Content for PhD Qualifying Examination Sub-Areas

Research Area_1: Artificial Intelligence, Machine Learning and Data Mining

Data Mining

Need for data mining, Preprocessing: Dimensionality reduction, Missing values, Normalization & standardization, Noise and outlier detection, Data smoothening Classification: Decision tree, K-nearest neighbors, Naive Bayesian classifiers, Rule based classifiers, Support vector machine, Underfitting/overfitting, Ensemble classifiers, Classification evaluation and model selection. Association rule mining, Frequent item set mining, Apriori and its optimizations, FP-growth , Efficient Rule generation, Other measures (lift, interest etc), correlation, Hierarchy based Frequent item set mining, Clustering Type of clustering Partitioning clustering k-means, k-mediod (PAM) algorithms, Hierarchical clustering algorithms, Agglomerative algorithms--s-link, complete link, average link etc, Divisive algorithms, Density based clustering, DBSCAN, OPTICS algorithms, Grid based Clustering, Cluster evaluation.

Machine Learning

Introduction Polynomial Curve Fitting, Overfitting/underfitting & Regularization, Curse of Dimensionality**. Some Useful Concepts** MAP Hypothesis, Minimum Description Length (MDL) principle, Expectation Maximization (EM) Algorithm, Bias-variance decomposition, Lagrange Multipliers Mixture of Gaussians, PCA & SVD. Linear Models for Regression, Linear Basis Function Models. Linear Models for Classification, Discriminant Functions (binary & multiple classes), least square, Fisher's Linear Discriminant, Perceptron Algorithm, Probabilistic Generative Classifiers, Naive Bayes Classifier, robabilistic Discriminative Classifiers, Logistic Regression, Probit Regression. Non-linear Models, Decision Tress, Ensemble Classifiers, ANN, Instance-based Learning, K-NN, Case-based Reasoning. Support Vector Machines, Graphical Models, Bayesian Belief Networks, Hidden Markov Models .Unsuprevised Learning K-means, Mixture Models Reinforcement Learning, Q Learning, Non-deterministic rewards & actions, Temporal difference learning, Generalization

Artificial Intelligence

Problem Solving by Searching

Uninformed and informed search techniques including breadth first search, depth first search, depth limited search, iterative deepening search, Avoiding repeated states. Heuristics based searches including Greedy best first search, A* search, memory bounded heuristic search. Local search algorithms and problem solving including Hill climbing, Simulated annealing, local beam search, genetic algorithms etc. Adversarial search, alpha beta pruning, games problems.

Knowledge and Reasoning

Knowledge based agents, Propositional logic, syntax and semantics, equivalence, validity and satisfiability, forward and backward chaining, resolution. First order logic (FOL), syntax and semantics of FOL, Representation of real world domain using propositional and first order logic, Unification and lifting, quantifiers, Inference rules, conjunctive normal form for FOL, resolution for FOL. Reasoning systems for categories, semantic networks, description logic.

Uncertain knowledge and Reasoning

Uncertainty representation, basic probability notation, Inference using joint probability distribution table, Bayes' rule and its applications. Bayesian Networks: representation and semantics, inference in Bayesian Networks, Alternatives for Uncertain Reasoning: Rule Based Methods, Dempster-Shafer Theory, Fuzzy sets, Fuzzy Logic.

Learning

Inductive Learning, Decision trees, Ensemble learning, knowledge in learning, explanation based learning, statistical learning, learning with complete data, Maximum-likelihood parameter learning, Naive Bayes models, Gaussian Mixture Models, hidden Markov models, Instance based learning, Nearest neighbour models, kernel models, Kernel machines, Neural Networks models for learning, reinforcement learning.

Problem Solving by Searching

Uninformed and informed search techniques including breadth first search, depth first search, depth limited search, iterative deepening search, Avoiding repeated states. Heuristics based searches including Greedy best first search, A* search, memory bounded heuristic search. Local search algorithms and problem solving including Hill climbing, Simulated annealing, local beam search, genetic algorithms etc. Adversarial search, alpha beta pruning, games problems.

Research Area_2: Computer Architecture, Embedded Systems & Robotics

Computer Architecture

Computer Organization vs. Computer Architecture, Structure and Functions of various components of a computer system, Top level view of computer function, Instruction fetch and execution, Interrupts and I/O functions, Computer Memory System Overview, Memory hierarchy, Cache Memory Organization and Design, Performance measurement of two level memory system, I/O Modules and Organization, I/O Techniques, Arithmetic and Logic Unit, Data Representation- Integer & Floating Point Representation (IEEE-754) and Arithmetic Operations, Instruction Set characteristics and functions, Intel's x86 ISA, Instruction Addressing Modes, Intel's x86 Addressing Modes and Instruction Formats, Processor Organization, RISC and CISC Architectures, Instruction-level parallelism and Superscalar Processors and Design Issues, P-4 Super Scalar Pipeline, Micro Operations, Design Concepts, Hardwired and Micro-Programmed Control Design Issues, Micro Instruction Sequencing Methods.

Embedded Systems & Robotics- Introduction to Embedded Systems, Real Time Embedded Systems, Embedded system components, embedded processors and memory structures, Programming and Software for Embedded Processors, Peripheral Interface Controller (PIC) family of processors, ARM Processor, Embedded Systems I/O, and Networking, Sensing and Sensors, Robotic Vision, Mobility, Statics and Dynamics, Robot Kinematics, Human Robot Interaction.

<h1 style="text-align: center;">Research Area_3: Data Warehousing Databases Advanced Databases</h1>

Data Warehousing

Introduction to Data Warehousing
Present Business Scenario, Operational and Informational Systems, What is a Data Warehouse? Applications of Data Warehouse, Problems with Data Warehousing

Data Warehouse Components, Processes & Architecture
Source Systems, Data Staging Area, Presentation Server, Data Marts, Operational Data Store (ODS), Metadata, Information Delivery, Basic Processes of a Data Warehouse

Data Warehouse Design
Dimensional Modeling Basics, Facts, Dimensions, & Star Schemas, Snowflake & Starflake Schemas, Design Steps, ER modeling vs. Dimensional modeling, Surrogate Keys, Changing Dimensions, Conformed Dimensions, Factless Fact Tables, Minidimensions & Outriggers, Role-playing Dimensions, Multi-valued Dimensions

Extraction, Transformation, & Loading (ETL)
Data Extraction, Data Transformation, Data Loading, ETL Data Structures, ETL Tools: Build or Buy?

Online Analytical Processing (OLAP)
Need for OLAP, Features & Functions, ROLAP, MOLAP, HOLAP, & DOLAP, OLAP Implementation, OLAP Tools

Performance Enhancing Techniques
Partitioning, Aggregation, Materialization of Views, Bitmap Indexes

SQL Features for DW
CUBE Operator, Roll-up Operator Top-N Queries, Window Queries, Real-Time Data Warehousing

Advanced Databases

Multidimensional Indexing: kD tree, Quad Tree, Partitioned Hash Indexes, R-tree

Query Opitmization: Heuristic optimization, Cost Based Optimization, Hybrid Approach, System-R Approach, View Materialization, Role of Metadata in Query Optimization

Distributed Database : Motivation & complexities, Homogeneous & Heterogeneous Distributed Databases, Distributed Data Storage, Data Fragmentation, Data Replication, Fragmentation & Replication, Data Transparency, Distributed Query Processing

Advanced Topics: NoSQL, Big Table, Big Data Management

Database Systems

Introduction to Database Systems

Objectives/Motivation, Evolution of Database Systems, Overview of a DBMS, Advantages of a DBMS, Database System Architecture
Data Modeling: Overview of Data Modeling**,** Entity-Relationship (ER) Modeling, Enhanced ER (EER) Modeling

Understanding Relational Model: Relational Model Concepts**,** Relation as a Mathematical Model**,** ER, EER to Relational model

Database Design through Functional Dependencies & Normalization: Functional Dependencies**,** Normal Forms: 1NF, 2NF, 3NF, BCNF**,** Criterion for Good Database Design**,** Multi-valued dependencies: 4NF

Query Language: Relational Algebra, SQL

Indexing: Indexing Structures, Primary & Secondary Indexes**,** Tree-structured Indexes**,** Hash-based Indexes**,** Bitmap Indexes

Query Processing: Introduction to Operator Evaluation**,** Algorithms for Relational Operators**,** Materialized and Pipelined Evaluation

Transaction management: Concurrency Control & Crash Recovery: Transaction Management Overview**,** Serial Schedule & Serializability**,** Conflict Serializability**,** View Serializability**,** Testing for Serializability**,** Recoverability & Cascadeless Schedules**,** Concurrency Control**,** Locking, Time-stamping**,** Crash Recovery**,** Log-Based**,** Shadow Paging

Software Engineering

Software Engineering Concepts and Methodologies; Software Requirements Analysis and Specification, Software Architecture, Detailed Design; Techniques of Design; Object Oriented Design, UML, Estimation; Software Project Planning, Integration & Validation; Software Quality Assurance; Software Maintenance; Automated Tools in Software Engineering.

<u>Research Area_4: High Performance Computing and Distributed Systems</u>

Parallel & High Performance Computing
- **General understanding**
  Shared Memory & Distributed Memory Systems, Concurrency & Multi-threaded systems and Multi-processor systems
- **Multicore-systems**
  Multi-core computing - homogeneous and heterogeneous, NUMA, and GPGPU computing;
- **Concurrency**
  Shared Data and Shared Memory Data Structures; Mutual Exclusion and solutions (for multi-processor systems)
- **High Performance Systems and Solutions; Scaling Models and Techniques; Development Models; High Performance Environments**
  Interconnects, Mapping, Scheduling, and Load Balancing.

Distributed Systems
- **Processes**
  Threads; Virtualization; Client-server structure; code migration;
- **Communication**
  RPC, Message & Stream Oriented Communication; Multicast communication;
- **Naming**
  Flat, structured and attribute based naming; DHT; DNS; LDAP;
- **Synchronization**
  Logical clocks; Mutual exclusion algorithms; Election Algorithms;
- **Caching, Consistency and Replication**
  Distributed Caches, Data centric consistency models; client-centric consistency models; replica management; consistency protocols;
- **Fault Tolerance**
  Failure models; Process resilience: agreement in faulty systems; failure detection; reliable client-server communication; reliable multicasting;
- **Distributed File Systems**
  Architecture; communication; naming; synchronization; consistency & replication; fault tolerance;

Introduction, Multimedia Authoring and Multimedia Data Representations

Introduction to Multimedia What is Multimedia / Components of Multimedia / Multimedia and Hypermedia / World Wide Web (HTTP, HTML, XML, SMIL) / Overview of Multimedia Software Tools (for Music Sequencing and Notation, Digital Audio, Graphics and Image Editing, Video Editing, Animation, Multimedia Authoring

Multimedia Authoring and Tools Multimedia Authoring (Metaphors, Production, Presentation, Automatic Authoring) / Some Useful Editing and Authoring Tools / Virtual Reality Manipulation Language

Graphics and Image Data Representations Graphics/Image Data Types (1-Bit Images, 8-Bit Gray-Level Images, Image Data Types, 24-Bit Color Images, 8-Bit Color Images, Color Lookup Tables) / Popular File Formats (GIF, JPEG, PNG, TIFF, EXIF, Graphics Animation Files, PS, PDF, Windows WMF & BMP, PAINT, PICT, PPM)

Color in Image and Video Color Science (Light and Spectra, Human Vision, Spectral Sensitivity of the Eye, Image Formation, Camera Systems, Gamma Correction, Color-Matching Functions, CIE Chromaticity Diagram, Color Monitor Specifications, Out-of-Gamut Colors, White-Point Correction, XYZ to RGB Transform, Transform with Gamma Correction, L*a*b* (CIELAB) Color Model, More Color-Coordinate Schemes, Munsell Color Naming System) / Color Models in Images (RGB, CMY, CMYK, Transformation from one model other, Printer Gamuts) / Color Models in Video (Video Color Transforms, YUV Color Model, YIQ Color Model, YCbCr Color Model)

Fundamental Concepts in Video Types of Video Signals, Analog Video (NTSC, PAL, SECAM) / Digital Video (Chroma Subsampling, CCIR Standards for Digital Video, High Definition TV)

Basics of Digital Audio Overview of Physics of sound / Digitization of Sound / Musical Instrument Digital Interface / Quantization and Transmission of Audio

Multimedia Data Compression

Lossless Compression Algorithms Introduction, Basics of Information Theory, Run-Length Coding, Variable-Length Coding, Shannon–Fano Algorithm, Huffman Coding / Adaptive Huffman Coding / Dictionary-Based Coding / Arithmetic Coding / Lossless Image Compression / Differential Coding of Images / Lossless JPEG

Lossy Compression Algorithms Distortion Measures / The Rate-Distortion Theory / Quantization / Uniform Scalar Quantization / Non-uniform Scalar Quantization / Vector Quantization / Transform Coding / Discrete Cosine Transform / Karhunen–Loeve Transform / Wavelet-Based Coding / Continuous Wavelet Transform / Discrete Wavelet Transform / Wavelet Packets / Embedded Zero-tree of Wavelet Coefficients / The Zerotree Data Structure / Successive Approximation Quantization / EZW Example / Set Partitioning in Hierarchical Trees

Image Compression Standards The JPEG Standard / main steps of JPEG / JPEG Modes / JPEG Bitstream / The JPEG2000 Standard / Main Steps of JPEG2000 Image Compression / Region-of-Interest Coding / Comparison of JPEG and JPEG2000 Performance / The JPEG-LS Standard / Prediction / Context Determination / Residual Coding / Near-Lossless Mode / Bilevel Image Compression Standards JBIG and JBIG2

Basic Video Compression Techniques and Video Coding Video Compression Based on Motion Compensation / Search for Motion Vectors (Sequential, 2D Logarithmic, and Hierarchical search) / Standards H.261 and H.263 / Overview of MPEG-1, 2, 4, 7, and 21

Audio Compression Techniques Basic Compression Techniques / G.726 ADPCM / MPEG Audio Compression / Psychoacoustics / MPEG Audio Coding

Multimedia System Architecture

Media and Streams, Multimedia System Architecture Media Types / Media Classification / Continuous Media / Discrete Media / Time-dependent Media / Time-independent media / Transmission Modes / Notion of Logical Data Unit

Storage Media for Multimedia Overview of magnetic storage / Optical Storage (CD-ROM, CD-WORM, CD-RW, DVD)

Multimedia Operating Systems Real-time requirements / Resource Management / Process Management / File System & Disk Scheduling Algorithms / Architecture

Multimedia communication systems Transport subsystems / QoS / Resource Management & the trends

Multimedia Database Management Systems Characteristics / Data Analysis / Data Structure / Operations

Multimedia Application Architecture

Overview of Multimedia Document, Hypertext & MHEG Document Architecture / Hypertext / Relations expressed by links / MHEG

Overview of Multimedia User Interface Characteristics / User friendliness / User Interface through Video and Sound

Multimedia Application Architecture Multimedia Food Chain / Media Preparation / Media Composition / Media Integration / Media Communication / Media Consumption / Overview of Virtual Reality Systems

Advanced Topics

Synchronization Notion of synchronization / Presentation Requirements / Reference Model & Specification

Content-Based Retrieval in Digital Libraries How Should We Retrieve Images? / Current Image Search Systems / Relevance Feedback / Quantifying Results / Querying on Videos / Querying on Other Formats / Outlook for Content-Based Retrieval

Multimedia Network Communications and Applications Quality of Multimedia Data Transmission / Multimedia over IP / Multimedia over ATM Networks / Transport of MPEG-4 / Media- on-Demand (MOD)

Image Processing & Computer Vision

Introduction, Mathematical and Physical Background

Introduction Motivation / why is Computer Vision Difficult? / Image Representation and Image Analysis Tasks

The Image, its Representations and Properties Image Representations, a Few Concepts / Image Digitization / Sampling / Quantization / Digital Image Properties / Metric and Topological Properties of Digital Images / Histograms / Entropy / Visual Perception of the Image / Image Quality / Noise in Images / Color Images / Physics of Color / Color Perceived by Humans / Color Spaces / Palette Images / Color Constancy / Cameras: An Overview / Photosensitive Sensors / A Monochromatic Camera / A Color Camera

The Image, its Mathematical and Physical Background Overview / Linearity / The Dirac Distribution and Convolution / Linear Integral Transforms / Images as Linear Systems / Introduction to Linear Integral Transforms / 1D Fourier Transform / 2D Fourier Transform / Sampling and the Shannon Constraint / Discrete Cosine Transform / Wavelet Transform / Eigen-Analysis / Singular Value Decomposition / Principle Component Analysis / Other Orthogonal Image Transforms / Images as Stochastic Processes / Image Formation Physics / Images as Radiometric Measurements / Image Capture and Geometric Optics / Lens Aberrations and Radial Distortion / Image Capture from a Radiometric Point of View / Surface Reflectance

Data Structures for Image Analysis Levels of Image Data Representation / Traditional Image Data Structures / Matrices / Chains / Topological Data Structures / Relational Structures / Hierarchical Data Structures / Pyramids / Quadtrees / Other Pyramidal Structures

Image Pre-processing, Segmentation and Mathematical Morphology)

Image Pre-Processing Pixel Brightness Transformations / Position-Dependent Brightness Correction / Gray-Scale Transformation / Geometric Transformations / Pixel Co-ordinate Transformations / Brightness Interpolation / Local Pre-Processing / Image Smoothing / Edge Detectors / Zero-Crossings of the Second Derivative / Scale in Image Processing / Canny Edge Detection / Parametric Edge Models / Edges in Multi-Spectral Images / Local Detection by Local Pre-Processing Operators / Detection of Corners (Interest Points) / Detection of Maximally Stable Extremal Regions / Image Restoration / Degradations That are Easy to Restore / Inverse Filtration / Wiener Filtration

Segmentation Thresholding / Threshold Detection Methods / Optimal Thresholding / Multi-Spectral Thresholding / Edge Based Segmentation / Edge Image Thresholding / Edge Relaxation / Border Tracing / Border Detection as graph Searching / Border Detection as Dynamic Programming / Hough Transforms / Border Detection Using Border Location

Information / Region Construction from Borders / Region Based Segmentation / Region Merging / Region Splitting / Splitting and Merging / Watershed Segmentation / Region Growing Post-Processing / Matching / Matching Criteria / Control Strategies of Matching / Evaluation Issues in Segmentation / Supervised Evaluation / Unsupervised Evaluation

Mathematical Morphology Basic Morphological Concepts / Four Morphological Principles / Binary Dilation and Erosion / Hit or Miss Transformation / Opening and Closing / Gray-Scale Dilation and Erosion / Top Surface, Umbra, and Gray-Scale Dilation and Erosion / Umbra Homeomorphism Theorem, Properties of Erosion and Dilation, Opening and Closing / Top Hat Transformation / Skeletons and Object Marking / Homotopic Transformations / Skeleton, Maximal Ball / Thinning, Thickening, and Homotopic Skeleton / Quench Function, Ultimate Erosion / Ultimate Erosion and Distance Functions / Geodesic Transformations / Morphological Reconstruction / Granulometry / Morphological Segmentation and Watersheds / Particles Segmentation, Marking, and Watersheds / Binary Morphological Segmentation / Gray-Scale Segmentation, Watersheds

Shape Description, Object Recognition and Image Understanding

Shape Representation and Description   Region Identification / Contour-Based Shape Representation and Description / Chain Codes / Simple Geometric Border Representation / Fourier Transforms of Boundaries / Boundary Description using Segment Sequences / B-Spline Representation/Other Contour-Based Shape Description Approaches / Shape Invariants / Region-Based Shape Representation and Description / Simple Scalar Region Descriptors / Moments / Convex Hull / Graph Representation Based on Region Skeleton / Region Decomposition / Region Neighborhood Graphs / Shape Classes

Object Recognition Knowledge Representation / Statistical Pattern Recognition / Classification Principles / Classifier Setting / Classifier Learning / Support Vector Machines / Cluster Analysis / Neural Nets / Feed-Forward Networks / Unsupervised Learning / Hopefield Neural Nets / Syntactic Pattern Recognition / Grammars and Languages / Syntactic Analysis, Syntactic Classifier / Syntactic Classifier Learning, Grammar Inference / Recognition as Graph Matching / Isomorphism of Graphs and Sub-Graphs / Similarity of Graphs / Optimization Techniques in Recognition / Genetic Algorithms / Simulated Annealing / Fuzzy Systems / Fuzzy Sets and Fuzzy Membership Functions / Fuzzy Set Operators / Fuzzy reasoning / Fuzzy System Design and Training / Boosting in Pattern Recognition

Image Understanding Image Understanding Control Strategies / Parallel and Serial Processing Control / Hierarchical Control / Bottom-Up Control / Model- Based Control / Combined Control / Non-Hierarchical Control / RANSAC: Fitting via Random Sample Consensus / Point Distribution Models / Active Appearance Models / Pattern Recognition Methods in Image Understanding / Classification-Based Segmentation / Contextual Image Classification / Boosted Cascade of Classifiers for Rapid Object Detection / Scene Labeling and Constraint Propagation / Discrete Relaxation / Probabilistic Relaxation / Searching Interpretation Trees / Semantic Image Segmentation and Understanding / Semantic Region Growing / Genetic Image Interpretation / Hidden Markov Models / Coupled HMMs / Bayesian Belief Networks / Gaussian Mixture Models and Expectation-Maximization

3D-Vision and its uses

3D Vision, Geometry 3D Vision Tasks / Marr's Theory / Other Vision Paradigms: Active and Purposive Vision / Basics of Projective Geometry / Points and Hyperplanes in Projective Space / Homography / Estimating Homography from Point Correspondences / A Single Perspective Camera / Camera Model / Projection and Back-Projection in Homogeneous Coordinates / Camera Calibration from a Known Scene / Scene Reconstruction from Multiple Views / Triangulation / Projective Reconstruction / Matching Constraints. Bundle Adjustment / Upgrading the Projective Reconstruction, Self-Calibration / Two Cameras, Stereopsis / Epipolar Geometry Fundamental Matrix / Relative Motion of the Camera Essential Matrix / Decomposing the Fundamental Matrix from Point Correspondences / Rectified Configuration of Two Cameras / Computing Rectification / Three Cameras and Trifocal Tensor / Stereo Correspondence Algorithms / Active Acquisition of Range Images / 3D Information from Radiometric Measurements / Shape from Shading / Photometric Stereo

Use of 3D Vision Shape from X / Shape from Motion / Shape from Texture / Other Shape from X Techniques / Full 3D Objects / 3D Objects, Models, and Related Issues / Line Labeling / Volumetric Representation, Direct Measurements / Volumetric Modeling Strategies / Surface Modeling Strategies / Registering Surface Patches and their Fusion to get a Full 3D Model / 3D Model-Based Vision / General Considerations / Goad's Algorithm / Model-Based Recognition of Curved Objects from Intensity Images / Model-Based Recognition Based on Range Images / 2D View-Based Representations of a 3D Scene / Viewing Space / Multi-View Representations and Aspect Graphs / Geons as a 2D View-based Structural Representation / Visualizing 3D Real-World Scenes Using Stored Collections of 2D Views / 3D Reconstruction from an Unorganized Set of 2D Views

Advanced Topics

Advanced Techniques for Segmentation Mean Shift Segmentation / Active Contour Models - Snakes / Traditional Snakes and Balloons / Extensions / Gradient Vector Flow Snakes / Geometric Deformable Models - Level Sets and Geodesic Active Contours / Fuzzy Connectivity / Towards 3D Graph-Based Image Segmentation / Simultaneous Detection of Border Pairs / Sub-optimal Surface Detection / Graph Cut Segmentation / Optimal Single and Multiple Surface Segmentation

Texture Statistical Texture Description / Methods Based on Spatial Frequencies / Co-occurrence Matrices / Edge Frequency / Primitive Length (Run Length) / Laws' Texture Energy Measures / Fractal Texture Description / Multiscale Texture Description - Wavelet Domain Approaches / other Statistical Methods of Texture Description / Syntactic Texture Description Methods / Shape Chain Grammars / Graph Grammars / Primitive Grouping in Hierarchical Textures / Hybrid Texture Description methods / Texture Recognition Method Applications

Computer Graphics

Introduction and Basic Concepts

Introduction Image Processing as Picture Analysis / The Advantages of Interactive Graphics / Representative Uses of Computer Graphics / Classification of Applications / Development of Hardware and Software for Computer Graphics / Conceptual Framework for Interactive Graphics.

Basic Raster Graphics Algorithms for Drawing 2d Primitives Overview / Scan Converting Lines / Scan Converting Circles / Scan Convertiing Ellipses / Filling Rectangles / Fillign Polygons / Filling Ellipse Arcs / Pattern Filling / Thick Primiives / Line Style and Pen Style / Clipping in a Raster World / Clipping Lines / Clipping Circles and Ellipses / Clipping Polygons / Generating Characters / SRGP_copyPixel / Antialiasing.

Graphics Hardware Hardcopy Technologies / Display Technologies / Raster-Scan Display Systems / The Video Controller / Random-Scan Display Processor / Input Devices for Operator Interaction / Image Scanners.

Transformations and Viewing in 3D

Geometrical Transformations 2D Transformations / Homogeneous Coordinates and Matrix Representation of 2D Transformations / Composition of 2D Transformations / The Window-to-Viewport Transformation / Efficiency / Matrix Representation of 3D Transformations / Composition of 3D Transformations / Transformations as a Change in Coordinate System.

Viewing in 3D   Projections / Specifying an Arbitrary 3D View / Examples of 3D Viewing / The Mathematics of Planar Geometric Projections / Implementing Planar Geometric Projections / Coordinate Systems.

3D Representation and Modeling

Representing Curves and Surfaces Polygon Meshes / Parametric Cubic Curves / Parametric Bicubic Surfaces / Quadric Surfaces.

Solid Modeling Representing Solids / Regularized Boolean Set Operations / Primitive Instancing / Sweep Representations / Boundary Representations / Spatial-Partitioning Representations / Constructive Solid Geometry / Comparison of Representations / User Interfaces for Solid Modeling.

Adding Realism and Color

Achromatic and Colored Light Achromatic Light / Chromatic Color / Color Models for Raster Graphics / Reproducing Color / Using Color in Computer Graphics.

The Quest for Visual Realism Why Realism? / Fundamental Difficulties / Rendering Techniques for Line Drawings / Rendering Techniques for Shaded Images / Improved Object Models / Dynamics / Stereopsis / Improved Displays / Interacting with Our Other Senses / Aliasing and Antialiasing.

Visible-Surface Determination Functions of Two Variables / Techniques for Efficient Visible-Surface Determination / Algorithms for Visible-Line Determination / The z-Buffer Algorithm / List-Priority Algorithms / Scan-Line Algorithms / Area-Subdivision Algorithms / Algorithms for Octrees / Algorithms for Curved Surfaces / Visible-Surface Ray Tracing.

Illumination And Shading Illumination Modeling / Shading Models for Polygons / Surface Detail / Shadows / Transparency / Interobject Reflections / Physically Based Illumination Models / Extended Light Sources / Spectral Sampling / Improving the Camera Model / Global

Illumination Algorithms / Recursive Ray Tracing / Radiosity Methods / The Rendering Pipeline.

Advanced Topics

Advanced Raster Graphic Architecture Simple Raster-Display System / Display-Processor Systems / Standard Graphics Pipeline / Introduction to Multiprocessing / Pipeline Front-End Architecture / Parallel Front-End Architectures / Multiprocessor Rasterization Architectures / Image-Parallel Rasterization / Object-Parallel Rasterization / Hybrid-Parallel Rasterization / Enhanced Display Capabilities.

Advanced Geometric and Raster Algorithms Clipping / Scan-Converting Primitives / Antialiasing / The Special Problems of Text / Filling Algorithms / Making copyPixel Fast / The Shape Data Structure and Shape Algebra / Managing Windows with bitBlt / Page Description Languages /

Advanced Modeling Techniques Extensions of Previous Techniques / Procedural Models / Fractal Models / Grammar-Based Models / Particle Systems / Volume Rendering / Physically Based Modeling / Special Models for Natural and Synthetic Objects / Automating Object Placement.

Computer Networks:

This course introduces concepts, terminologies and techniques used in computer networking. The objective of this course is to introduce students to functions of different layers, protocols and different components of a modern day computer network. Example network covered in this course is the Internet.

Introduction: Uses of Computer Networks, Network Hardware: The Network Edge, Network Core, Access Networks; ISPs and Internet Backbones, Delay and Loss in Packet Switched Networks, Network Software: Protocol Hierarchies, and their Service Models, Reference Models (OSI, TCP/IP)

Application Layer: Hypertext Transfer Protocol, HTTP Message Format, Cookies, Conditional GET. File Transfer Protocol: FTP, TFTP. Mail Transfer Protocols (SMTP, POP3, MIME), Domain Name Systems (DNS), P2P File Sharing

Transport Layer: Multiplexing, Demultiplexing, UDP, Principles of Reliable Data Transfer (Go-Back-N, and Selective Repeat). Introduction to Socket Programming; TCP, UDP, Simple Client Server Application;

TCP: RTT Estimation and Timeout, TCP Flow Control; TCP Error Control and Congestion Control, SCTP protocol.

Network Layer: Virtual Circuits and Datagram Networks, Inside a Router, Forwarding and Addressing in the Internet. IPv4 Addressing, IPv6 Addressing, Routing Algorithms: Shortest Path, Flooding, Link State, Distance Vector, and Hierarchical Routing, Routing in the Internet: RIP, OSPF, Border Gateway Protocol (BGP), and Multicast Routing Protocols: DVMRP, MOSPF, PIM-SM, PIM-DM.

Data Link Layer: Services, Error Detection and Correction Techniques (Parity Checks, Checksums, CRC); Multiple Access Protocol: TDM, FDM, Slotted ALOHA, Pure ALOHA, CSMA, CSMA/CD, Local Area Networks, Ethernet, Point to Point Protocol. Link Virtualization: Asynchronous Transfer Mode (ATM), Multi Protocol Label Switching (MPLS), Link Layer Addressing: MAC Addresses, ARP, RARP , DHCP, Interconnections: Hubs, Bridges, and Switches.

Physical layer: Bandwidth limited signals, Fourier analysis, Guided and Unguided media, Signal encoding, Maximum data rate, etc.

Mobile Computing

Introduction to Mobile Communications and Computing, Introduction to the concepts of mobility and roaming, Types of mobility, Types of Mobile Networking environments: Personal, Local, Metropolitan Area and Wide Area, Cellular forms of Mobility: 2 G, 2.5 G, 3 G, 4 G and evolving directions towards so-called 5 G, Medium Access Control for Wireless Protocols, Mobile Network Layer, Mobile Transport Layer, Data Dissemination, Mobile Ad

hoc Networks (MANETs), Protocols and Tools. Mobile IPv4 and Mobile IPv6 environments: basics, challenges and emerging trends, Hand-off issues involving mobility, Security issues, Energy-efficiency issues, Body-safety aspects: Myths versus Reality, VoIP over Mobile Networks, Video streaming over mobile networks, Ad-hoc and Infrastucture-based mobility: benefits and issues involved, Mobile Routing Algorithms and Protocols, Mobile Access Routers, Mobile VPN, Mobile Clouds.

Network Security

Overview of Network Security, Introduction to Cryptography, Secret Key Cryptography, Confidentiality using Symmetric Encryption, Public Key Cryptography, Integrity, Authentication and Non-Repudiation, Public Key Infrastructure, Security Protocols-: Needham Schroeder Protocol, Kerberos, IPSec: AH and ESP, Web security using SSl, Security Protocols-: E-cash and secure electronic transaction (SET), Pretty Good Privacy, and S/MIME, Common attacks: Passive & Active forms, DES, 3-DES, AES, RSA, DSA, ECC. Firewalls, VPNs, IDS, Anti-Malware strategies and Mechanisms.

Advance Topics in Computer Networks

Introduction: Internet Architecture and design principles, Challenges & Solutions Resource Management: Congestion control principles, Hop-by-hop vs. End-to-end congestion control, Explicit vs. Implicit Feedback, Fair Queuing, Flow control, TCP variants (Tahoe, Reno, Vegas, New-Ren o, SACK, Westwood),

Internetworking: Design Principles, IP Design, Inter-domain Routing vs. Inter-domain Routing, Challenges in Internet Routing, Security challenges/Issues and solutions for Inter-domain Routing, Adaptive Routing, Multipath and QoS Routing, Scalable & Reliable Application layer Multicast Routing, Multi Protocol label Switching (MPLS) and Generalized-MPLS

Wireless Networks: Multihop Wireless Networks and Adhoc routing, Wireless WAN, TCP performance Issues and improvement in Wireless Networks. Network Applications & Services: Overlay Networks: Resilient Overlay Networks (RON), lookup Problem in P2P Networks, Scalable P2P lookup Service for, Internet Applications, Chord Protocol, Content Distribution Networks, Cloud and Data Center Networks, DNS and Naming System, DNS and CDN, HTTP and CDN, Coral CDN, DNS caching and performance

Research Area_7: Algorithms & Theoretical Computer Science

Data Structures and Algorithms

Algorithm analysis and asymptotic notation. Sorting and searching algorithms and applications. Design, implementation and applications of data structures including stacks, queues, priority queues, linked lists, hash table, heap, binary search tree, balanced binary search tree. Algorithm design techniques like Divide and Conquer, Greedy Approach, Dynamic Programming, Backtracking, Branch & Bound for designing algorithms. P, NP, NP Completeness. Theory of Computations- Finite automata and regular languages-equivalences, closure properties; Context free languages and push down automata-equivalences, closure properties; concepts in parsing; Turing machines; Computability and decidability-universal Turing Machine; recursive functions; church-Turing hypothesis; complexity classes - P, NP, reducibility and NP completeness.

Discrete Structures for Computer Science

Sets & operation on sets; relations & equivalence relations; number theory; weak & strong form of mathematical induction; principle of inclusion & exclusion, pigeonhole principle; recurrence relations & generating functions; digraphs & graphs, graph isomorphism & sub-graphs, spanning trees, Euler & Hamiltonian graphs, planar graphs, chromatic numbers & graph coloring; groups.

Design & Analysis of Algorithms-

Basic Design Techniques –Divide-and-Conquer, Greedy, Dynamic Programming (Examples, Analysis, General Structure of Solutions, Limitations and Applicability). Specialized Design Techniques: Network Flow, Randomization (Examples, Analysis, Limitations). Complexity Classes and Hardness of Problems – P, NP, Reductions, NP hardness and NP- Completeness, Reduction Techniques, Basic NP-complete problems. Design Techniques for Hard Problems – Backtracking, Branch-and-Bound, and Approximation (General approaches and structure of solution, Analysis, and Limitations). Linear Programming – LP Problem and Simplex Algorithm, Approach for using LP for modeling and solving problems. Introduction to Design and Analysis of Parallel and Multithreaded Algorithms.