M.Tech. (Electrical Engineering) with specialization in Control & Instrumentation

(Effective from the session 2013-2014)

Course Structure & Scheme of Evaluation

I Semester

Subject Code	**Subject Name**	**L**	**T**	**P**	**Credits**				**Total Marks**
						TA	MSE	ESE	
EE2101	Applied System Theory	3	1	0	4	20	20	60	**100**
EE2102	Digital Control System	3	1	0	4	20	20	60	**100**
EE21xx	Elective I	3	1	0	4	20	20	60	**100**
EE21xx	Elective II	3	1	0	4	20	20	60	**100**
EE21xx	Elective III	0	0	6	4	50	0	50	**100**

Total Credits = 20

II Semester

Subject Code	**Subject Name**	**L**	**T**	**P**	**Credits**				**Total Marks**
						TA	MSE	ESE	
EE2201	Industrial Instrumentation	3	1	0	4	20	20	60	**100**
EE2202	Optimal and Adaptive Control	3	1	0	4	20	20	60	**100**
EE22xx	Elective IV	3	1	0	4	20	20	60	**100**
EE22xx	Elective V	3	1	0	4	20	20	60	**100**
EE22xx	Elective VI	0	0	6	4	50		50	**100**

Total Credits = 20

III Semester

Subject Code	**Subject Name**	**Credits**	**Eval (100)**
EE 2391	State of Art Seminar	4	Marks
EE 2392	Thesis	16	Marks

IV Semester

Subject Code	**Subject Name**	**Credits**	**Eval (100)**
EE 2491	Thesis	20	Marks

Note: The distribution of thesis evaluation marks will be as follows:

1. **Supervisor(s) evaluation component 60%**
2. **Oral Board evaluation component 40%**

First Semester

EE 2101 Applied System Theory:

Vector spaces, linear subspaces, eigenvalue and eigenvectors, matrix inversion formulae, invariant subspaces, vector norms and matrix norms, Singular value decomposition(SVD), semi-definite matrices, singular values, H_2, H_∞ and L_p, spaces and norms for transfer matrices, small gain theorem.

Linear systems, similarity transformations, canonical forms, state space realization of transfer matrices, controllability and observability, pole placement and observer based controllers, digital systems, Lyapunov theorem, nonlinear systems.

Mathematical models of physical systems, state space averaged models for power converters, dynamic model of induction motor, modeling of turbine generator.

References:

1. Chin-Tsong Chen, *Linear system theory and design*
2. T. Kailath, *Linear system theory*
3. Sage, *Large scale systems methodology*
4. M. Gopal, *Modern control system theory*
5. K. Ogata, *System dynamics*
6. Ben Noble, *Applied linear algebra*
7. M.Vidyasagar, *Non-linear systems analysis*
8. M. H. Rashid, *Power electronics handbook*

EE 2102 Digital Control Systems

Introduction and historical development of computer controlled systems, components of digital control, sample & hold, Z-transform and difference equations, translation of analog design-approximations, realization of z-transform function, Digital PID, Jury's stability, closed loop transfer function of sampled data-control systems, state-space representation of computer-controlled systems, Lyapunov-stability analysis, pole-placement and observer design, dead-beat control, Modified Z Transform, Control using microcomputer, microprocessor, micro-controller and DSP-based control system, programming technique for real time control.

References:

1. M. Gopal, *Digital control and state variable methods*
2. G. H. Hostetter, *Digital control system design*
3. Stuart Bennette, *Real time computer control*
4. W. Forsythe & R. M. Goodall, *Digital control*
5. Katz, *Digital Control*
6. Astrom & Wittennark , *Computer controlled systems*

7. K. Ogata, *Discrete time control systems*
8. B. C. Kuo, *Digital control systems*

Second Semester

EE 2201 Industrial Instrumentation

Review of transducers for strain, temperature, pressure, flow etc., Signal conditioning design-Specification, error considerations; Selection & design of typical subsystems; Instrumentation amplifiers, MUX, sample and hold, active filters; Data converters ADCs & DACs; Design of data instrumentation systems, Data flow and graphical programming techniques

Data acquisition methods, DAQ hardware, PC hardware; Structure, Operating Systems, ISA, PCI, USB, PCMICA buses, Instrumentation buses, IEEE488.2, Serial analysis techniques, Networking methods and their applications in instrumentation.

References:

1. Sonde, *Introduction to system design using integrated circuits*
2. Hoeschele, *Analog to digital and digital to analog conversion techniques*
3. Hnatek, *A User's Handbook of D/A and A/D converters*
4. Considine, *Process Instrumentation and control handbook*
5. D. Patranbis, *Principle of industrial instrumentation*
6. Ronald L. Krutz, *Interfacing techniques in digital design*

EE 2202 Optimal and Adaptive Control

Review of system synthesis methods-performance criterion for optimal design-analytic design techniques, Use of computers in optimal design, review of calculus of variations, Maximum principle, dynamic programming and optimal estimation techniques. The adaptive control problem-computational methods based on linearization- STR and MRAC, periodic perturbation-systems-peak holding systems-signal synthesis-adaptive control-learning systems-practical applications of adaptive control.

References:

1. Brown Martin, *Neurofuzzy Adaptive modeling and control*
2. Narendra S. Kumpati , *Advances in adaptive control*
3. A. P. Sage, *Optimal system control*
4. Kirk, *Optimal control theory*
5. Astrom & Wittenmar, *Adaptive control*

List of Professional Elective for Control & Instrumentation

List of Professional Elective I

1. EE 2111 Optimization Techniques
2. EE 2112 Expert Systems
3. EE 2113 Neuro-Fuzzy Control Systems
4. EE2114 CAD of Control

List of Professional Elective II

1. EE 2115 Digital Signal Processing
2. EE 2116 Non Linear Systems
3. EE 2117 Digital System Simulation
4. EE 2125 Virtual Instrumentation

List of Professional Elective III

1. EE 2151 Advanced Control Lab
2. EE 2152 Power System Lab
3. EE 2153 Power Electronics Lab
4. EE 2161 Mini Project / Term Project

List of Electives IV

1. EE 2211 Robot Modeling and Control
2. EE 2212 Robust Control Systems
3. EE 2213 Process Automation
4. EE 2214 Robotics Vision

List of Electives V

1. EE 2215 Special topics in Control Systems
2. EE 2216 Stochastic Control System
3. EE 2217 System Identification &Estimation

List of Electives VI

1. EE 2251 Instrumentation Lab
2. EE 2252 Advanced Power Electronics & Drives Lab
3. EE 2253 Advanced Power System Protection Lab
4. EE 2261 Mini Project / Term Project

EE 2111 Optimization Techniques

Introduction to optimization-classification. Linear programming – Problem in two variable-graphical solutions – Formulation of LP problems in more than two variables-standard form simplex method-simple-Algorithm special cases-2 phase's method-Duality and Dual LP problems-10.
Application of LP in Transportation problem-Balanced and unbalanced transportation problems-Use of North West corner rule-Least cost coefficient method-Vogel approximation method.
Non-linear programming problem – philosophy of numerical methods, various elimination method for one dimensional problems- unconstrained and constrained optimization, Nonlinear programming problems, Use of univariate method – Pattern search method – Steepest descent method-Davidon, Fletcher Power method – cutting plane method , Penalty function-Derivative free method, Finite differential and method of sum of squares and non-linear equations-comparison of methods.
Classical optimization techniques – single variable problem-multivariable optimisation with constraints and without constraints Necessary and sufficient conditions.
Basics ideas of Geometric programming-Dynamic programming and Integer programming

References:

1. S.S.Rao, *Optimization: theory and application*
2. L.S.Srinath, *Linear programming: principles and application*
3. Leunberger D, *Linear & non linear programming*, 2^{nd} ed. Add. Wesley, 1984
4. Schirisieer A, *Theory of linear and integer programming*, John Wiley and sons 1986

EE 2112 Expert Systems

Introduction, Expertise and Heuristic knowledge, knowledge based systems, Structure of knowledge based systems, Logic and automated reasoning, Predicate logic, logical inference, Resolution, Truth maintenance systems, Rule based reasoning, Forward chaining , Backward chaining, Rule based architectures, conflict resolution schemes, Associative networks, Frames and Objects, uncertainty management, Baynesian approaches, Certainty factors, Dempeter-Shefer theory of Evidence, Fuzzy sets and Fuzzy logic, knowledge Acquisition search strategies and matching techniques.

References:

1. Peter Jackson, *Introduction to expert systems*
2. ArchinoJ.Gonzalez, *The Engineering of knowledge based systems*
3. Dan W. Patterson , *An introduction to artificial intelligence and expert systems*
4. Sasikumar et al. , *Rule based expert systems*
5. Kowalik , *Knowledge based problem solving*
6. Roth, *Building expert systems*

EE 2113 Neuro-Fuzzy Control Systems

Introduction, neuron model, activation functions, perceptions, multilayer network, Back propagation, re-current networks, supervised and unsupervised learning, principle component analysis, modeling, identification, prediction and control using neural network controllers, Basics of sets and fuzzy arithmetic, crisp sets, operation, relation and composition of sets, Fuzzification and defuzzification methods, Fuzzy logic, software and hardware application to closed loop control, Fuzzy controllers.

References:

1. Simon Haykin, *Neural networks - A comprehensive foundation*
2. M. T. Hagan , *Neural network design*
3. D. T. Pham and X Liu, *Neural network for identification, prediction and control*
4. E .H. Mamdani et al, *Fuzzy sets*
5. B. Kosko, *Neural network and fuzzy systems*
6. T. J. Ross , *Fuzzy logic : With engineering applications*

EE 2214 CAD of Control

Requirement of interactive computing, modes, graphical quality, Line drawing, solid area graphics and three dimensional display, Scaling and transformation, Comparison of languages in terms of structured programming, Interactive use of languages, portability, Program evaluation, CAD of SISO systems, system specification, nyquist, inverse nyquist, bode and root locus plots, Development of software for graphic display of these plots, Design of compensators, software development for simulation. CAD of MIMO systems: stability, integrity, software development for optimal control, simulation of MIMO systems.

References:

1. Karl J. Astrom, *Computer controlled systems-theory and design*
2. Ramamoorthy, *Computer aided design of electrical equipment*
3. M.Gopal, *Digital control and State variable methods*

EE 2115 Digital Signal Processing

DFT- Walsh- Hadamard transforms, discrete convolution and correlation, FFT algorithms, Digital filters-flow graph and Matrix representation, IIR and FIR filter design, Signal processing algorithm, waveform generation, Quadrature signal processing, Signal detection , modulation techniques, frequency translation, over ranging, Issues involved in DSP processor design-speed, cost, accuracy, pipelining, parallelism, quantization error, etc., Key DSP hardware elements - Multiplier, ALU, Shifter, Address Generator, etc., Software development tools-assembler, linker and simulator, Applications using DSP Processor - spectral analysis.

References:

1. A.V. Oppenheim & Schfar, *Digital signal processing*
2. Bateman & Yates, *Digital signal processing design*
3. A. Antoniou, *Digital filters analysis and design*

EE 2116 Nonlinear Systems

Introduction, common physical nonlinearities, Phase plane method, describing function method, limit cycle, jump resonance, perturbation method, dither signal, Lyapunov stability criterion, Lure's V functions, Popov criterion, feedback Linearization, sliding mode control, back stepping control.

References:

1. M.Vidyasagar, *Nonlinear system analysis*
2. D.Graham, *Analysis of nonlinear control systems*
3. N.Minorsky, *Theory of nonlinear control systems*
4. H. K. Khalil, *Nonlinear systems*
5. J. J. E. Slotine, *Applied nonlinear control*

EE 2117 Digital System Simulation

Introduction to digital system simulation, continuous and discrete system simulation, Queuing system simulation, A PERT network simulation, Inventory control system simulation and forecasting techniques, Design and evaluation of experiments on system simulation, system simulation languages with particular reference to GPSS, SIMULA & Continuous system simulation languages (CSSLs), Introduction to system models.

Approximation of functions: Linear regression, polynomial regression, Fitting of exponential and trigonometric functions, Taylor Series, Chebyshev series and rational functions approximations.

Differentiation and Integration: Formulae for numerical differentiation, numerical integration, Simpson's rule.

References:

1. John F. Wakerly, *Digital design principles and practices*
2. G. Borriello, R. H. Katz , *Contemporary logic design*
3. Howard G. Johnson, *High-speed digital design - A handbook of black magic*
4. M. Abramovici, M. Breuer & A. Friedman, *Digital systems testing and testable design*

EE- 2125 Virtual Instrumentation

Introduction, Virtual instrumentation (VI) advantages, Graphical programming techniques, Data flow programming , VI's and sub VI's, Structures, Arrays and Clusters, Data acquisition methods, File I/O, DAQ hardware, PC hardware: operating systems, Instrumentation buses, ISA, PCI, USB, PXI, Instrument control, Data communication standards, RS-232C, GPIB, Real time operating systems, Reconfigurable I/O, FPGA.

References

1. S. Gupta & J. John, *Virtual instrumentation using Lab VIEW*
2. Robert Bishop, *Lab VIEW 7 express student edition*
3. National Instruments, *Lab VIEW user manual*
4. National Instruments, *Lab VIEW RT user manual*
5. National Instruments, *Lab VIEW FPGA module user manual*
6. Leonard Sokoloff, *Application in Lab VIEW*
7. Nesimi Ertugrul, *Lab VIEW for electrical circuits*, *machine drives and labs*
8. John Essick, *Advanced Lab VIEW Labs*
9. Gary Johnsons, *Lab VIEW graphical programming*

EE2151 Advanced Control Lab

List of Experiments

Optimization Techniques

[1] Find the solution of the following nonlinear optimization problem using the MATLAB function fmincon:

$$\text{Minimize } f(x_1, x_2) = 9.82x_1x_2 + 2x_1$$

subject to

$$\begin{cases} g_1(x_1, x_2) = \dfrac{2500}{\pi x_1 x_2} - 500 \le 0 \\ g_2(x_1, x_2) = \dfrac{2500}{\pi x_1 x_2} - \dfrac{\pi\left(x_1^2 + x_2^2\right)}{0.5882} \le 0 \\ g_3(x_1, x_2) = -x_1 + 2 \le 0 \\ g_4(x_1, x_2) = x_1 - 4 \le 0 \\ g_5(x_1, x_2) = -x_2 + 0.2 \le 0 \\ g_6(x_1, x_2) = x_2 - 0.8 \le 0 \end{cases}$$

[2] Find the solution of the following linear programming problem using MATLAB:

Minimize $f\left(x_1, x_2, x_3\right) = -x_1 - 2x_2 - x_3$

subject to

$$\begin{cases} 2x_1 + x_2 - x_3 \le 2 \\ 2x_1 - x_2 + 5x_3 \le 6 \\ 4x_1 + x_2 + x_3 \le 6 \\ x_i \ge 0 \; ; \; i = 1, 2, 3 \end{cases}$$

[3] Find the maximum of the function

$$f\left(x\right) = x^2 - 2x - 11$$

in the range $-2 \le x \le 2$ using the PSO method. Use 4 particles (N = 4) with the initial

Positions x1 = −1.5, x2 = 0.0, x3 = 0.5, and x4 = 1.25.

[4] Find the minimum of the following function using simulated annealing:

$$f\left(x_1, x_2, x_3\right) = 500 - 20x_1 - 26x_2 - 4x_1x_2 + 4x_1^2 + 3x_2^2$$

Digital System Simulation

[1] Each wheel with a mass *m* in an automobile has an independent suspension system, consisting of a spring and a shock absorber, as shown in the Fig. 1. The resistance force of the spring is proportional to the displacement (i.e., compression) and the resistive force of the shock absorber is mostly proportional to the rate of change of displacement. The exact equation of motion for the system is $m\ddot{y} + k_1(\dot{y} - k_2\ddot{y}) + k_3 y = k_3.F(t)$.

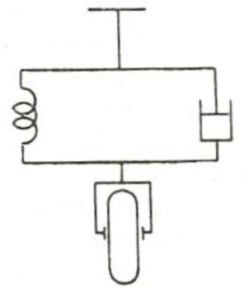


Fig. 1. Spring and a shock absorber arrangement

Find the transient behaviour of this system with the following values of the constants: $mass\ m = 1.0\,Kg.$, $k_1 = 5.0$, $k_2 = 0.05$, sprint stiffness $k_3 = 700$ for two types of forces:

(a) Step function $F(t) = \begin{cases} 0, & (t \le 0) \\ a, & (t > 0) \end{cases}$

(b) Ramp function $F(t) = \begin{cases} 0, & (t \le 0) \\ at, & (t > 0) \end{cases}$

Write a program to simulate the system. Observe, in particular, the time required for the wheel to return to normal after it runs over a square pothole and amount of overshoot.

[2] Using a random number generator, write a program to simulate the following game of dice.

A pair of six-sided fair dice, each carrying spots 1, 2, 3, 4, 5 and 6, is rolled. If on the first roll the sum of the two dice faces is 7 or 11 the person rolling the dice wins. If this sum is 2, 3 or 12, then the person rolling the dice loses. If the sum is any of the other six numbers (4, 5, 6, 8, 9 or 10) this number becomes the 'point' of the person rolling the dice, and the rolling continues till either (i) the 'point' is rolled again, in which case the person rolling the dice wins, or (ii) a 7 is rolled in which case he loses. Run the program to simulate 100 rolls and find who won how many times.

[3] At a college library the following situation exists. The library remains open from 7 a.m. to 9 p.m. There are two counters for issuing books to students. The students arrive for taking out books according to the Poisson distribution, but their arrival rate changes every two hours as follows:

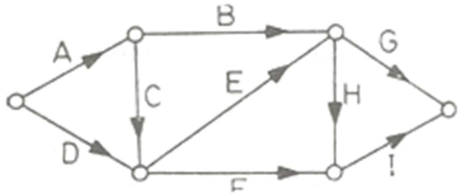
Hours	Average inter-arrival time

7-9	5.7 min
9-11	3.3 min.
11-13	1.8 min.
13-15	2.5 min.
15-17	4.8 min.
17-19	6.2 min.
19-21	10.7 min.

The check-out time (service time) varies uniformly from 1 minute to 5 minutes per student depending on the individual student and the number of books he wants to take out. Write a MATLAB program to get the maximum queue length, average queue length and the total idle time of the counters each day. Simulate the system for 100 days and comment.

Suppose there was a third counter for issuing books exclusively to the faculty members. The inter-arrival time of faculty is also distributed exponentially with the same average of 10 minutes throughout the day. The service time for faculty is the same as for the students. A new librarian takes charge and allows the faculty counter to be used for students also. However, he puts the faculty on a non-pre-emptive priority. Simulate the system now and determine if the new arrangement has improved the students' lot.

[4] A project network with nine activities is given in following figure. All activity durations are uniformly distributed, ranging 20 percent from the mean. The mean values for the durations of activities A, B, C, D, E, F, G, H, I are 7, 8, 2, 8, 5, 7, 13, 2, 12, respectively. Simulate the network, with 1000 runs, to obtain a histogram (Frequency of occurrence in 1000 trails Vs Tmin). Compare the simulation results with those obtained by a deterministic analysis using the mean values only.



[5] Suppose $\{x_1, x_2, \ldots, x_N\}$ and $\{y_1, y_2, \ldots, y_N\}$ are independent samples from two approximately two normal populations having means μ_1 and μ_2 (unknown) and the same variance σ^2 (also unknown) Let $\bar{x}$ and $\bar{y}$ denote the two sample means. Clearly, the random variables $\bar{x}$ and $\bar{y}$ have means μ_1 and μ_2 and variance $\frac{\sigma^2}{N}$

and $\frac{\sigma^2}{M}$, respectively. The random variable $(\bar{x}-\bar{y})$ has mean $(\mu_1-\mu_2)$ and variance$\left(\frac{\sigma^2}{N}+\frac{\sigma^2}{M}\right)$.

(a) Show that the variable $t=\frac{(\bar{x}-\bar{y})-(\mu_1-\mu_2)}{s\sqrt{\frac{1}{N}+\frac{1}{M}}}$ has the student-t distribution with (N+M-2) degrees of freedom, where s^2 is estimate of the variance, given by

$$s^2=\frac{\sum(x_i-\bar{x})^2+\sum(y_i-\bar{y})^2}{N+M-2}$$

(b) Suppose the following are two sets of samples:

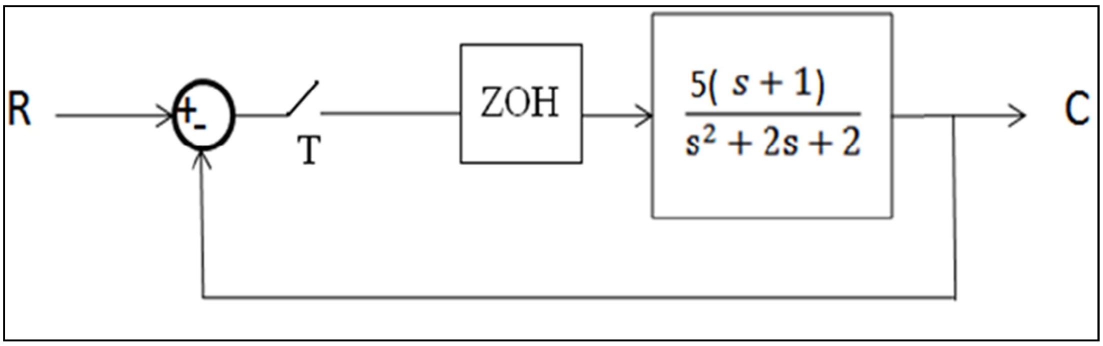
x:	79,	84,	120,	108,	114,	103,	122,	120		
y:	54,	99,	91,	103,	90,	113,	108,	87,	100,	80

Calculate $\bar{x}$, $\bar{y}$, s^2 ; and test the hypothesis that the two means are equal, i.e.,

$$(\mu_1-\mu_2)=0.$$

Digital Control System

[1] Convert the open loop continuous model shown in Figure 1 below into discrete form taking the sampling time (1 sec). Find the closed loop transfer function and unit step response.



<u>Figure 1 : Discrete Control System</u>

Select the sampling time to be (0.5, 0.3, 0.2, 0.1 and 0.05) and find step response for each sampling time.

[2] Consider the inverted pendulum system:

$$\dot{x} = Ax + bu$$

$$y = cx$$

where,

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 16.3106 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ -1.0637 & 0 & 0 & 0 \end{bmatrix}; b = \begin{bmatrix} 0 \\ -1.4458 \\ 0 \\ 0.9639 \end{bmatrix}; C = \begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix}; \text{ and}$$

$x = \begin{bmatrix} \Theta \\ \dot{\Theta} \\ z \\ \dot{z} \end{bmatrix}$; z(t)=Horizontal displacement of the pivot on the cart; Θ(t)=rotational angle of the pendulum.

(a) Check the controllability and observability of the system.

(b) Discretize the system for T= 0.1, 0.5 and 1 secs and again check the controllability and observability for each sampling time.

[3] The motion of a satellite in the equatorial (r,Θ) plane is given by the state equation:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 3\omega^2 & 0 & 0 & 2\omega \\ 0 & 0 & 0 & 1 \\ 0 & -2\omega & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

where, ω is the angular frequency of the satellite in circular , equatorial orbit; x_1(t) and x_3(t) are, respectively, the deviations in position variables r(t) and θ(t) of the satellite; and x_2(t) and x_4(t) are, respectively, the deviations in velocity variables $\dot{r}(t)$ and $\dot{\theta}(t)$. The inputs u_1 (t) and u_2(t) are the thrusts u_r and u_θ in the radial and tangential directions, respectively, applied by small rocket engines or gas jets (u=0 when x=0 and take ω=1).

(a) Discretize the system for T=0.1 sec and prove that it is completely controllable.
(b) Suppose that the tangential thruster becomes inoperable. Determine the controllability of the discretized system with radial thruster alone.
(c) Suppose that the radial thruster becomes inoperable. Determine the controllability of the discretized system with tangential thruster alone.
(d) Prove that the discretized system is completely observable from radial ($x_1 = r$) and tangential ($x_3 = \theta$) position measurements.
(e) Suppose that the tangential measuring device becomes inoperable. Determine the observability of the discretized system from radial position measurement alone.
(f) Suppose that the radial measuring device becomes inoperable. Determine the observability of the discretized system from tangential position measurement alone.

[4] Consider the linearized model of twin rotor MIMO system given:

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ -4.7059 & -0.0882 & 0 & 0 & 1.3588 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -5 & 1.617 & 4.5 \\ 0 & 0 & 0 & 0 & -0.9091 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 0.8 \end{bmatrix} \text{ and } C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}$$

(a) Determine Controllability and Observability properties of the given system.
(b) Discretize the system for T= 0.5, 1, 2, 3, 4 and 5 sec. Determine Controllability and Observability properties of the discretized systems. Are Controllability and observability properties lost due to discretization? If yes then at which sampling time and why?
(c) Find Unit Step, Impulse & Ramp responses of the discretized system.

(d) Plot the response of discretized system for the initial conditions given by $X_0 = [1 \quad 1 \quad 1 \quad 1]^T$.

(e) Find the characteristic equation of the discretized system and its roots. Comment on the stability.

(f) Convert the discretized system to the unity feedback system and find its response to unit step input also comment on its stability.

(g) For the discretized system find all the forms of the state space representation.

[5] Consider the linearized model of twin rotor MIMO system given in [4]:

(a) Discretize the system for T=0.5 sec.

(b) Design a state feedback controller which will place the close loop poles at $-\frac{1}{2} \pm \frac{1}{2} j,\ \frac{1}{2} \pm \frac{1}{2} j,\ \frac{1}{2}\ and\ -\frac{1}{2}$.

(c) Also design a deadbeat controller for TRMS system.

(d) Design a full state observer for discretized TRMS system, the observer poles are required to be located at $-\frac{1}{2} \pm \frac{1}{2} j,\ \frac{1}{2} \pm \frac{1}{2} j,\ \pm 0.25$.

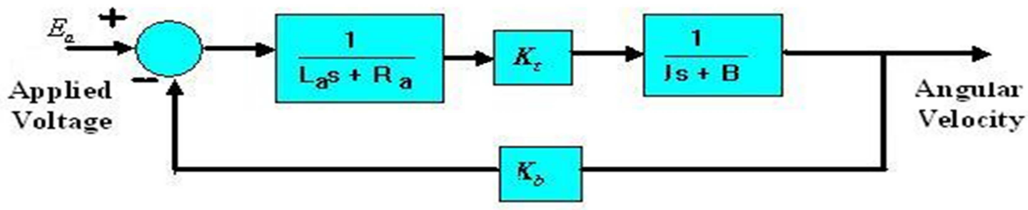
(e) Design a reduced order observer for discretized system, the observer poles are required to be located at ±0.25 and states x_2, x_4, x_5 and x_6 have to be observed.

(f) Write a MATLAB program for designing a deadbeat controller for discretized system.

(g) Write MATLAB program for designing a deadbeat observer for discretized system

Applied System Theory

[1] Draw in Simulink .Plot the step Response



for given values of L_a=0.09, R_a=2, J=0.05, B=2, K_b =0.98.

[2] A closed loop control system has Transfer Function $\frac{C(s)}{R(s)} = \frac{s+5}{s^3+2s^2+3s+5}$. Obtain the response of the system for input r (t) $= e^{-0.2t}$ for t=0 to 9 in steps of 0.12 sec.

[3] Determine the Controllability and Observability of the following systems:

(a) $\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 2 & -3 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u \; ; y = \begin{bmatrix} 10 & 0 & 0 \end{bmatrix} x$

(b) $\dot{x} = \begin{bmatrix} -1 & 0 & 0 \\ 0 & -2 & 0 \\ 0 & 0 & -3 \end{bmatrix} x + \begin{bmatrix} 1 & 0 \\ 1 & 2 \\ 2 & 1 \end{bmatrix} u \; ; y = \begin{bmatrix} 1 & 1 & 2 \\ 3 & 1 & 5 \end{bmatrix} x$

[4] Consider the system given by:

$$\frac{Y(s)}{U(s)} = \frac{s^2+8s+15}{s^3+8s^2+17s+10}$$

(a) Represent the system in 1st, 2nd and 3rd canonical forms.
(b) Comment on the stability of the system.
(c) Obtain the plot of states.

[5] For the system shown below write a program in MATLAB that will use an open loop Transfer function

$$G(s) = \frac{K(s+6)}{s(s+4)(s^2+4s+8)}$$

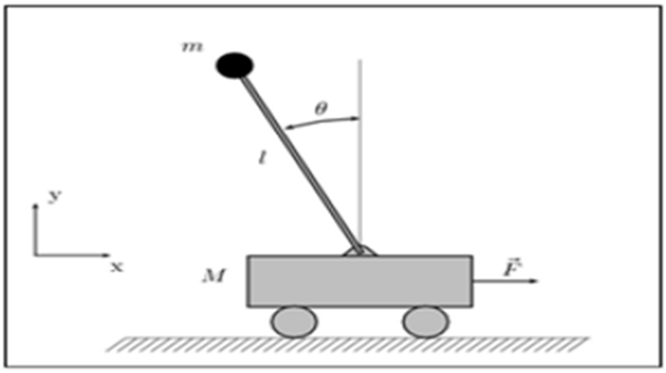
(a) Obtain a Bode plot
(b) Obtain the closed-loop step response.
(c) Estimate the percent overshoot, settling time and peak time

[6] Consider the inverted pendulum system shown in below figure. Its linearized model is given by:

$$\dot{x} = Ax + Bu$$
$$y = Cx$$

where $A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 16.3106 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ -1.0637 & 0 & 0 & 0 \end{bmatrix}; B = \begin{bmatrix} 0 \\ -1.4458 \\ 0 \\ 0.9639 \end{bmatrix}; \; C = \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix};$ and $x = \begin{bmatrix} \theta \\ \dot{\theta} \\ z \\ \dot{z} \end{bmatrix}$

z(t) =Horizontal displacement of the pivot on the cart; Θ(t)=rotational angle of the pendulum.



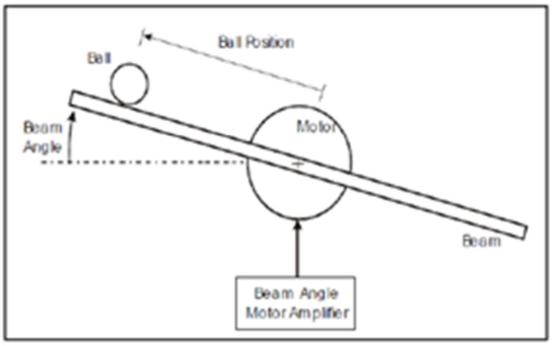
Inverted Pendulum

(a) Find the eigenvalues of the system and plot the response to initial condition $X_0 = [1 \quad 0 \quad 0 \quad 0]^T$ and check stability of the system.
(b) Check the controllability and observability of the system.
(c) Is it possible to design a state feedback control law u= -kx for the given system? If yes, then design a state feedback controller which will place the poles at -2, -2±j, -3.
(d) Find the response of the system with controller to initial condition $X_0 = [1 \quad 0 \quad 0 \quad 0]^T$.

[7] Consider the ball and beam system as shown in below figure. Its linearized model is given by:

$$\begin{bmatrix} \dot{r} \\ \ddot{r} \\ \dot{\alpha} \\ \ddot{\alpha} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & \dfrac{-mg}{\left(\dfrac{J}{R^2}+m\right)} & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} r \\ \dot{r} \\ \alpha \\ \dot{\alpha} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = [1 \quad 0 \quad 0 \quad 0] \begin{bmatrix} \dot{r} \\ \ddot{r} \\ \dot{\alpha} \\ \ddot{\alpha} \end{bmatrix}$$



Ball and Beam System

where m mass of the ball - 0.11 Kg
R radius of the ball - 0.015 m
G gravitational acceleration- 9.8m/s^2
J ball's moment of inertia- 9.99 x10^{-6} kg/m^2
r- ball position co-ordinate
α- beam angle co-ordinate

(a) Repeat part (a) and (b) of question 3 for this system and also find the response of the system for 0.25 step input.

(b) Is it possible to design a state feedback control law u=-kx for the given system? If yes, then design a state feedback controller. The design criteria for this problem are:

   (i) Settling time less than 3 seconds
   (ii) Overshoot less than 5%.

(c) Find the response of the system with controller to initial condition $X_0 = [1 \quad 0 \quad 0 \quad 0]^T$. Also find the response of close loop system for 0.25 step input.

EE2211 Robot Modeling and Control

Robotics system components, coordinate frames, different orientation descriptions, free vectors, translation, rotation and relative motion, Homogeneous transformations, Link coordinate frames, Denavit-Hartenberg convention, Joint and End-effector, Cartesian space, Forward kinematics transformations of position, Inverse kinematics of position, Trigonometric equations, Closed-Forum Solutions, Workspace, Lagrangian formulation, Model properties, Newton-Euler equations of motion, Simulations, Computed torque control, Approximated CT control, Nonlinear controller design, Digital Control.

References:

1. John J. Craig, *Introduction to robotics, mechanics & control*
2. John J. Craig, *Adaptive control of mechanical manipulators*
3. F.L. Lewis, S. Jagannathan & A. Yesildirek, *Neural network control of robot manipulators*
4. F. L.. Lewis, Abdallah C.T., and Dawson D.M., *Control of robot manipulators*

EE2212 Robust Control Systems

Review of Linear Algebra , Review of Linear Time Invariant Systems - State Space Theory, Linear Analysis - Function Spaces, Model Realizations and Reductions , Stabilizing Controllers , H_2Optimal Control , H_∞ Synthesis , Modeling Uncertain Systems - the Structured Singular Value, Robust Feedback Control of Uncertain Systems , Robust Stability and Performance under Mixed Perturbations , State Space Parameter Perturbations

References:

1. K.Zou&J.C.Doyle , *Essentials of robust control*
2. M. Green & D. Limebeer, *Linear robust control*

EE2213 Process Automation

Automation and its importance, automation applications, Types of plant and control – categories in industry, open loop and close loop control functions, continuous processes, discrete processes, and mixed processes, Automation hierarchy, Control system architectures (Specific)
Introduction to Distributed Control system (DCS) , architecture of DCS, specifications of DCS, Introduction to Hierarchical Control and memory: Task listing, Higher & Lower Computer level tasks, Supervisory computer tasks and DCS configuration – Supervisory Computer functions, Control techniques, Supervisory Control Algorithm, DCS & Supervisory Computer displays, advanced control Strategies, Computer interface with DCS, DCS – system integration with PLCs and computer, Man machine interface.

References:

1. K. L .S. Sharma, *Overview of industrial process automation*
2. Love, Jonathan, *Process automation handbook*

EE2214 Robotics Vision

Overview, computer imaging systems, lenses, Image formation and sensing, Review of open source Image processing Packages, Image analysis, preprocessing, Binary image analysis, Edge detection, Edge detection performance, Hough transform, Segmentation, Morphological filtering, Fourier and Orthogonal Image transforms, Feature extraction, shape, histogram, color, spectral, texture, Feature analysis, feature vectors, distance /similarity measures, data preprocessing, Pattern classification, character classification, pedestrian and face recognition/detection

References:

1. R.C.Gonzalez & P.Wintz , *Digital image processing*
2. B. K . P.Horn, *Robot vision*
3. D. H .Ballard & C .M .Brown, *Computer vision*
4. R. C. Gonzalez & M .G. Thomason, *Syntactic pattern recognition: An introduction*

EE2215 Special topics in Control Systems

Model Order Reduction: Importance of reduced order models, Time domain Techniques, Frequency Domain Classical techniques, Optimal Hankel Norm Approximation. Supervisory control of discrete Events Dynamic Systems (DES): Formation of discrete event system's models. Supervision of discrete event system: State based control of DES, supervisory control of timed discrete event system.

References:

1. Criag, J., *Fundamentals of robotics analysis and control*
2. Schilling. R. J., *Fundamentals of robotics: Analysis and control*
3. M. S. Mahmoud and M.G. Singh, *Large scale systems modeling*
4. G. Obinata and B.D.O. Anderson, *Model reduction for control system design*
5. M. Jamshid, *Large scale systems modeling and control*

EE2216 Stochastic Control System

Introduction to stochastic control, with applications from areas including supply-chain optimization, advertising, finance, dynamic resource allocation, caching, and traditional automatic control. Markov decision processes, optimal policy with full state information for finite-horizon case, infinite-horizon discounted, and average stage cost problems. Bellman value function, value iteration, and policy iteration. Approximate dynamic programming. Linear quadratic stochastic control.

References:

1. Goong Chen, Shih Hsun Hsu, *Linear stochastic control system*

2. Jon H Davis, *Foundations of deterministic and stochastic control*
3. Jiongmin Yong & Xun Yu Zhou, *Stochastic controls*

EE2217 System Identification & Estimation

System Identification - Motivation and Overview, random variables and stochastic processes, stochastic static models, Disturbance models - random processes, representation of stationary processes, white-noise process, auto-covariance function (ACF), ARMA models. Parametric model structures - ARX, ARMAX etc.

The identification problem, classical methods of identification of transfer functions models, Linear Regression - Least Squares estimates, Statistical properties of LS Estimates. Weighted Least Squares, Recursive Least Squares, Maximum Likelihood Estimation.Minimum variance algorithm, stochastic approximation.

Estimation of non-parametric models - impulse / step response coefficients, frequency response models. Estimation of parametric models - notions of prediction and simulation, predictors for parametric models, prediction-error methods, Instrumental Variable method. Kalman-filters for state estimationGauss Markov, Model for vector random processes. Model Structure Selection and Diagnostics - estimation of delay and order, residual checks, properties of parameter estimates, model validation.

References:

1. PictorFykhoff , *Trends and progress in system identification*
2. Raman K. Mehra, *System identification advanced and case studies*
3. D. G .Lainioti G.N.Sarodos , *Stochastic processes, estimation and control*
4. K. J. Astrom, *Introduction to stochastic processes*

EE 2251 Industrial Instrumentation Lab

1. Study and experimentation on various transducers such as:

   a) Strain measurement
   b) Displacement measurement(using LVDT)
   c) Pressure measurement.
   d) Thermocouple, thermistor, and RTD.
   e) Speed measurement
   f) Piezoelectric transducer

2. Design, fabrication and testing of active filters.
3. Design, fabrication and testing of instrumentation amplifiers.
4. Study and interfacing of converters. A) digital to analog b) Analog to digital.
5. Interfacing of transducers with Microprocessor 8085/8086.

6. Study of Process Control Trainer for various control applications.
7. Study of virtual instrumentation.