Master of Technology

in

Computer Science & Engineering

Program Outline and Details

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Version 2.6

Indian **I**nstitute of **I**nformation **T**echnology
Vadodara

1. Program Overview

MTech in Computer Science program is designed such that the students can complete it based on advanced coursework along with minor and a major project. The students interested to pursue a research oriented career are provided with an option to take up thesis work for a year in place of projects.

The first semester is aimed at laying down the foundations necessary for the computer science discipline. It gives students an opportunity to tune into the instructional philosophy and pedagogy of learning at IIIT, Vadodara. Subsequent semesters provide avenues for specializing in one or more areas of computer science.

1.1 Areas of Specialization

(a) Computer Vision, Graphics and Multimedia

The fields of graphics, vision and imaging increasingly rely on one another. This specialization provides training in computer graphics, computer vision, geometric processing and multimedia, enabling students to specialize in any of these areas and gain a grounding in the others.

Graduates will understand the basic mathematical principles underlying the development and application of new techniques in computer graphics and computer vision and will be aware of the range of algorithms and approaches available, and be able to design, develop and evaluate algorithms and methods for new problems, emerging technologies and applications.

(b) Data Analytics

It is an interdisciplinary specialization designed to meet the huge manpower shortage in the area of data analytics. The specialization trains students in computational techniques and systems to draw insights from data in a variety of application domains.

(c) Signal and Information Processing

The program has been specially designed to meet the increasing need of professionals who would be able to respond to the needs of modern day signal and data processing/analysis tasks. It is meant for students who wish to build a professional career oriented towards research and development, working at the cutting edge of technology in the area of Signal and Information Processing. The curriculum is developed keeping in view the convergence of signal and information processing paradigm with data analytics. It is a step forward towards data processing and analysis for signal processing background students.

2 Program Structure

2.1 Credit Structure of M.Tech. in Computer Science & Engineering (Project Mode)

Semester	Course Code	Courses	Credit Structure (L-T-P-C)	Credits
I		Essential Mathematics	3-0-0-3	3
		Design and Analysis of Algorithms (Foundation-1)	3-1-0-4	4
		Operating Systems (System - 1)	3-0-2-4	4
		(PE-1) Program Elective – 1	3-0-0-3	3
		Information Governance and Ethics	2-0-0-2	2
			Total	**16**
II		Modeling and Simulation	3-0-2-4	4
		Optimization Techniques (Foundation – 2)	3-0-0-3	3
		Advanced Computer Architecture (System – 2)	3-0-2-4	4
		(PE-2) Program Elective – 2	3-0-0-3	3
		Technical Writing	2-0-0-2	2
			Total	**16**
III		(PE-3) Program Elective – 3	3-0-0-3	3
		(PE-4) Program Elective – 4	3-0-0-3	3
		Elective – 1	3-0-0-3	3
		Elective – 2	3-0-0-3	3
		Minor Project		3
			Total	**15**
IV		Major Project		15
			Total	**15**
			Grand Total	**62**

2.2 Credit Structure of M.Tech. in Computer Science & Engineering (Thesis Mode)

Semester	Course Code	Courses	Credit Structure (L-T-P-C)	Credits
I		Essential Mathematics	3-0-0-3	3
		Design and Analysis of Algorithms (Foundation-1)	3-1-0-4	4
		Operating Systems (System - 1)	3-0-2-4	4
		(PE-1) Program Elective – 1	3-0-0-3	3
		Information Governance and Ethics	2-0-0-2	2
			Total	**16**
II		Modeling and Simulation	3-0-2-4	4
		Optimization Techniques (Foundation – 2)	3-0-0-3	3
		Advanced Computer Architecture (System – 2)	3-0-2-4	4
		(PE-2) Program Elective – 2	3-0-0-3	3
		Technical Writing	2-0-0-2	2
			Total	**16**
III		Thesis		15
		Research Progress Seminar		
			Total	**15**
IV		Thesis		15
		Thesis Defense		
			Total	**15**
			Grand Total	**62**

2.3 Specialization specific Program Electives

1. Computer Vision, Graphics and Visualization

PE-1: Computer Vision, Digital Image Processing, Speech Processing,
PE-2: Curves and Surfaces for Computer Graphics, Numerical Differential Geometry,
PE-3: Image Analysis, Video Processing and Analytics, Pattern Recognition
PE-4: Mesh Processing, Satellite Image Processing, Dynamics of Animation, Scientific Visualization,

2. Data Analytics

PE-1: Information Retrieval, Data Warehousing,
PE-2: Financial Data Analytics, Data Mining,
PE-3: Machine Intelligence, Pattern Recognition,
PE-4: Distributed Algorithms, Advanced Algorithms

3. Signal and Information Processing

PE-1: Embedded Systems, Speech Processing, Digital Image Processing
PE-2: Models of Signals and Systems, Advanced Digital Signal Processing
PE-3: Information Theory Inference and Learning Algorithms, Statistical Signal Processing,
PE-4: Topics in Signal Processing, Coding Theory, Compressive Sensing,

2.4 Elective Courses

Apart from the program electives, students may also opt for courses offered in other specializations as elective courses.

2.5 Course Details

2.5.1 Essential Mathematics (3-0-0-3)

Objective

Students entering PG program usually find that their mathematical foundation is inadequate to pursue research for their thesis. It is also a fact that, for them to achieve the required level of mathematical maturity entirely through self-study is difficult. This course is designed with an objective to provide the essential knowledge required to remove this inadequacy. The content of the course is designed keeping in mind the mixed audience coming from electronics and communication engineering and computer science and engineering disciplines. At the conclusion of this course, students should have a sound understanding of what mathematics is about, and should have acquired a level of mathematical literacy that would enable them to see its relevance in their own domain of knowledge.

Course Content

Module 1: Sets, Relations and Functions [4]: Order, Equivalence and Correspondence [2] (4 Hrs)

Module 2: Groups, Rings and Fields [3, 5, 2]: Permutations, Symmetries, Polynomials (8 Hrs)

Module 3: Vector Space [7]: Basis, Linear transformations, Norm and Inner-Product, Orthogonality, Metric [4]: continuity, convergence and completeness, Finite Dimensional Vector Space [7]: System of linear equations, Eigen values, Eigen vectors, Matrix inverse, Least squares and Pseudo inverse, Change of basis and similarity transform (16 Hrs)

Module 4: Introduction to Graphs and Connections with Linear Algebra: Adjacency and Incident matrices, Graph spectrum, Graph Partitioning and Clustering, Max-Min flow and Graph cuts, Shortest path algorithms [6, 2] (6 Hrs)

Text Book and References

[1] T. A. Garrity. All the Mathematics You Missed: But Need to Know for Graduate School. Cambridge University Press, 2002.
[2] Kolman, Busby, Ross. Discrete Mathematical Structures, PHI, 6th Edition
[3] A. Papantonopoulou. Algebra: Pure & Applied. Prentice Hall, 2002.
[4] G.F. Simmons. Introduction to Topology and Modern Analysis. International series in pure and applied mathematics. Krieger Publishing Company, 2003.
[5] V. P. Sinha. Symmetries and Groups in Signal Processing: An Introducuction. Signals and Communication Technology. Springer, 2010.
[6] Daniel A Spielman. Spectral graph theory and its applications. Most, i:1–75, 2007.
[7] G. Strang. Introduction to Linear Algebra. Wellsley-Cambrige Press, 2003.

2.5.2 Design and Analysis of Algorithms (3-1-0-4)

Objective

- Analyze the asymptotic performance of algorithms.
- Write rigorous correctness proofs for algorithms.
- Demonstrate a familiarity with major algorithms and data structures.
- Apply important algorithmic design paradigms and methods of analysis.
- Synthesize efficient algorithms in common engineering design situations.

Course Content

Techniques for the design and analysis of efficient algorithms, emphasizing methods useful in practice. Topics include asymptotic analysis of algorithms; sorting; search trees, heaps, and hashing; divide-and-conquer; dynamic programming; greedy algorithms; graph algorithms; and shortest paths. Advanced topics may include network flow, computational geometry, number-theoretic algorithms, polynomial and matrix calculations, and parallel computing.

References

1. Dasgupta, Sanjoy, Christos Papadimitriou, and Umesh Vazirani. *Algorithms*. McGraw-Hill, 2006. ISBN: 9780073523408.

2. Kleinberg, Jon, and Eva Tardos. *Algorithm Design*. Addison-Wesley, 2005. ISBN: 9780321295354.

2.5.4 Information Governance and Ethics (2-0-0-2)

Objectives

The purpose of this course is to investigate topics related to the handling and governance of digital information and data in organizational and networked contexts.

Course Content

A) Substantive issues and concerns e.g. accountability, decision-making, freedom, identity, intellectual property, openness, privacy, risk, security, and surveillance
B) the design and use of relevant technologies e.g. Internet, DPI, digital rights, open source, P2P, social media
C) systematic approaches and frameworks used in the regulation, governance and use of information in organizational and networked contexts e.g. copyright/left, data protection, freedom of information etc.
D) Examples from business, government, health, law, and technology will illustrate the topics investigated

References

1. The Handbook of Information and Computer Ethics, K. E. Himma and H. T. Tavani

2.5.5 Modeling and Simulation (3-0-2-4)

Course Content

Module 1: Probability Theory Refresher: Axiomatic construction of probability spaces; random variables and vectors, expected value; Moment generating functions, Characteristic functions and Laplace transforms; conditional expectations and Bayes Theorem; laws of large numbers, central limit theorem; Exponential and geometric distributions and memory less properties (7 lectures)

Module 2: The Poisson process: Arrival processes and the Poisson process; inter-arrival and waiting time distributions. PASTA property, examples (4 Lectures)

Module 3:. Renewal Theory: the key Renewal theorem and applications; Renewal Reward processes and applications, examples in ARQ schemes (4 Lectures)

Module 4: Introduction to Stochastic Processes (SPs): Definition and examples of SPs, classification of random processes according to state space and parameter space, types of SPs, elementary problems (5 Lectures)

Module 5: Discrete-time Markov Chains (DMCs): Definition and examples of DMCs; transition probability matrix, Chapman-Kolmogorov equations; calculation of n-step transition probabilities, limiting probabilities, classification of states, ergodicity, stationary distribution, transient MC; random walk and gamblers ruin problem; semi-Markov processes; applications, applications and examples: frog leaps, Brady speech model, Gilbert and Gilbert Elliott channel model etc. (8

lectures)

Module 6: Continuous-time Markov Chains (CMCs): introduction to CMC; birth- death process, Kolmogorov-Feller differential equations, infinitesimal generator, Poisson process, Time reversibility, Erlang loss formula, examples (6 Lectures)

Module 7: Brownian Motion: Wiener process as a limit of random walk; first -passage time and other problems, Application to queuing theory: Introduction to m/m/1, m/g/1, m/m/1/n, d/d/1 models (7 Lectures)

Text Books and References

[1] Sheldon Ross, Stochastic Process, 1996
[2] Bertsekas and Gallagher, Data Networks, 2000
[3] Betsekas and Tsitsiklis, Introduction to Probability

2.5.6 Optimization Methods and Signal Processing

Course Content

1. Foundations: Sequences, open and closed sets, continuous functions, vector spaces, inner products, norms, dual spaces.
2. Introduction: Unconstrained vs. Constrained Optimization and Conditions for Local and Global Optimum
3. Convexity: Convex sets and convex functions, Separation theorems, Dual Cones, Conjugate functions and Fenchel's inequality
4. Convex optimization: Linear optimization, Quadratic optimization,
5. Duality: Lagrangian, KKT, Subgradient Methods (optional)
6. Applications: Compressive sensing, Combinatorial optimization, learning theory, Convex games, Communication theory, Networks.

References

1. Convex Optimization Theory by D. Bertsekas, A. Ozdaglar, and A. Nedic.
2. Convex Optimization by Stephen Boyd
3. Optimization by Vector Space Methods, D. G. Luenberger
4. A Course in Convexity by A. Barvinok

2.5.8 Technical Writing and Research Methodology

Objectives and Course Content:

This course discusses the principles of conducting high quality research and composing decent pieces of technical writings. Besides, writing strategies for a variety type of menuscripts, including presentation slides, resume/CV, statement of purpose, and popular science articles will also be discussed.

This course adopts the concept of learning by doing, which means the students will experience through the whole process of researching, including the selection of topics, literature review, experiment design and evaluation, technical paper writing (for advanced readers) and popular science paper writing (for normal readers). The course will lay emphasis more on research and writing than on language.

The course will be divided evenly into lecture and discussion sections. The goal of discussion sections is to improve the writing and research skill of each individual student through editing and commenting on the submitted homework.

Students are expected to investigate a decent amount of efforts in learning, just like a regular graduate level course.

References

(1) How To Write & Publish a Scientific Paper, Robert Day, 5th Edition, Oryx Press/Greenwood Publishing, ISBN: 1573561657.
(2) Writing for Computer Science, Justin Zobel, 2nd Edition, Springer-Verlag, ISBN: 1852338024
(3) The Elements of Style, William Strunk Jr. and E.B. White, 4th Edition, Pearson Allyn & Bacon/Longman Publishers, ISBN: 0205313426
(4) Academic Writing for Graduate Students: Essential Tasks and Skills: A Course for Nonnative Speakers of English. John M. Swales, Christine B. Feak University of Michigan Press/ESL, ISBN: 0472082639
(5) Handbook of Technical Writing, 8th edition Gerald J. Alred (Author), Charles T. Brusaw (Author), Walter E. Oliu (Author) , ISBN: 0312352670
(6) Graduate Research: A Guide for Students in the Sciences, Robert V. Smith

3. Academic Requirement

- Maximum duration - 03 years
- Minimum CPI (for graduation) - 6.0/10.0
- Minimum CPI (for continuation in program) - 5.0/10.0
- Minimum CPI (TA/RA-ship eligibility) - 6.5/10.0 (Full) & 6.0/10.0 (Half)
- Minimum credits for M.Tech with Project/Thesis - 62 credits
- A semester load is defined as equivalent of 12 credits. A student registered for a full semester load solely by course work would typically take 4 courses. Depending on the merits of the case, the PGC may permit a student to register for a maximum of 20 credits or a minimum of 9 credits.
- In addition to general M.Tech degree, the institute also offers M.Tech degrees with specialization in any one of the specialization areas. Guidelines and requirements for degree with specialization in an area is stipulated below.
- If a student completes all the requirements for the M.Tech, but not the requirements of specialization, the student will be awarded only M.Tech in Computer Science degree

3.1 Requirements of M.Tech. in CSE with Specialization

The requirement for the specialization degree is that the student must complete at least 32 credits in area of subject to the following constraints

3.2 M.Tech. with Project

1. Minimum credits required 62
2. 44 credits of course work + 18 credits of project.
3. Minor and Major projects are in the area of specialization adding to 18 credits. (The supervisor certifies that the project is in the area of specialization.)
4. Minimum 12 credits are earned from the basket of specialization specific program electives.
5. Students may opt for an industrial project as major project.

3.3 M.Tech. by Thesis

1. Minimum credits required 62
2. 32 credits of course work + 30 credits of thesis work.

Student entering the M.Tech by Thesis program is expected to carry out research during the second year, beginning in the Summer semester (around May) and ending around the next Summer semester (around June/July). The student will carry out research under the supervision of a faculty member at IIIT, Vadodara in an area of mutual interest.

On completion of first year, three member Research Progress Committee will be formulated for each student based on his/her area of research.

Students will have to present the status of their research work continuously in the form of Research Progress Seminars scheduled in July/August, November/December and March/April in front of the committee. Finally, at the time of thesis evaluation, an thesis examination committee will be constituted in consultation with the Dean Academic Program. A Public Thesis Defense will be scheduled after successful completion of research progress seminars and thesis evaluation by examiners.

3.4 Switching Programs

It is possible to switch program of study mid-way. Interested students who have demonstrated excellent research potential have the opportunity to convert to the PhD program.