	Understand
CO6	Explain the adaptive signal processing techniques for specific applications.	Understand

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**S**	**M**	**L**					**M**		**M**	
CO2	**S**	**S**	**M**	L				**M**		**M**	
CO3	**S**	**M**	**L**					**M**		**M**	
CO4	**S**	**M**	**L**					**M**		**M**	
CO5	**M**	**L**						**M**		**M**	
CO6	**M**	**L**						**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	**Continuous Assessment Tests**			**Terminal Examination**
	1	**2**	**3**	
Remember	20	20	20	20
Understand	30	40	30	30

Apply	40	40	40	40
Analyze	10	0	10	10
Evaluate	0	0	0	0
Create	0	0	0	0

Assignments are based on MATLAB simulation

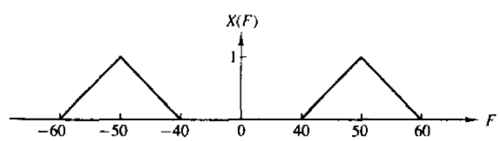
Course Level Assessment Questions

Course Outcome 1 (CO1):

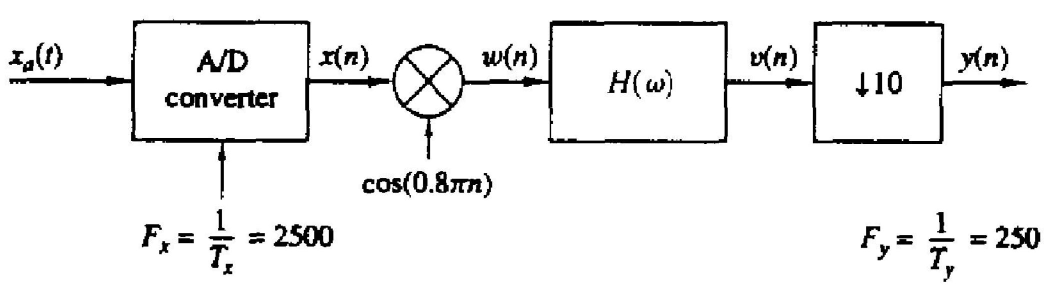
1. Using a rectangular window technique design a LPF with pass band gain of unity, cutoff frequency of 1000Hz and working sampling frequency of 5kHz. The length of impulse be 7.
2. Design and also realize a high pass FIR filter with a cutoff frequency of 1.3 rad/sec and N=9.
3. Design an analog BPF to satisfy the following specifications:
   i) 3dB upper and lower cut-off frequencies are 100 Hz and 3.8kHz
   ii) Stop attenuation of 20dB at 20Hz and 8Hz
   iii) No ripple with pass band and stop band

Course Outcome 2(CO2):

1. Consider the sampling of band pass signal whose spectrum is given in the figure. Determine minimum sampling rate to avoid aliasing.



2. Explain the effects due to upsampling.
3. An analog signal Xa(t)is band limited to the range 900≤F≤1100Hz. It is used as an input to the system shown in the figure. In this system H(w) is an ideal LPF with cutoff frequency Fc= 125Hz.



a) Determine and sketch the spectra for the signals x(n),w(n),v(n)and y(n).
b) Show that it is possible to obtain y(n) by sampling Xa(t) with period T= 4msecs.

Course Outcome 3 (CO3):

1. Define and give the properties of DWT.

2. Explain impulse and magnitude responses of the four level trees of Haar Wavelets.
3. Discuss how the data compression can be obtained as an application of Wavelet transform.

Course Outcome 4 (CO4):

1. Consider the ARMA process generated by the difference equation,

$$x(n) = 1.6x(n-1) - 0.63x(n-2) + w(n) + 0.9w(n-1)$$

   a) Determine the system function of the whitening filter and its poles and zeros.
   b) Determine the power density spectrum of [x(n)].
2. Explain the properties of linear prediction error filters.
3. Let us consider a signal $x(n) = s(n)+w(n)$. where $s(n)$ is an AR(1) process that satisfies the difference equation $s(n) = 0.6s(n-1) + v(n)$
   where [v(n)] is a white noise sequence with variance $\sigma^2 = 0.64$. and [w(n)] is a white noise sequence with variance $\sigma^2 = 1$. We will design a Wiener filter of length M = 2 to estimate [s(n)].

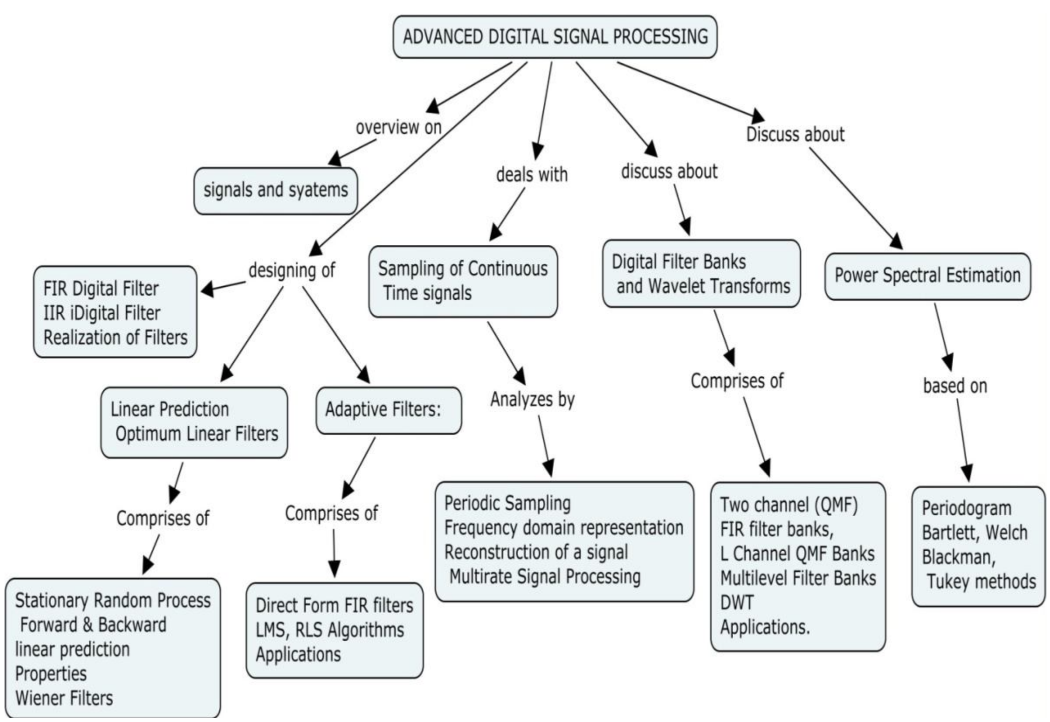
Course Outcome 5 (CO5):

1. Suppose that we are given the autocorrelation values $\gamma_{yy}(0) = 3$, $\gamma_{yy}(1) = 1$, and $\gamma_{yy}(2) = 0$ for a process consisting of a single sinusoid in additive white noise. Determine the frequency, its power, and the variance of the additive noise.
2. Explain in detail of ARMA model for power spectrum estimation.
3. Discuss the performance characteristics of nonparametric power spectrum estimators.

Course Outcome 6 (CO6):

1. Explain the Applications of Adaptive Filters.
2. Write the Properties of LMS Algorithm.
3. With example explain RLS Algorithms.

Concept Map



Syllabus

Introduction: Signals and systems

Digital Filter Design: Design of FIR filter using windowing techniques – Design of IIR filter from analog filters using bilinear and impulse invariance transformation. Realization of Digital Filters

Sampling of Continuous Time signals: Periodic Sampling- Frequency domain representation-reconstruction of a Band limited Signal –Changing the sampling Rate- Multirate Signal Processing- Digital Processing of Analog Signals- Oversampling and Noise shaping in A/D and D/A conversion-Random Sampling Theory

Digital Filter Banks and Wavelet Transforms: Two channel Quadrature Mirror Filter (QMF) Reconstruction of FIR filter banks, L Channel QMF Banks, Multilevel Filter Banks Discrete Wavelet Transform -Wavelets, orthogonal Wavelets and bi orthogonal Wavelets, Applications.

Linear Prediction And Optimum Linear Filters: Innovations Representation of a Stationary Random Process, Forward and Backward linear prediction, Solution of the Normal Equations, Properties of linear prediction-Error Filter, AR Lattice and ARMA Lattice-Ladder Filters Wiener Filters

Power Spectral Estimation: Estimation of Spectra from Finite Duration Observations of a signal, the Periodogram, Use DFT in power Spectral Estimation, Bartlett, Welch and Blackman, Tukey methods, Comparison of performance of Non-Parametric Power Spectrum Estimation Methods

Adaptive Filters: Applications of Adaptive Filters-Adaptive Direct Form FIR filters- LMS, RLS Algorithms

Reference Books

1. John G.Proakis & Dimitris G.Manolakis, - Digital Signal Processing Principles, Algorithm and Applications – Pearson Education, New Delhi, 4th Edition, 2003.
2. A.V. Oppenheim and R.W.Schafer - Digital Signal Processing, Prentice Hall of India, 2001.
3. Sanjit K.Mithra – Digital Signal Processing-A computer based approach, Tata McGraw-Hill, New Delhi, 2004.
4. Monson H. Hayes, “Statistical Digital Signal Processing and Modeling”, John Wiley and Sons Inc., New York, 2008.

Course Contents and Lecture Schedule

Module No.	Topic	No of lecture Hours
1	**Introduction**	
1.1	**Signals and systems**	1
2	**Design of digital Filters**	
2.1	Design of FIR filter using windowing techniques	2
2.2	Design of IIR filter from analog filters using bilinear and impulse invariance transformation	2
2.3	Realization of FIR and IIR filters	1
3	**Sampling of Continuous Time signals:**	
3.1	Periodic Sampling	1

3.2	Frequency domain representation	1
3.3	reconstruction of a Band limited Signal	1
3.4	Changing the sampling Rate	1
3.5	Multirate Signal Processing	1
3.7	Digital Processing of Analog Signals &Oversampling and Noise shaping in A/D and D/A conversion	1
3.8	Random Sampling Theory	1
4	**Digital Filter Banks and Wavelet Transforms:**	
4.1	Digital Filter Banks	1
4.2	Two channel Quadrature Mirror Filter (QMF)	1
4.3	Reconstruction of FIR filter bank	1
4.4	Discrete Wavelet Transform	1
4.4.1	Orthogonal & Biorthogonal Wavelets	1
4.5	Applications	1
5	**Linear Prediction And Optimum Linear Filters**	
5.1	Innovations Representation of a Stationary Random Process	1
5.2	Forward and Backward linear prediction	1
5.3	Solution of the Normal Equations	1
5.4	Properties of linear prediction-Error Filter	1
5.5	AR Lattice and ARMA Lattice-Ladder Filters	1
5.6	Wiener Filters	1
6	**Power Spectral Estimation:**	
6.1	Estimation of Spectra from Finite Duration Observations of a signal	1
6.2	Solution of the Normal Equations, the Periodogram	1
6.3	Use DFT in power Spectral Estimation, Bartlett, Welch and Blackman, Tukey methods	2
6.4	Comparison of performance of Non-Parametric Power Spectrum Estimation Methods	2
7	**Adaptive Filters:**	
7.1	Applications of Adaptive Filters	1
7.2	Adaptive Direct Form FIR filters	2
7.3	LMS, RLS Algorithms	2
	Total	36

Course Designers:

1. Dr.R.Helen rheee@tce.edu
2. Dr.V.Seetharaman vseetharaman@tce.edu

18PSPL0/18CIPS0	POWER PLANT INSTRUMENTATION AND CONTROL	CATEGORY	L	T	P	CREDIT
		PE	3	0	0	3

Preamble

This course aims to give the fundamental concepts and practical aspects of power plant instrumentation and control. A power station is a complex entity. It involves a wide range of engineering disciplines. The basic principles of steam and water cycles, fuel, air and flue gas circuits are discussed. Also the steam generator, boiler drum and circulation, water treatment and various types of controls in a steam power plant has been discussed. It includes compression and draught control, feed water control, steam temperature control and control equipment have been discussed. The updated information on combined cycle generation is also provided.

Prerequisite

- NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Explain the basic principles of power system instrumentation and control	Understand
CO2.	Describe the boiler operation and its control in a thermal power plant.	Understand
CO3.	Determine the performance of various power plant instrumentation and control systems.	Apply
CO4.	Select from currently commercially available power plant instrumentation and control systems for a given application.	Apply
CO5.	Explain the control equipment Practices in power plant.	Understand
CO6.	Suggest suitable instrumentation system for Turbine- Monitoring and control in a power plant.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	L						M		M	
CO2.	M	L						M		M	
CO3.	S	M	L	L				M		M	
CO4.	S	M	L	L				M		M	
CO5.	M	L						M		M	
CO6.	S	M	L	L				M		M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	50	50	50	50
Apply	30	30	30	30
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Name the different methods of conventional power generation.
2. Explain the role of instrumentation and control in power plants.
3. Explain the basic principles of power system control.
4. Draw and explain the Piping and Instrumentation (P & I) diagram for steam flow control in a boiler.

Course Outcome 2 (CO2):

1. Explain the nature of steam and the uses of steam.
2. Define the term thermal efficiency.
3. Explain the operation of Gas turbine and combined cycle plants.
4. List the different modules of boiler control mechanism.

Course Outcome 3 (CO3):

1. Describe how the demand setting in power station is done.
1. Discuss briefly about waste to energy plants.
2. Explain how temperature is controlled with tilting burners.
3. List any two types of attemperator.
4. Compare the operation of two element and three element control used for feed water pumping.

Course Outcome 4 (CO4):

1. Organize the steps involved in compression control.
2. Compare and contrast between an oxygen analyzer and a flue gas analyzer.
3. Name three different drafts used in connection with boilers.
4. State any two advantages of electrical actuators.

Course Outcome 5 (CO5):

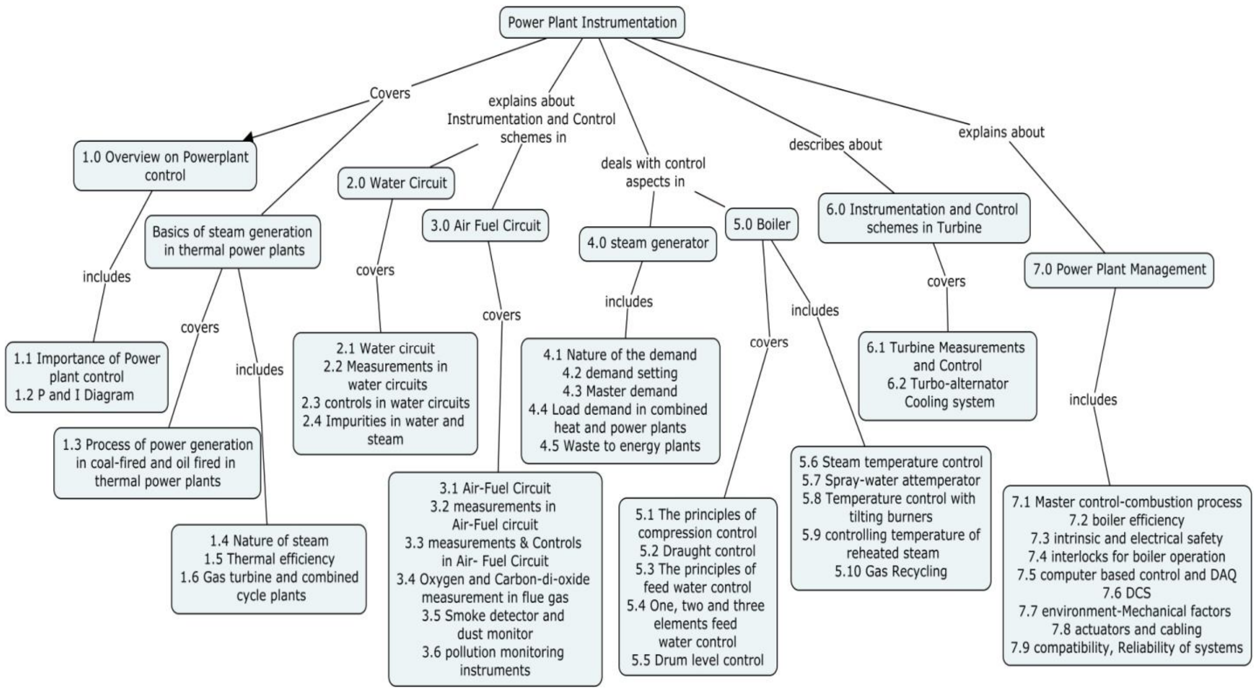
1. How system reliability is enhanced through redundancy in DCS?
2. List out basic safety interlocks used in boilers.
3. Describe how the functions of DDC and PLC combined in a DCS system.
4. Name various approaches for protection of explosion.

Course Outcome 6 (CO6):

1. Compare the technical features of safety control system and process control system in a turbine.
2. Explain how the speed and vibration of a steam turbine monitored.
3. Enumerate the essential steam turbine parameters to be monitored and controlled.
4. Select the suitable method for temperature measurements with suitable ranges, suitable sensors protection devices etc. for the following:

a. Shell temperature measurements
b. Bearing temperature measurements
c. Stem inlet temperature measurements
d. Lube oil temperature measurements

Concept Map



Syllabus

Introduction: Importance of instrumentation and control in Power plants-Piping and Instrumentation Diagram (P and I diagram).
Basics of steam generation process in thermal power plants: Process of power generation in coal-fired and oil fired in thermal power plants-Nature of steam-Thermal efficiency-Gas turbine and combined cycle plants.

Instrumentation and Control schemes in Water Circuit: Water circuit-Measurements in water circuits-controls in water circuits-impurities in water and steam.

Instrumentation and Control schemes in Air- Fuel Circuit: Air-Fuel Circuit-measurements in Air-Fuel circuit – Controls in Air- Fuel Circuit-Analytical Measurements- Oxygen measurement in flue gas- Carbon-di-oxide measurement in flue gas-Infra red flue gas analysis-Smoke detector-dust monitor-chromatography-pollution monitoring instruments

Control aspects in setting the demand for the steam generator: Nature of the demand-Setting the demand in power stations applications-Master demand in power station applications-Load demand in combined heat and power plants-Waste to energy plants

Control aspects in Boiler: The principles of compression control-Draught control-The principles of feed water control-One, two and three elements feed water control
Drum level control-Steam temperature control-Spray-water attemperator-Temperature control with tilting burners-controlling temperature of reheated steam-Gas Recycling

Instrumentation and Control schemes in Turbine:

Turbine steam Inlet System- Turbine Measurements-Turbine Control system- Turbo-alternator Cooling system.

Power Plant Management: Introduction-Master control-combustion process-boiler efficiency-maintenance of measuring instruments-intrinsic and electrical safety-interlocks for boiler operation-computer based control and data acquisition system-distributed control system (DCS)-A Typical DCS configuration-Interconnections between systems-Equipment selection and environment-Mechanical factors and ergonomics-Electrical actuators-Hydraulic actuators-Cabling-Electromagnetic compatibility-Reliability of systems.

Reference Books

1. David Lindsley, "Power Plant Control & Instrumentation ",IEE Publications, London, UK (2001).
2. Sam G.Dukelow, The control of Boilers, Instrument Society of America, 1991.
3. Elonka, S.M. and Kohal A.L.Standard Boiler Operations, McGraw Hill, New Delhi, 1994.
4. R.K.Jain, Mechanical and Industrial Measurements, Khanna Publishers, New Delhi, 1995.
5. P.K.Nag, "Power Plant Engineering" Tata McGraw-Hill, New Delhi, 2005.
6. A.K.Mahalanbias-"Power System Instrumentation"-Tata McGraw Hill.
7. K.Krishnaswamy and M.Ponni Bala-"Power Plant Instrumentation-" – PHI Learning Pvt. Ltd., New Delhi, 2015.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.0	**Introduction**	
1.1	Importance of instrumentation and control in Power plants-	1
1.2	Piping and Instrumentation Diagram (P and I diagram).	1
	Basics of steam generation in thermal power plants	
1.3	Process of power generation in coal-fired and oil fired in thermal power plants	1
1.4	Nature of steam	1
1.5	Thermal efficiency	1
1.6.	Gas turbine and combined cycle plants	1
2.0	**Instrumentation and Control schemes in Water Circuit:**	
2.1	Water circuit-	1
2.2	Measurement and control in water circuits	1
2.3	Impurities in water and steam.	1
3.0	**Instrumentation and Control schemes Air- Fuel Circuit**	
3.1	Air-Fuel Circuit	1
3.2	Measurement and control in Air-Fuel circuit	1
3.3	Oxygen measurement in flue gas- Carbon-di-oxide measurement in flue gas	1
3.4	Infra red flue gas analysis-Smoke detector-dust monitor	1
3.5	chromatography-pollution monitoring instruments	1
4.0	**Control aspects in setting the demand for the steam generator**	
4.1	Nature of the demand	1
4.2	Setting the demand in power station applications	1

4.3	Master demand in power station applications	1
4.4	Load demand in combined heat and power plants	1
4.5	Waste to energy plants	1
5.0	**Control aspects in Boiler**	
5.1	The principles of compression control	1
5.2	Draught control	1
5.3	The principles of feed water control	1
5.4	One, two and three elements feed water control	1
5.5	Drum level control	1
5.6	Steam temperature control	1
5.7	Spray-water attemperator	1
5.8	Temperature control with tilting burners, controlling temperature of reheated steam	1
5.9	Gas Recycling	1
6.0	**Instrumentation and Control schemes in Turbine**	
6.1	Turbine steam Inlet System-Turbine Measurements	1
6.2	Turbine Control system- Turbo-alternator Cooling system	1
7.0	**Power Plant Management**	
7.1	Master control-combustion process	1
7.2	boiler efficiency-maintenance of measuring instruments	1
7.3	intrinsic and electrical safety, interlocks for boiler operation	1
7.4	computer based control and data acquisition system	1
7.5	DCS-A Typical DCS configuration-Interconnections between systems	1
7.6	Equipment selection and environment-Mechanical factors and ergonomics	1
7.7	Electrical actuators-Hydraulic actuators-Cabling	1
7.8	Electromagnetic compatibility, Reliability of systems	1
	Total	**36**

Course Designers:

1. Dr.V.Saravanan vseee@tce.edu

2. Dr.M.Geethanjali mgeee@tce.edu

18CIPT0 MACHINE LEARNING

Category	L	T	P	Credit
PE	2	0	2	3

Preamble

Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it learn for themselves. The process of learning begins with observations or data, such as examples, direct experience, or instruction, in order to look for patterns in data and make better decisions in the future based on the examples that we provide. The primary aim is to allow the computers learn automatically without human intervention or assistance and adjust actions accordingly. This course covers the fundamentals of machine learning, supervised and unsupervised learning and an case studies of existing algorithms.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO No	Course Outcome	Blooms Level
CO1	Explain about the various steps involved in the Data pre-processing steps	Understand
CO2	Develop a Linear Multivariate Regression model for an available dataset	Apply
CO3	Develop a NN Model for multiclass classification problem	Apply
CO4	Develop an SVM classifier for a given classification problem	Apply
CO5	Explain about the evaluation of algorithms	Understand
CO6	Develop a k-mean clustering algorithm for an unsupervised learning problem	Apply
CO7	Use multivariate Gaussian distribution for detection of anomaly	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	**M**	**L**						**M**		**M**	
CO2	**S**	**M**	**L**	**L**	**M**			**M**		**M**	
CO3	**S**	**M**	**L**	**L**	**M**			**M**		**M**	
CO4	**S**	**M**	**L**	**L**	**M**			**M**		**M**	
CO5	**M**	**L**						**M**		**M**	
CO6	**S**	**M**	**L**	**L**	**M**			**M**		**M**	
CO7	**S**	**M**	**L**	**L**	**M**			**M**		**M**	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	60	60	60	60

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Discuss about the steps involved in Data pre-processing
2. Explain about the various types of Machine Learning
3. Discuss about the advantages of Machine Learning and its applications
4. Differentiate the supervised and unsupervised Learning
5. Explain about PCA in detail with example
6. Explain about the Data Normalization and Data Discretization in details
7. Explain how the Covariance and correlation function used in interpretation of features.

Course Outcome 2 (CO2):

1. Explain about the cost function formulation for Linear Multivariate regression
2. Discuss about the various algorithms used for the cost function minimization
3. Discuss about the manual feature selection among many features with example.

Course Outcome 3(CO3):

1. Explain about the Back propagation and forward propagation
2. Explain about the advantages of the NN model
3. Explain about the gradient checking and the Regularization

Course Outcome 4 (CO4):

1. Explain about the case where SVM works better than the NN classifier
2. Explain about the various kernel functions use to transform non-linear mapping to linear mapping.
3. Explain about the SVM classifier with example

Course Outcome 5 (CO5):

1. Explain about the Model validation using learning curve.
2. Explain the error metrics used for skewed data

3. Explain about the bias and variance with suitable example graph representation

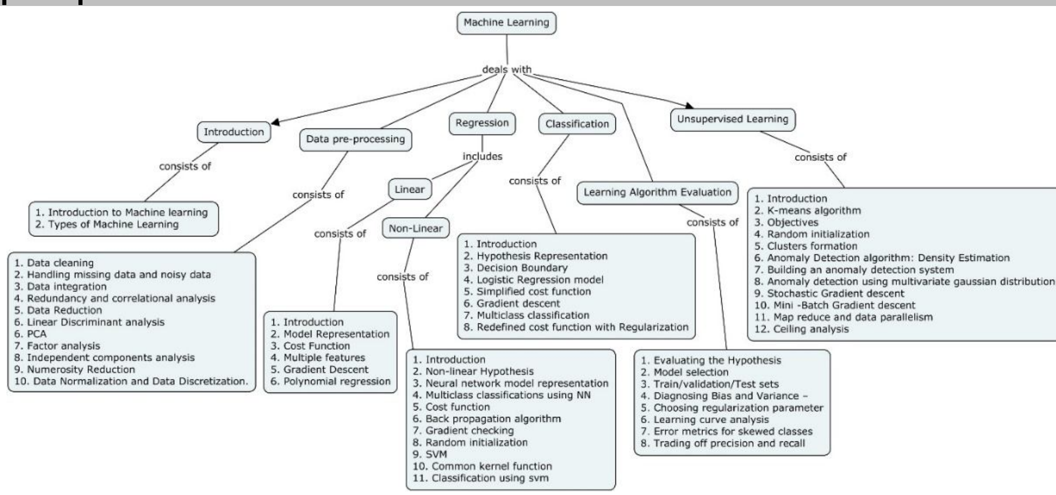
Course Outcome 6 (CO6):

1. State the objectives of k-mean algorithm
2. Discuss about the k-mean algorithm steps involved
3. State any Real-time applications of the clustering algorithms

Course Outcome 7 (CO7):

1. Differentiate the normal gaussian distribution and stochastic gaussian distribution
2. Discuss about the applications of anomaly detection.
3. Discuss about the algorithm steps involved in the anomaly detection

Concept Map



Syllabus

Introduction to Machine Learning:

Introduction to Machine learning – Types of Machine Learning – Supervised Learning – Unsupervised Learning – Reinforced Learning – Evolutionary Learning – Regression

Data pre-processing:

Data preprocessing – Data cleaning – Handling missing data and noisy data – Data integration – Redundancy and correlational analysis – Data Reduction – Linear Discriminant analysis - PCA – Factor analysis – Independent components analysis – Numerosity Reduction – Data compression – Data Normalization and Data Discretization.

Linear multivariate Regression

Introduction – Model Representation – Cost Function –Multiple features - Gradient Descent – polynomial regression

Non-Linear Regression:

Introduction – Non-linear Hypothesis – Neural network model representation – Multiclass classifications using NN - cost function – Back propagation algorithm – Gradient checking – Random initialization – SVM - common kernel function – classification using SVM.

Classification

Introduction – Hypothesis Representation – Decision Boundary – Logistic Regression model – simplified cost function and gradient descent – Multiclass classification –Redefined cost function with Regularization.

Learning Algorithm Evaluation:
Evaluating the Hypothesis – Model selection and Train/validation/Test sets – Diagnosing Bias and Variance – choosing regularization parameter - Learning curve analysis – Error metrics for skewed classes – Trading off precision and recall

Unsupervised Learning:
Introduction – K-means algorithm – Objectives – Random initialization – clusters formation – Anomaly Detection algorithm: Density Estimation - Building an anomaly detection system – Anomaly detection using multivariate Gaussian distribution - Stochastic Gradient descent – Mini-Batch Gradient descent – Map reduce and data parallelism – Ceiling analysis

Reference Books

1. Stephen Marsland, Machine Learning: An Algorithmic Perspective, CRC Press, 2011.
2. Ian H. Witten, Eibe Frank, Mark A. Hall, Data Mining: Practical Machine Learning Tools and Techniques, Elsevier, 2011
3. Jiawei Han, Micheline Kamber, Jian Pei, Data Mining: Concepts and Techniques: Concepts and Techniques, Elsevier, 2011.
4. Ferdinand van der Heijden, Robert Duin, Dick de Ridder, David M. J. Tax, Classification, Parameter Estimation and State Estimation: An Engineering Approach Using MATLAB, John Wiley & Sons, 2005.
5. https://www.coursera.org/learn/machine-learning

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1	**Introduction to Machine Learning**	
1.1	Machine Learning Definition – Types of Machine Learning	1
2	**Data preprocessing**	
2.1	Data cleaning – Handling missing data and noisy data – Data integration	1
2.2	Redundancy and correlational analysis	1
2.3	Data Reduction – Linear Discriminant analysis – PCA	1
2.4	Factor analysis – Independent components analysis	2
2.5	Numerosity Reduction – Data compression	1
2.6	Data Normalization and Data Discretization	1
3	**Linear multivariate Regression**	
3.1	Introduction – Model Representation	1
3.2	Cost Function – Gradient Descent	1
4	**Non-Linear Regression**	
4.1	Introduction – Non-linear Hypothesis	1

4.3	Neural network model representation - Cost function – Back propagation algorithm	1
4.4	SVM - common kernel function	2
5	**Supervised Learning –Classification**	
5.1	Introduction – Hypothesis Representation	1
5.2	Decision Boundary – Logistic Regression model	1
6	**Learning Algorithm Evaluation:**	
6.1	Evaluating the Hypothesis – Model selection and Train/validation/Test sets	2
6.2	Diagnosing Bias and Variance – choosing regularization parameter	1
6.3	Learning curve analysis – Error metrics for skewed classes	1
6.4	Trading off precision and recall	1
7	**Unsupervised Learning:**	
7.1	Introduction – K-means algorithm– Objectives	2
7.3	Anomaly Detection algorithm: Density Estimation	1
	Total	**24**

Lab Experiments: 24 hours

1. Develop a Linear Multivariate Regression model for an available dataset.
2. Develop a NN Model for multiclass classification problem
3. Develop an SVM classifier for a given classification problem
4. Develop a k-mean clustering algorithm for an unsupervised learning problem
5. Develop an Anomaly Detection algorithm for the given datasets.

mini project:

Students should develop machine learning algorithms for the given control/identification problems

Course Designers:

1. Mr.M.Varatharajan varatharajan@tce.edu
2. Mr.S.Surendhar ssreee@tce.edu

18CIPU0	**INTERNET OF THINGS**	Category	L	T	P	Credit
			2	0	2	3

Preamble

The objectives of this course are to provide in-depth understanding of the underlying concepts of Internet of things, building blocks, domain-specific IoTs, and Design methodology for IOT. Also the course provides knowledge on Python coding to embed the coding in various open source hardware such as Raspberry Pi. Eventually the course extends the students knowledge up to the level of building cost effective IOT system for real world scenario with the open source hardware and software tool chains.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to:

COs No.	**Course outcomes**	**Blooms level**
CO1	Explain the details and functionality of IOT	**Understand**
CO2	Identify design methodology for the IOT implementation	**Understand**
CO3	Explain the logical design using python	**Understand**
CO4	Explain the Programming Raspberry Pi with Python	**Understand**
CO5	Choose the suitable hardware and software tools chains to fulfill the IOT requirements	**Apply**
CO6	Application of IOT system for the given scenario	**Analyze**

Mapping with Programme Outcomes

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**
CO1	**M**	**L**						**M**		**M**	
CO2	**M**	**L**						**M**		**M**	
CO3	**M**	**L**						**M**		**M**	
CO4	**M**	**L**						**M**		**M**	
C05	**S**	**M**	**L**	**L**	**S**			**M**		**M**	
CO6	**S**	**S**	**M**	**L**	**S**			**M**		**M**	

S- Strong; **M**-Medium; **L**-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	40	0	20	20
Understand	40	0	20	20

Apply	20	100	60	60
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

- CAT 2 is compulsory based on laboratory experiments.

Course Level Assessment Questions

Course Outcome 1 (CO1)
1. Mention important benefits of IOT
2. What are the key functions of IOT?
3. Identify the components for weather reporting with IOT .
4. What do you mean by IOT protocol?
5. Describe and compare the network architectures of OSI model and TCP/IP Model.

Course Outcome 2 (CO2)
1. What are the advantages of having a switch rather than a hub to interconnect several machines?
2. What is the use of cloud for IOT?
3. Why protocol is necessary for IOT routing?
4. Describe how an algorithm is used in configuring a IOT network.
5. How does OSHW support for IOT

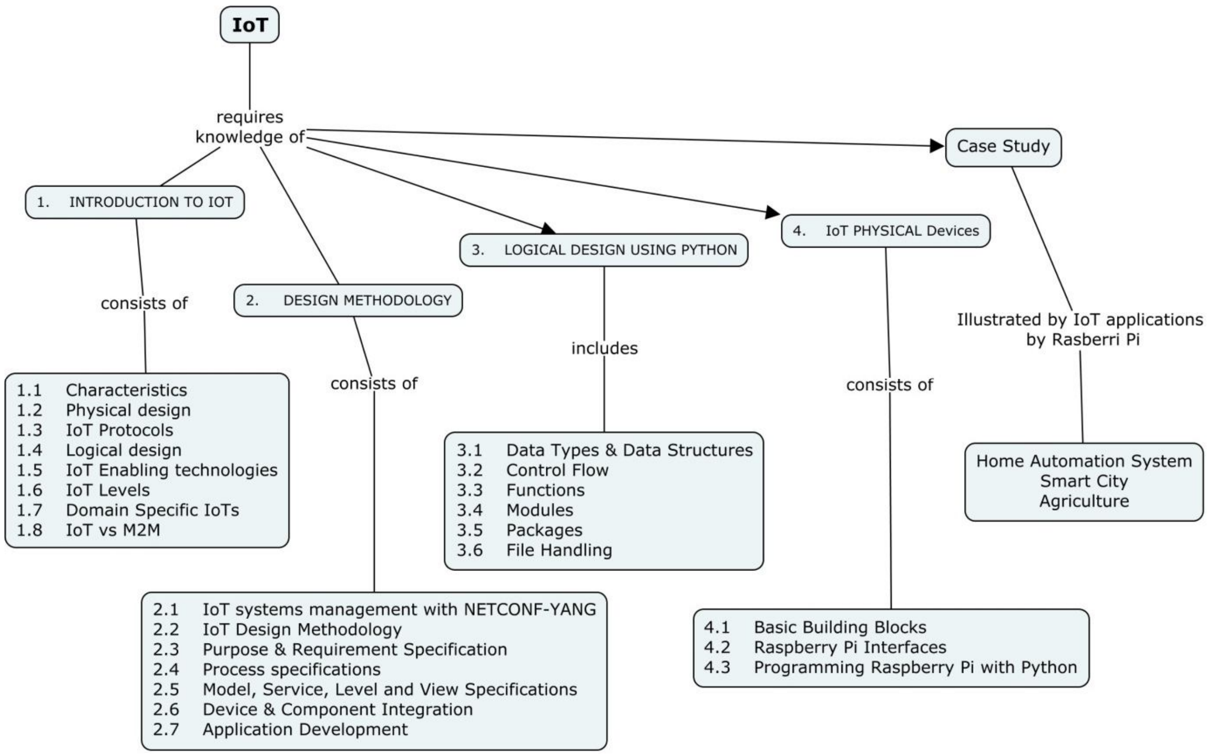
Course Outcome 3 (CO3)
1. Identify the components of IOT.
2. Compare the roles of switch and router.
3. What is the roll of cloud for IOT in different scenario?
4. Why is the roll of different protocol for IOT?
5. Suggest the sensors for IOT for the given application

Course Outcome 4 (CO4)
1. Explain how route optimization is done in IOT.
2. Develop pseudo code for accessing sensors in python
3. Develop an ardiuno code for accessing sensors and actuators

Course Outcome 5 (CO5)
1. Consider a point to point link 50 Km. in length. At what bandwidth would propagation delay equal transmit delay for 100 bytes packet? What about 512 byte packets?
2. Develop an IOT System with sensors for monitoring agriculture field
3. Develop an IOT System with sensors for street light monitoring and control

Course Outcome 6 (CO6)
1. Compute the propagation delay of an IOT system when an algorithm is running with a defined rate and networking delay
2. Analyze the criticality, implementation issues and constrain of the IOT system for the given real world scenario..

Concept Map



Syllabus

INTRODUCTION TO IOT: Characteristics, Physical design, IoT Protocols, Logical design, IoT Enabling technologies, IoT Levels, Domain Specific IoTs, IoT vs M2M, Cyber security, IPv 4 and IPv 6.

DESIGN METHODOLOGY: IoT systems management with NETCONF-YANG, IoT Design Methodology - Purpose & Requirement Specification, Process specifications, Model, Service, Level and View Specifications, Device & Component Integration, Application Development

LOGICAL DESIGN USING PYTHON: Data Types & Data Structures, Control Flow, Functions, Modules, Packages, File Handling

IoT PHYSICAL Devices: Basic Building Blocks, Raspberry Pi Interfaces, Programming Raspberry Pi with Python

CASE STUDIES: Home Automation, Smart city, Agriculture

ReferenceBooks

1. Arshdeep Bahga, Vijay Madisetti, “Internet of Things – A hands-on approach”, Universities Press, 2015
2. Peter Waher “Learning Internet of Things”, Packt Publishing,UK, 2015.
3. Miguel de Sousa”, Internet of Things with Intel Galileo” ”, Packt Publishing,UK, 2015
4. Marco Schwartz, “Internet of Things with the Arduino Yun”, Packt Publishing, 2014
5. Adrian McEwen, Hakim Cassimally “Designing the Internet of Things ”,Wiley Publishing, 2015
6. https://nptel.ac.in/courses/106105166/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.	**INTRODUCTION TO IOT**	
1.1	Characteristics	1
1.2	Physical design	1
1.3	IoT Protocols	1
1.4	Logical design	1
1.5	IoT Enabling technologies	1
1.6	IoT Levels	1
1.7	Domain Specific IoTs	1
1.8	IoT vs M2M, Cyber security, IPv 4, IPv 6	1
2.	**DESIGN METHODOLOGY**	
2.1	IoT systems management with NETCONF-YANG	1
2.2	IoT Design Methodology	1
2.3	Purpose & Requirement Specification	1
2.4	Process specifications	1
2.5	Model, Service, Level and View Specifications	1
2.6	Device & Component Integration	1
2.7	Application Development	1
3.	**LOGICAL DESIGN USING PYTHON**	
3.1	Data Types & Data Structures	1
3.2	Control Flow	1
3.3	Functions	1
3.4	Modules	1
3.5	Packages	1
3.6	File Handling	1
4.	**IoT PHYSICAL Devices**	
4.1	Basic Building Blocks	1
4.2	Raspberry Pi Interfaces	1
4.3	Programming Raspberry Pi with Python	1
Total		24

List of Experiments (24 Hours)

- Application of IoT for Home Automation System
- Application of IoT for Smart city
- Application of IoT for Agriculture

Course Designers

1. Dr.M.Saravanan mseee@tce.edu

2. Dr.P.S.Manoharan psmeee@tce.edu

		Category	L	T	P	Credit
18CIPV0	**DEEP LEARNING**	PE	2	1	0	3

Preamble

Deep Learning is one of the most exciting and promising subset of Artificial Intelligence and machine learning Neural networks allow computers to mimic the human brain. Just like our brain has the innate capability to recognize patterns that allow categorizing and classifying information, neural networks achieve the same for computers.

Deep Learning does incorporate deep neural networks due to the numerous layers of nested hierarchy of decision trees as millions of data points. Deep Learning leverages Natural Language Processing (NLP) and deep neural networks to establish insights facilitating effective decision-making.

Prerequisite

- nil

Course Outcomes

On the successful completion of the course, students will be able to :

COs	**Course outcomes**	**Blooms Level**
CO1	Apply supervised and unsupervised learning algorithms to solve complex problems with an understanding of the trade-offs involved.	Apply
CO2	Apply the optimization training methods for Deep Neural Networks	Apply
CO3	Develop the architectures of Recurrent Neural Networks for given applications.	Apply
CO4	Design the architectures of Convolutional Neural Networks for specific applications.	Apply
CO5	Develop the Restrictive Boltzmann Machines (RBMs) and Deep Restrictive Boltzmann Machines (RBMs) for Classification and feature learning application.	Apply
CO6	Develop learning algorithm for Deep Unsupervised Learning models like for specific application.	Apply

Mapping with Programme Outcomes

Cos	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO3.	**S**	**M**	**L**	**L**								
CO4.	**S**	**M**	**L**	**L**								
CO3	**S**	**M**	**L**	**L**								
CO4	**S**	**M**	**L**	**L**								
CO5.	**S**	**M**	**L**	**L**								
CO6	**S**	**M**	**L**	**L**								

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	--	--	--	--
Evaluate	--	--	--	--
Create	--	--	--	--
There will be three Assignments each carrying 10 marks.				

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define linear model for regression
2. Illustrate how you will avoid overfitting data in decision tree algorithm.
3. Apply the concept of machine learning problem in checkers playing game.

Course Outcome 2 (CO2):

1. Define Empirical Risk Minimization
2. Explain the challenges in neural network optimization.
3. Design Adam optimization algorithm for XOR problem and find the error for epoch 1 and 2.

Course Outcome 3 (CO3)

1. List Some of important design patterns for recurrent neural networks.(RNN)
2. Develop Diagonal RNN with one hidden layer to solve 2-dimensional binary data vectors, according to the following table
   (0,0)--->1,(0,1)--->0,(1,0)--->0,(1,1)--->1
3. Explain the architecture of bidirectional RNNs.

Course Outcome 4 (CO4)

1. **Define tiled Convolution.**
2. **Explain the architecture of Convolution Neural Network LeNet.**
3. **Classify the images using Convolution Neural Network LeNet and Alexnet using matlab and compare its response.**

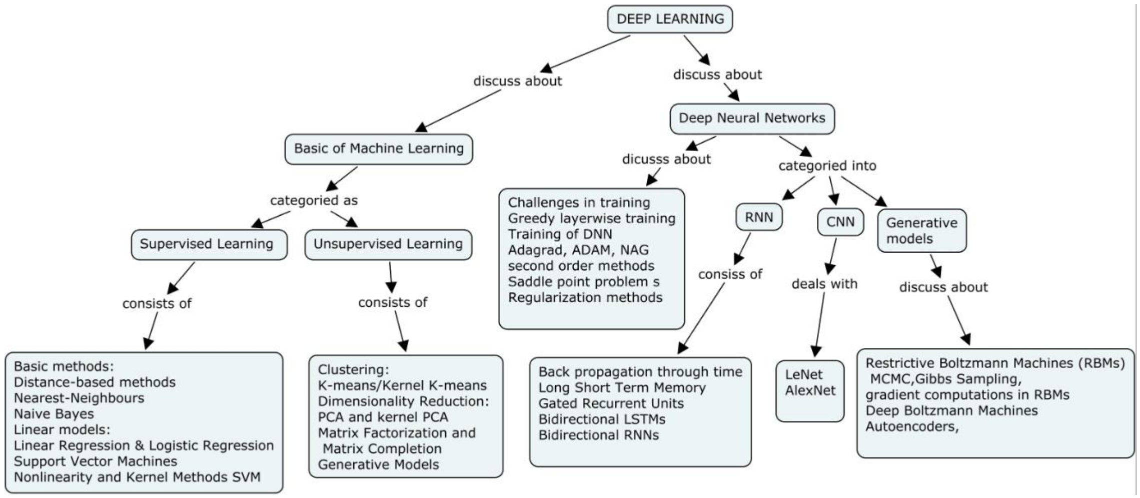
Course Outcome 5 (CO5)

1. Write the energy function of Restrictive Boltzmann Machines (RBMs).
2. Explain Deep Boltzmann Machines (DBMs) and its properties.
3. Develop the variational stochastic maximum likelihood algorithm for training a DBM with two hidden layers.

Course Outcome 6 (CO6)

1. Define contractive autoencoder CAE.
2. Give the limits of autoencoders and denoising autoencoders
3. Using Matlab De-noising the given images using different Autoencoder and compare it

Concept Map



Syllabus

Basics of Machine learning:

Supervised Learning (Regression/Classification)

Basic methods: Distance-based methods, Nearest-Neighbours, Decision Trees, Naive Bayes, Linear models: Linear Regression, Logistic Regression, Support Vector Machines, Nonlinearity and Kernel Methods

Unsupervised Learning

Clustering: K-means/Kernel K-means, Dimensionality Reduction: PCA and kernel PCA
Matrix Factorization and Matrix Completion, Generative Models (mixture models and latent factor models)

Deep Neural Networks: Challenges in training deep neural networks, Greedy layerwise training. Training of Neural Networks: Newer optimization methods for neural networks (Adagrad, ADAM, NAG), second order methods for training, Saddle point problem in neural networks, Regularization methods (dropout, drop connect, batch normalization).

Recurrent Neural Networks: Back propagation through time, Long Short Term Memory, Gated Recurrent Units, Bidirectional LSTMs, Bidirectional RNNs

Convolutional Neural Networks: LeNet, AlexNet.

Generative models: Restrictive Boltzmann Machines (RBMs), Introduction to MCMC and Gibbs Sampling, gradient computations in RBMs, Deep Boltzmann Machines, Autoencoders

Reference Books

1. Deep Learning, Ian Goodfellow and Yoshua Bengio and Aaron Courville, MIT Press, 2016.
2. Kevin Murphy, Machine Learning - A Probabilistic Perspective, Adaptive Computation and Machine Learning, MIT Press, 2012.
3. Christopher M.Bishop, ―Pattern recognition and machine learning‖, Springer,2007.
4. Josh Patterson , Adam Gibson, "Deep Learning: A Practitioner's Approach" 1st Edition, Kindle Edition
5. http://www.deeplearningbook.org/

Course Contents and Lecture Schedule

SNo.	Topic	Lectures
1	**Basics of Machine learning:** **SupervisedLearning (Regression/Classification)**	
1.1	Basic methods:	
1.1.1	Distance-based methods	1
1.1.2	Nearest-Neighbours	1
1.1.3	Naive Bayes	1

1.1.4	Linear models:	
1.1.5	Linear Regression & Logistic Regression	1
1.1.6	Support Vector Machines	2
1.1.7	Nonlinearity and Kernel Methods Support Vector Machines	2
1.2	**Unsupervised Learning**	
1.2.1	Clustering: K-means/Kernel K-means	1
1.2.2	Dimensionality Reduction: PCA and kernel PCA	1
1.2.3	Matrix Factorization and Matrix Completion	1
1.2.4	Generative Models (mixture models and latent factor models)	2
2	**Deep Neural Networks:**	
2.1	Challenges in training deep neural networks	1
2.2	Greedy layerwise training	1
2.3	Training of Neural Networks	1
2.4	Newer optimization methods for neural networks (Adagrad, ADAM, NAG)	2
2.5	second order methods for training	1
2.6	Saddle point problem in neural networks	1
2.7	Regularization methods (dropout, drop connect, batch normalization).	1
3	**Recurrent Neural Networks**	1
3.1	Back propagation through time	1
3.2	Long Short Term Memory	1
3.3	Gated Recurrent Units	1
3.4	Bidirectional LSTMs	1
3.5	Bidirectional RNNs	
4	**Convolutional Neural Networks**:	1
4.1	LeNet	2
4.2	AlexNet	2
5	**Generative models**	
5.1	Restrictive Boltzmann Machines (RBMs)	1
5.2	Introduction to MCMC and Gibbs Sampling, gradient computations in RBMs	1
5.3	Deep Boltzmann Machines	1
5.4	Autoencoders	2
	Total	36

Course Designers:

1. Dr.R.Helen rheee@tce.edu

18PGAA0	PROFESSIONAL AUTHORING	Category	L	T	P	Credit
		AC	2	0	0	2

Preamble

On the successful completion of the course, the students will be able to:

1. Explain how to improve your writing skills and level of readability
2. Write each section of research paper
3. Write good quality technical paper

Syllabus

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction

Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.

Key skills for writing a Title, writing an Abstract, writing an Introduction, writing a Review of the Literature,

Skills for Writing the Methods, Results, Discussion and Conclusions
Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission

Assessment Pattern

Abstract	:	10
Introduction	:	10
Literature Review	:	10
Research Question	:	10
Methods	:	10
Results and Discussion	:	10
Conclusions	:	10
Appropriateness of Title	:	05
Quality of the Paper and Plagiarism	:	25

References

1. Goldbort R, ‘Writing for Science’, Yale University Press, 2006
2. Day R, ‘How to Write and Publish a Scientific Paper’, Cambridge University Press, 2006
3. Highman N, ‘Handbook of Writing for the Mathematical Sciences, SIAM Highman’s book, 1998
4. Adrian Wallwork, ‘English for Writing Research Papers’, Springer New York Dordrecht Heidelberg London, 2011

18PGAB0	VALUE EDUCATION	Category	L	T	P	Credit
		AC	2	0	0	2

Preamble

On the successful completion of the course, the students will be able to:

1. Experience self-development
2. Explain the importance of Human values
3. Develop the overall personality

Syllabus

Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non- moral valuation. Standards and principles, Value judgements

Importance of cultivation of values, Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness, Honesty, Humanity, Power of faith, National Unity, Patriotism, Love for nature, Discipline

Personality and Behavior Development, Soul and Scientific attitude, Positive Thinking. Integrity and discipline, Punctuality, Love and Kindness, Avoid fault Thinking, Free from anger, Dignity of labour, Universal brotherhood and religious tolerance, True friendship, Happiness Vs suffering, love for truth.

Aware of self-destructive habits, Association and Cooperation, Doing best for saving nature

Character and Competence –Holy books vs Blind faith, Self-management and Good health, Science of reincarnation, Equality, Nonviolence , Humility, Role of Women, All religions and same message, Mind your Mind, Self-control, Honesty, Studying effectively

Assessment Pattern

Bloom's Category	Continuous Assessment Test	Terminal Examination
Remember	20	20
Understand	40	40
Apply	40	40
Analyse	0	0
Evaluate	0	0
Create	0	0

References

1. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", OxforUniversity Press, New Delhi