**Computer Science & Engineering**

**Department Electives**

| Electives | Course Number | L | T | P | Credits | Semester |
|---|---|---|---|---|---|---|
| Model Checking and Software Verification | CS 570 | 3 | 0 | 0 | 6 | UG V, UG VII, PG-I, PhD |
| Modelling and Simulation of Systems | CS 572 | 3 | 0 | 0 | 6 | UG V, UG VII, PG-I, PhD |
| Markov chains and their Applications | CS 462 CS 662 | 3 | 0 | 0 | 6 | UG VII, PG, PhD |

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|---|---|
| **Course Name:** Model Checking and Software Verification | **Course Code: CS 570** |
| **Course Instructor:** | **Course Type:** Elective UG-PG |

**Description**

Arguing for program correctness is a challenging task. But it is non-optional, especially as the software has permeated our lives, in forms that are many times even safety- or business-critical. Formal Verification is an attractive and increasingly appealing alternative to simulation and testing. While the latter only explores a subset of possible behaviors, and leaves open the question of whether the unexplored behaviors may contain a fatal bug, formal verification explores all behaviors exhaustively. This course will focus on model checking as an approach to do formal verification.

**Syllabus**

Propositional and Predicate Logic (Overview); Modelling systems – Kripke Structure, Concurrent Systems, and NuSMV Model Checker; Linear-time properties – paths, traces, invariants, safety, liveness, fairness; Automata on finite and infinite words - Model checking omega-regular properties.

Temporal logics - Linear temporal logic (LTL), Computation tree logic (CTL)– Introduction to Promela and SPIN; Binary decision diagrams (BDDs) and Symbolic Model Checking.

Program Verification – Hoare Triples and Hoare Logic; Propositional satisfiability - SAT-based Model Checking (BMC, Inductive invariants), Introduction to CBMC; Predicate abstraction and Counterexample-Guided Abstraction Refinement (CEGAR).

**References**

1. Principles of Model Checking by *Christel Baier* and *Joost-Pieter Katoen*
2. Logic in Computer Science by *Michael Huth* and *Mark Ryan*
3. Model Checking (Second Edition, The Cyber-Physical Systems Series) by *Edmund Clark, Orna Grumberg, Daniel Kroening, Doron Peled,* and *Helmut Veith*

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|---|---|
| **Course Name**: Modeling and Simulation of Systems | **Course Code: CS 572** |
| **Course Instructor:** | **Course Type:** Elective (PG,UG) |

**Description**

Simulation plays a critical role in the design, analysis and optimization of complex systems in most engineering disciplines. This course focuses on the simulation of *discrete-event systems* (that is, systems in which the state is assumed to change at discrete time-instants only, as opposed to a continuously evolving system). Computer networks, manufacturing systems, clocked digital circuits and queueing systems are some examples where discrete-event simulation is widely used.

The objectives of this course are to help the student build a strong intuition of how discrete-event simulation works, and to develop the ability to model and simulate a given system effectively and interpret the results correctly. The course will be heavily based on examples from several application areas, and coding-based assignments will form a significant component of the course.
**Prerequisites:** Basic probability theory, familiarity with Python and C++.

**Syllabus**

Introduction to models and simulation, types of simulation. Introduction to Python's SimPy library using examples. Approaches to discrete-event simulation. Review of basic probability theory and Markov chains. Random number generation, Input/output analysis. Simulation use cases (queueing networks, manufacturing systems, computer networks). Parallel and distributed simulation.

**References**

1. Discrete-Event System Simulation, 5th Edition, By: Jerry Banks, Carson II, Nelson, Nicol
2. Discrete-Event Simulation: A First Course, by Leemis and Park
3. Parallel and Distributed Simulation Systems, by Richard Fujimoto
4. SimPy Documentation: https://simpy.readthedocs.io/en/latest/

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|---|---|
| **Course Name**: Markov chains and their Applications | **Course Code: CS 462/CS 662** |
| **Course Instructor:** | **Course Type:** UG and PG |

**Description**

The course deals with applications of Markov chains techniques in certain areas of computer science and of biology. The unifying aspect in these applications is the role played by mixing time analysis, which is the focus of the course.

**Syllabus**

In a typical combinatorial optimization problem, each instance $x$ is associated with a state space $S_x$, usually of size exponential in the size of $x$, where each element of $S_x$ has an associated cost (or a value). The problem is to find a state with minimum cost (or with maximum value). In the Markov chains approach to solving such a problem, a Markov chain is associated with each instance with the property that the goal state has the highest probability in the stationary distribution of the chain. Success of this approach crucially depends on the mixing time of the associated chain, that is, how quickly does the chain come close to its stationary distribution.

Markov chains have also been used to model evolution for the finite population case lending themselves to stochastic effects. For a population of size $N$ of $m$ types, a state of the chain is the labelling of the $N$ individuals each into one of the $m$ types. The population goes from one state to another through reproduction, mutation, and selection. The specific way in which each of these happens determine the the transition probability matrix of the chain. The result of the evolution modelled by the chain is given by the stationary distribution of the chain. In most cases however, it is not known how to determine the stationary distribution directly, we need to simulate the chain 'sufficiently long' and then sample from the resulting distribution to obtain statistical properties of the distribution. We need to determine the mixing time of the chain to find out how long is 'sufficiently long'. It has been established recently that the expected motion of such evolutionary chains turns out to be a dynamical system, the trajectory of which determines the mixing time properties like rapid mixing.

Approximate outline of the course: Ergodicity theorem of Markov chains. Mixing time of Markov chains. Combinatorial optimization using Markov chains. Metropolis algorithm. Notion of conductance and its relation to rapid mixing. Necessary and sufficient conditions for Markov chains approach to succeed for combinatorial optimization. Coupling of Markov chains. Markov chains modelling of molecular evolution. Quasispecies model. Viral evolution and notion of error threshold. Evolution for the finite population case. Expected motion of evolutionary Markov chains and corresponding dynamical system. Detailed analysis when the population is of two types. A qualitative understanding of the general $m$ types case.
Each student will be required to do a term paper.

**Textbooks and References**


1. Finite Markov Chains and Algorithmic Applications, Olle Haggstrom, Cambridge Univ. Press, 2002.
2. Markov Chains, JR Norris, Cambridge Univ. Press, 1997.
3. Algorithms for random Generation and Counting: A Markov Chain Approach, Alistair Sinclair, Birkhauser, 1993.
4. Markov chains and mixing times, David A. Levin, Yuval Peres, and Elizabeth Wilmer, American Mathematical Society, 2006.
5. Relevant papers.

## Institute Electives

### Technology And Society - Learning (TASLe)

Course number: SL300, SL400

**Pre-requisite(s):** None
Credits: 6

**1. Aim:** This course is envisaged to be a platform for faculty and students of IIT Goa to work on the regional problems of developmental interest. This course intends to serve as an academic avenue of the Center for Appropriate Technology for Rural Sectors (CATeRS).

**2. Methodology:** The course will have one instructor in-charge. The course can be offered in each semester, including summer term, subject to the availability of the project(s). The interested faculty members will float the projects, providing the detailed information and possible outcomes, along with the number of students required for each project. The projects will be of regional interest and involve field work, liaison with regional agencies, gathering and analysing data, documentation and reporting, and possibly design and implementation. The guidelines for project selection are as follows. The projects

(a) must involve field work,
(b) must address basic issues related to, e.g., water, medical, transportation, public policy, etc.,
(c) must be relevant to external stakeholders, such as, government, NGOs, small enterprises, etc.

**2.1 Evaluation:** Students must work as a team guided by the concerned faculty member. At the end of the course, the students are required to submit a team report in a suitable format to their faculty mentors, along with a copy to the instructor in-charge. The team will also make a presentation before a panel consisting of three faculty members, including faculty mentor and, possibly, external stake-holders.

**2.2 Grading:** The grades will be awarded for each student based on the criteria, including but not limited to, as follows.

(a) The extent of the field work and analysis. (b) Quality of the report. (c) Utility of the report to regional agencies/external stakeholders. The grade will be forwarded to the instructor in-charge by the faculty members mentoring the projects. The instructor in-charge will be responsible for submitting the grades to the Academic Office.

**3. Course outline:** Field work of five days is the integral and mandatory part of this course. An initial training module will be of 8 hours, wherein 5 hours of instructions on general concepts will be given by the instructor in-charge and 3 hours of project-specific training will be provided by the faculty mentors.

An outline of the initial training module is given below.

(i) A perspective on society, regional development and field work.

(ii) An introduction to statistical tools.

(iii) Geographical and regional data.

(iv) Data analysis techniques.

(v) Project-specific training.

**Electrical Engineering**

**Department Electives**

| Course Code | Course Name | Credit Structure | | | |
|---|---|---|---|---|---|
| | | L | T | P | C |
| EE 601 | Introduction to Switched Electrical Circuits | 2 | 1 | 0 | 6 |
| EE 602 | Advanced Digital Signal Processing | 2 | 1 | 0 | 6 |
| EE 603 | Sensors and Analog Interfacing Circuits | 2 | 1 | 0 | 6 |

**EE 601 Introduction to Switched Electrical Circuits 2-1-0-6**

Ideal switch and switching function, Voltage–current relations in switched circuits, Switched Differential Algebraic Equations and state- space models, Pulse width modulation, Practical switch realization using semiconductor devices, Practical limitations of the switches, losses and efficiency of Power switching converters. Switching circuits for DC/DC power conversion, Dynamic average modeling of switched DC/DC converter circuits, Switching circuits for Single phase AC/DC conversion, Switching circuits for inversion and class D amplification, Multilevel converters, Switched-capacitor power conversion circuits for low power applications, Synchronous rectifiers, Control strategies for variable structure systems applied to switching circuits.

References:


01. Fundamentals of Power Electronics: Robert Erickson
02. The switching function: Analysis of Power Electronic Circuits, C.C Marouchos
03. Fast Analytical Techniques for Electrical and Electronic Circuits: Vache Vorperian
04. References from recent literature
05. Data sheets from manufacturers.


**EE 602 Advanced Digital Signal Processing 2-1-0-6**

Multirate Digital Signal Processing Introduction, Decimation by a Factor D, Interpolation by a Factor I, Sampling Rate Conversion by a Rational Factor I/D, Filter Design and Implementation for sampling rate Conversion Multirate Digital Signal Processing Multistage Implementation of Sampling Rate Conversion, Applications of Multirate Signal Processing, Sampling Rate Conversion of Bandpass Signals 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. Power Speciral 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 Parametric Method Of Power Spectrum Estimation: Parametric Methods for power spectrum estimation, Relationship between Auto-Correlation and Model Parameters, AR

(Auto-Regressive) Process and Linear Prediction, Yule-Walker, Burg and Unconstrained Least Squares Methods, Sequential Estimation, Moving Average(MA) and ARMA Models Minimum Variance Method, Piscaranko's Harmonic Decomposition Methods, MUSIC Method

References:

01. Proakis and Manolakis "Digital Signal Processing Principles, Algorithms and Application," PHI.
02. Openheim AV & Schafer RW, "Discrete Time Signal Processing" PHI

**EE 603 Sensors and Analog Interfacing Circuits 2-1-0-6**

Physical Micro-sensors: Classification of physical sensors- Active and Passive sensors. Sensing mechanism and Examples: Thermal sensors, Electrical Sensors, Mechanical Sensors, Chemical and Biosensors. Sensor Applications: Cantilever array sensors, Nanotube based sensors, Nanowire based sensors. Interfacing blocks: Current mirrors, Basic CMOS gain stages, Cascode circuits. Frequency response, noise analysis in amplifiers. Differential amplifier, OPAMP design and compensation. Readout circuits, biasing circuits: BandGap Reference, Voltage Regulators, Charge-pumps, Introduction to Low-Voltage and Low-Power Circuits. Circuit design with FinFETs, Analog Layout design.

References:

01. Allen, Phillip E., and Douglas R. Holberg. CMOS analog circuit design. Oxford university press, 1987.
02. B. Razavi, Design of analog CMOS integrated circuits, Mcgraw Higher Ed, 2017
03. Kourosh Kalantar – Zadeh, Benjamin Fry, "Nanotechnology- Enabled Sensors", Springer
04. R.Jacob Baker,H.W.Li, and D.E. Boyce CMOS Circuit Design ,Layout and Simulation, Prentice-Hall of ,1998.
05. Journals from IEEE Transactions on Circuits and Systems I & II, Journal of solid state circuits
06. M.-H. Bao, Micromechanical Transducers: Pressure sensors, accelerometers, and gyroscopes by Elsevier, New York, 2000.
07. Ramon Pallas- Areny, John G. Webster, "Sensors and signal conditioning" John Wiley & Sons, 2001.
08. H. Rosemary Taylor, "Data acquisition for sensor systems", Chapman & Hall, 1997.

**Institute Electives**

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|---|---|---|---|---|---|
| EE 611 | Applied Linear Algebra in Electrical Engineering | 2 | 1 | 0 | 6 |

**EE 611 Applied Linear Algebra in Electrical Engineering 2-1-0-6**

Vector spaces, linear dependence, basis; Representation of linear transformations with respect to a basis; Inner product spaces, Hilbert spaces, linear functions; Riesz representation theorem and adjoins; Orthogonal projections, products of projections, orthogonal direct sums; Unitary and orthogonal transformations, complete orthonormal sets and Parseval's identity; Closed subspaces and the projection theorem for Hilbert spaces.; Polynomials: The algebra of polynomials, matrix polynomials, annihilating polynomials and invariant subspaces, forms.; Applications: Complementary orthogonal spaces in networks, properties of graphs and their relation to vector space properties of their matrix representations; Solution of state equations in linear system theory; Relation between the rational and Jordan forms.; Numerical linear algebra: Direct and iterative methods of solutions of linear equations; Matrices, norms, complete metric spaces and complete normal linear spaces (Banach spaces); Least squares problems (constrained and unconstrained); Eigenvalue problem.

References:

01. K. Hoffman and R. Kunze, Linear Algebra, Prentice-Hall , (1986).
02. G.H. Golub and C.F. Van Loan, Matrix Computations, Academic, 1983.
03. Bachman and L. Narici, Functional Analysis, Academic Press, 1966.
04. E.Kreyszig, introductory functional analysis with applications John Wiley, 1978.

**Mechanical Engineering**

**Department Electives**

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| ME 623 | Computer Integrated Manufacturing | 3 | 0 | 0 | 6 |
| ME 621 | Continuum Mechanics | 3 | 0 | 0 | 6 |
| ME 622 | Mathematical Methods | 3 | 0 | 0 | 6 |

**ME 610 Mathematical Methods [3-0-0-6]**

**Pre-requisite**: None

**Course level**: PG/ PhD course, Open elective

**Course content**

**Linear Algebra:** Linear vector space, Matrices and determinants, Inner product and Gram-Schmidt orthonormalization, Eigenvalues and eigenvectors, Hermitian and symmetric matrices, Methods to solve system of simultaneous equations.

**Ordinary Differential Equation:** Linear homogeneous and inhomogeneous equations for linear differential equations, Bernouilli and Riccati equations, adjoint operators, Strum- Liouville equations, Series solutions, special functions – Bessel, Legendre and Hermite equations.

**Complex variables:** Complex numbers and their properties, limits, analytic function, Cauchy Riemann equations, Singularity – Poles, Branch points and branch cuts, Taylor and Laurent series, Cauchy residue theorem and contour integration, conformal mapping.

**Vectors and Tensors:** Vector analysis, introduction to Tensor analysis, Coordinate transformation and Jacobian, Gauss divergence, Stokes theorem, Irrotational and solenoidal vector fields, Helmholtz decomposition, Metric tensor, covariant and contravariant derivatives.

**Partial Differential Equation:** Characterization of PDEs, Separation of variables- wave equation and Laplace equation in multi-dimensions, Poisson equation, eigenfunction expansion method, Green’s function, Fourier and Laplace transform and their application to differential equation.

**References**

1) Bender, C.M and Orsag S.A. (1978) *Advanced Mathematical methods for Scientists and Engineers*, McGraw-Hill

2) Horn R.A. and Johnson C.R., *Matrix analysis*, Cambridge University Press

3) Ablowitz M.J, and Fokas A.S. (1998) *Complex variable: Introduction and Applications*, Cambridge University Press,

4) Aris R. (1962) *Vectors, Tensors and the basic equations of fluid mechanics*, Dover Publications

5) Arfken, Weber, Harris (2012), *Mathematical methods for physicists*, Seventh edition, Academic Press.

**ME 623 COMPUTER INTEGRATED MANUFACTURING 3-0-0-6**

Offered to : UG/PG

Pre-requisites: Nil

Introduction to Computer Integrated Manufacturing (CIM). Computer-Aided Design (CAD)., Computer Graphics, Computer-Aided Manufacturing (CAM). CAD/CAM Integration. Industrial automation and control technologies, ADC and DAC, CNC programming, Material Handling technologies. Automatic Data Acquisition technologies. Various Manufacturing Systems: Group Technology & Cellular Manufacturing Systems, Flexible Manufacturing Systems, Robotics, Transfer lines, Automated Material Handling and Assembly Systems, Automated Guided Vehicles, Automated Storage and Retrieval System. Quality Control Systems. Computer-Aided Process Planning. Concurrent Engineering. Production Planning and Control Systems. Lean and Agile Manufacturing. Concurrent engineering, Web-based manufacturing.

**Texts/References:**


[1] S. S. Pande, Computer Graphics and Product Modeling for CAD/CAM, Narosa Publication, ISBN 978-81-8487-128-9, 2012

[2] Groover, M. P., Automation production systems, and computer-integrated manufacturing, second edition, Prentice-Hall of India, New Delhi, 2001.

[3] System approach to Computer-integrated design and manufacturing, Nanua Singh, Wiley India.1995. ISBN: 978-0-471-58517-6


**ME 621** **Continuum Mechanics** [**3-0-0-6]**

1. Introduction and essential mathematics: Concept of continuum, Vectors and Tensors, Indicial notation, Coordinate transformations, Principal values and directions, Invariants of a second-order tensor, Dyadic product, Vector and tensor calculus.

2. Kinematics of deformation: Configurations of a body, displacement, velocity, acceleration, Lagrangian and Eulerian descriptions of ow field. Deformation gradient tensor, Finite strain tensor, Infinitesimal strain, Principal strains, Dilatation, Compatibility equations. Velocity gradient tensor, Rate of deformation tensor, Spin tensor. Example of some simple flows.

3. Stress and conservation laws: Surface traction, Cauchy's stress principle, Symmetry of stress tensor, Principal stresses, Stress invariants, Stress deviator tensor. Some simple states of stress: uniform extension, pure bending, pure torsion, etc. Conservation laws: mass, linear momentum, angular momentum, and energy.

4. Constitutive law and boundary value problems: Frame indifference, Material symmetry. Constitutive equations for general linear elastic solid: isotropic, orthotropic and transversely isotropic solid. Constitutive equation for Newtonian fluid. Incompressibility. Solution of some boundary value problems of solids and fluids.

**Reference/Text books:**


1. Continuum Mechanics, A. J. M. Spencer. Dover Publications, New York.
2. Continuum Mechanics, P. Chadwick. Dover Publications.
3. Continuum Mechanics for Engineers, G. Thomas Mase and George E. Mase. CRC Press.
4. Continuum Mechanics: Foundations and Applications of Mechanics (Vol. 1), C. S. Jog. Cambridge University Press.
5. Elasticity: Theory, Applications and Numerics, Martin H. Sadd. Elsevier.
6. Theory of Elasticity, S. Timoshenko and J. N. Goodier. McGraw Hill Education.

**Institute Elective/Department Elective**

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|---|---|---|---|---|---|
| ME 650 | Finite Element Analysis | 3 | 0 | 0 | 6 |

**Humanities and Social Sciences**

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| HS 431 | HSS Institute Elective | 3 | 0 | 0 | 6 |
| HS441 | HSS Elective | 3 | 0 | 0 | 6 |

**Institute Electives**

HS 431 - Film Appreciation through World Cinema (3-0-0-6)

**Elective Course on Entrepreneurship**

HS 441 - Foundational Course in Entrepreneurship. (3-0-0-6)

**HS 431 Film Appreciation through World Cinema (3-0-0-6)**

This course introduces students to the study of cinematic works from across the world. It proposes two streams, the first, to introduce representative films of the masters: Akira Kurosawa, Ingmar Bergman, Satyajit Ray, Stanley Kubrick, and François Roland Truffaut. The masters' films will be studied critically in order to give an exposure to students to divergent cinematic styles, film theory and culturally & politically constructed modes of cinematic expressions. The second stream will employ the critical sensibilities gained from the aforementioned cinematic styles and theories in the making of short films as part of the evaluation.

The topics covered by the course include: Defining Art; defining Cinema as art - An overview, History of Cinematic Techniques, Modes of a narrative, New idiom in Indian cinema, Works of Stanley Kubrick, French cinema, *Mise-en-scene* as a Structural Method for filmmaking (Stream II)

**References:**

Nichols, Bill. *Movies and Methods. Vol.I & II.* Berkeley, Los Angeles & London: U of California P, 1996. Print.

Ascher & Pincus. *The Filmmakers Handbook* (Third Ed). New York: Plume Publications, 2007. Print.

Kaminsky, Stuart M. *Ingmar Bergman- Essays in Criticism.* London: OUP, 1975. Print.

Kanigsbay, Ira. *The Complete Film Dictionary.* Great Britain: Penguin, 1981. Print.

Richie, Donald. *The Films of Akira Kurosawa*. California: UCP, 1965. Print.

Ray, Satyajit. *My Years With Apu*. Great Britain: Faber & Faber, 1997. Print.

Truffaut. *The Films in My Life*. New York: Da Capo Press, 1978. Print.

Dickie, George, Richard Sclafani & Ronald Roblin. Eds. *Aesthetics: A Critical Anthology.* New York: St. Martin’s Press, 1989. Print.

**HS 441 Foundational Course in Entrepreneurship (3-0-0-6)**

The aim of this course is to equip students to develop an entrepreneurial mindset and become future entrepreneurs. It is designed to help them learn and practice the skills necessary to identify and develop an opportunity into a new venture. In the course, they will learn about themselves, the risks and rewards in choosing entrepreneurship as a career option, how to identify new business opportunities and quickly validate them by building a series of prototypes of their product or service and test it with an initial set of customers.

The course covers Self Discovery and Opportunity Discovery; Customer, Solution, and Lean Methodology; Problem-Solution Fit and Building MVP; Financial Planning & Team Building; Marketing, Sales, Regulations and Intellectual Property.

**References:**

Maurya, A., 2012. Running Lean: Iterate from Plan A to a Plan That Works. O'Reilly Media

Roy, R., 2012. Entrepreneurship. Oxford University Press

Gupta, T. S., 2011. Intellectual Property Law in India. Kluwer Law International

Csikszentmihalyi, M., 2008. Flow: The Psychology of Optimal Experience. Harper Perennial Modern Classics

Sarasvathy, S. D., 2009. Effectuation: Elements of Entrepreneurial Expertise. Edward Elgar Publishing Ltd.

Ries, E., 2011. The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses. The Crown Publishing Group

Kim, W. C. & Mauborgne, R., 2005. Blue Ocean Strategy. Harvard Business School Press Boston, Massachusetts