SCHOOL OF ENGINEERING SCIENCES

Department of Computer Engineering

Master of Engineering (MENG) in Computer Engineering

1.0 Introduction

The programme of the Department is structured along three thematic or research focus areas:

(a) Computer and intelligent systems
(b) Control and automation systems
(c) Communications and networks systems

2.0 Graduation Requirements

To graduate with MEng Degree in Computer Engineering, a candidate will be expected to have successfully taken and passed a *minimum total* of **42 credits** (and ***maximum of 48 credits***) from course work (both core and elective), seminar, and graduation project work. The graduation requirements are summarized as follows:

1	Core courses	15 credits
2	Elective courses	12 credits
3	Seminar I	3 credits
4	Graduation Project	12 credits
	Total	**42 credits**

Additionally, the candidate will be required to make a formal defense of the graduation project.

3.0 Course Structure

A summary of the courses required under the MEng programme is as follows:

3.1 Core Courses

Semester I

- CPEN 601 Engineering Research Methods – 3 credits
- CPEN 603 System-On-Chip Design – 3 credits
- CPEN 605 Probability and Random Processes – 3 credits
- CPEN 610 Seminar I – 3 credits

Semester II

- CPEN 600 MEng Project – 12 credits
- CPEN 602 Engineering Project Management – 3 credits
- CPEN 604 Real Time Computing Systems – 3 credits

3.2 Elective Courses

Candidates will be expected to select a minimum of four (**4**) elective courses (12 credits) from any of the under-listed specialization area of interest. Candidates have the option to select courses across the various specialization disciplines based on recommendations from academic supervisors or Department. However, to provide adequate theoretical foundation in any preferred specialization or research area, it is recommended that candidates select not less than 4 elective courses from that area of specialization.

3.2.1 Computer Systems Elective Courses

Semester I - Elective Courses

- CPEN 607 VLSI System Design – 3 credits
- CPEN 609 Microprocessor Systems Design – 3 credits
- CPEN 611 Parallel Computing Systems – 3 credits

Semester II - Elective Courses

- CPEN 606 Computer System Testability – 3 credits
- CPEN 608 VLSI System for Signal Processing – 3 credits
- CPEN 612 Reconfigurable Systems – 3 credits

3.2.2 Telecommunications Systems Elective Courses

Semester I - Elective Courses

- CPEN 613 Communication Policy and Management – 3 credits
- CPEN 615 Information Theory and Coding – 3 credits
- CPEN 617 Communication Networks Design – 3 credits
- CPEN 619 Wireless and Mobile Communication Systems – 3 credits
- CPEN 621 Communication Network Management – 3 credits
- CPEN 623 Optical Fibre Communication Systems – 3 credits
- CPEN 627 Adaptive Signal Processing – 3 credits

Semester II - Elective Courses

- CPEN 614 Error Detection and Control – 3 credits
- CPEN 616 Communication Networks Algorithms – 3 credits
- CPEN 618 Digital Communications – 3 credits
- CPEN 622 Mobile Computing Systems – 3 credits
- CPEN 624 Optical Devices – 3 credits
- CPEN 626 Wireless Communication Security – 3 credits
- CPEN 628 Multimedia Signal Processing – 3 credits

3.2.3 Automation Engineering Elective Courses

Semester I - Elective Courses

- CPEN 631 Applied Optimization Methods – 3 credits
- CPEN 633 Control Systems Design – 3 credits
- CPEN 635 Robotic Systems – 3 credits
- CPEN 637 Human Computer Interaction – 3 credits

Semester II - Elective Courses

- CPEN 632 Industrial Controls – 3 credits
- CPEN 634 Programming for Industrial Automation – 3 credits
- CPEN 636 Communication in Automation – 3 credits
- CPEN 638 Machine Learning – 3 credits

3.2.4 Software Engineering Elective Courses

Semester I - Elective Courses

- CPEN 641 Advanced Operating Systems – 3 credits
- CPEN 643 Software Engineering – 3 credits
- CPEN 645 Software Design – 3 credits
- CPEN 647 Systems Engineering – 3 credits
- CPEN 649 Enterprise Application Integration – 3 credits

Semester II - Elective Courses

- CPEN 642 Real-Time Software and Systems – 3 credits
- CPEN 644 Software Testing – 3 credits
- CPEN 646 Software Measurements and Quality – 3 credits
- CPEN 648 Software Maintenance – 3 credits
- CPEN 686 Software Architecture Systems – 3 credits

3.2.5 Networks Engineering Elective Courses

Semester I - Elective Courses

- CPEN 651 High Speed Networks – 3 credits
- CPEN 653 Network Protocols and Services – 3 credits
- CPEN 655 Distributed Networks – 3 credits
- CPEN 657 Wireless Sensor Networks – 3 credits

Semester II - Elective Courses

- CPEN 652 Advanced Topics in Wireless Networks – 3 credits
- CPEN 654 Multimedia Networks and Storage – 3 credits
- CPEN 656 Computer Network Security – 3 credits
- CPEN 658 E-Commerce Technologies – 3 credits

3.2.6 Information Systems Engineering Elective Courses

Semester I - Elective Courses

- CPEN 661 Information Security – 3 credits
- CPEN 663 Cryptography and Analysis – 3 credits
- CPEN 665 Neural Networks – 3 credits
- CPEN 667 Advanced Database Systems – 3 credits
- CPEN 669 Speech Processing and Recognition – 3 credits

Semester II - Elective Courses

- CPEN 662 Pattern Recognition – 3 credits
- CPEN 664 Artificial Intelligence – 3 credits
- CPEN 668 Data Compression – 3 credits
- CPEN 672 Data Mining – 3 credits
- CPEN 674 Computer Vision – 3 credits

3.2.7 Bio-Computing Elective Courses

Semester I - Elective Courses

- CPEN 673 Biomedical Signal Processing – 3 credits
- CPEN 675 Theory of Computations – 3 credits
- CPEN 677 Bioinformatics – 3 credits
- CPEN 679 Advanced Algorithm Design – 3 credits

Semester II - Elective Courses

- CPEN 674 Digital Image Processing – 3 credits
- CPEN 676 Algorithms for Computational Biology – 3 credits
- CPEN 678 Mathematical Neurobiology – 3 credits
- CPEN 682 Analysis of Genomic Data – 3 credits

3.3 Description of Core Courses

CPEN 600 MEng Project

The MEng project involves a candidate working closely with an approved principal supervisor or supervisors in an independent work to investigate an industry-oriented project idea or solving a local problem in a selected specialization discipline, and writing a project report. The report will be evaluated based either on its academic contribution or contribution to the relevant industrial application.

CPEN 601 Engineering Research Methods

The engineering research methods course highlights on the principle and developmental process for conducting effective research and documentation. Topics include research process, nature of contribution of research to theory development in the discipline, development of research proposals, design of questionnaire and interviewing techniques, content analysis, research report writing, quantitative and qualitative research, measurement strategies, sources of data and collection procedures, literature survey, statistical evaluation of data and testing, interpretation and presentation of results, experimental research design forms and development processes, use of statistical software packages.

CPEN 602 Engineering Project Management

The engineering project management course explores the theoretical, practical and strategic development management tools necessary to manage a project. Topics include scope and value of project, project clarity and goals, systems engineering, management processes and strategies, various functional areas in project management including project planning, organizing, monitoring and control, integration, communication and reporting, risk management, human resource management, procurement management, engineering economics including for-profit and not-for profit decision-making, uncertainty, and multiple attribute decisions.

CPEN 603 System-On-Chip Design

The system-on-chip design course examines the tools and techniques for modeling, designing, verification, and implementation of system-on chip designs on a single chip using FPGAs.

Topics include emerging trends in system-on-chips, concepts of system-on-chips, architectures of networks on chip and multi-core organization, design flow process and IP reuse, FPGA design, software design, embedded processor architecture, hardware/software co-design, high-level synthesis, scheduling system, system performance analysis, testing, ASIP design, reconfigurable computing, and case studies. Completion of a substantial design project will be part of the course.

CPEN 604 Real Time Computing Systems

The real-time systems course examines technologies used for real-time systems and networks for systems such as multimedia, telecommunication management, and smart manufacturing. Topics include overview of real-time systems, design and implementation issues, system interfacing concepts, real-time scheduling paradigms, resource management issues in uniprocessor and multiprocessor real-time systems, embedded software design constraints, feedback control real-time scheduling, performance management, reliability, software timing and functional validation, supporting applications from real-time wireless sensor networks, distributed real-time systems, and real-time networks.

CPEN 605 Probability and Random Processes

The probability and random processes course provides in-depth analysis of the statistical tools for engineering applications. Topics include basic probability, conditional probability, Bayes' theorem, PDF and CDF, random variables, transformations, expected values, moments, characteristic functions, limit theorem, random processes, wide sense stationary processes, spectral density, Markov processes and Markov chains, Gaussian, Poisson and shot noise processes, and elementary queuing analysis.

CPEN 610 Seminar I

The seminar I course focuses on the development of the professional presentation skills as well as problem solving skill of candidates in the discipline through special seminars. Some of the areas to cover include introduction of ideas, methods, and techniques to improve the content and presentation of scientific seminars. As part of the course, candidates will provide a title and an abstract for a seminar, compose and present a seminar, compose and present feedback on other delivered seminars. Candidates will be involved in informal group studies on special problems, group participation in comprehensive design problems, or group research on complete problems for analysis and experimentation. Each candidate will give at least one oral presentation and also submit a full write up of the presentation for assessment.

3.4 Description of Elective Courses

3.4.1 Computer System Courses

CPEN 606 Computer System Testability

The computer system testability course examines fault models and testing techniques, errors, failures, reliability and availability techniques in digital systems. Topics include designing techniques for reliable systems, redundancy management, fault modeling, fault detection, fault location and reconfiguration, testing, design for testability, self-checking circuit, fail-safe circuit, system-level fault diagnosis, fault-tolerant communication, fault tolerant multiprocessor systems, reliable software design, low-overhead high-availability techniques, and evaluation methods.

CPEN 607 VLSI Systems Design

The VLSI systems design course examines the concepts behind the development of digital systems and their testing techniques. Topics include trends in VLSI development, architectures of VLSI, design methodologies, circuit design using structured systems, CMOS and MOS device modeling, design of CMOS combinational and sequential circuits, noise and signal integrity, design techniques for system power reduction, interconnect analysis and timing issues, clocking and synchronization, testing and verification, programmable ASICs and design methodologies, ASIC architecture and programming methodologies, routing techniques, fault analysis and design testability. Completion of a substantial design project will be part of the course.

CPEN 608 VLSI System for Signal Processing

The VLSI system for signal processing course focuses on the hardware implementation of signal processing systems on SoC (system-on-chip) used for communications, compression, encryption, and coding applications. Topics include signal processing algorithms, principles of datapath design, FIR and IIR filter architectures, communication systems including OFDM and multirate signal processing, fast transforms and algorithms including FFT, DCT, Wavelet transform, and Walsh-Hadamard transform, computer arithmetic methods including Galois fields, residue number systems, distributed arithmetic, canonic signed digit systems and reduced adder graph algorithms.

CPEN 609 Microprocessor Systems Design

The microprocessor systems design course explores the architectures for microprocessors and the supporting components for application. Topics include microprocessor components, design, analysis and performance of microprocessor architectures, comparison of design paradigms for architectures such as CISC, RISC, and DSP, instruction level parallelism, bus timing analysis, design considerations for high-performance systems, execution problems, memory architectures and performance, benchmarking and optimization, parallel architectures and processing, systolic and data flow architectures, multiprocessor performance and iterations, power dissipation, support software, and simulation tools.

CPEN 611 Parallel Computing Systems

The parallel computing systems course examines modern parallel and distributed systems design, engineering and evaluation. Topics include parallel systems design concepts, architectural evolution of parallel systems, technological driving forces of parallel systems, programming algorithms and models, communication primitives, programming and compilation techniques, multiprogramming workloads and methodology, latency avoidance techniques, cache-coherency, protocols, directories, and memory consistency models, message passing protocols, storage management, and deadlock, network interface, protection, events, active messages, latency tolerance techniques, pre-fetching, multithreading, dynamic instruction scheduling, and software techniques, network design and synchronization.

CPEN 612 Reconfigurable Systems

The reconfigurable systems course focuses on the design and implementation of high-performance computing machinery using configurable computing technology. Topics include introduction to configurable computing and developments, performance metrics for configurable systems, architectures for configurable computing, FPGA architectures, spatial computing architectures, adaptive network architectures, systolic and bit serial architectures, contemporary configurable systems, hardware/software co-design for computing systems, pipeline, caches, configurable computing operating systems, and adaptive computing machines and applications.

3.4.2 Telecommunications System Courses

CPEN 613 Communication Policy and Management

The communication and policy and management course provides the necessary policy frame work, standards and management of telecommunication systems. Topics include ICT industry and developmental issues, overview of the telecommunication systems including fixed, mobile, internet, and cable systems, telecommunications services and delivery, communications policy and regulation, role of ITU and challenges, radio frequency management, allocation of spectrum, regulations for the use of spectrum, common carriers, competition and compliance, long term policy planning, and telecommunications management including internal and external views of telecommunication management, and telecommunication network management model.

CPEN 614 Error Detection and Control

The error detection and control course examines error detection in communication and recording systems and control measures for reliable digital transmission and storage. Topics include signal detection in white and colored noise, random waveform, matched filtering, m-ary signal detection, nonparametric detection, error control coding including major classes of codes that important in practice such as binary linear block codes, Reed Muller codes, Galois fields, linear block codes over a finite field, cyclic codes, BCH and Reed Solomon codes, convolutional codes

and trellis decoding, message passing decoding algorithms, trellis based soft decision decoding of block codes, turbo codes, and low density parity check codes.

CPEN 615 Information Theory and Coding

The information theory and coding course provides the fundamental background on the Shannon theory and their application. Topics include information theory, encoders and decoders for digital data in noisy channels, linear block coding, cyclic coding, BCH coding, convolutional coding, burst error correcting codes, Huffman code and universal code, channel capacity, differential entropy and Gaussian channels, multi-user information theory including broadcast and multiple access channels, rate distortion including quantization, proof of achievability and converse rate distortion, performance of block and convolutional coding in noisy channels.

CPEN 616 Communication Network Algorithms

The communication network algorithms course provides the methodologies and algorithms used for designing and optimizing communications networks with focus on the algorithmic aspects of network design. Topics include modeling networks as graphs, graph algorithms for finding minimum spanning trees, shortest paths, and matroids, topological design including selecting terminal concentrator locations, heuristic algorithms and network topology optimization, algorithms including flow deviation algorithm, Bertsekas-Gallager algorithm, cut-saturation algorithm for distributed computer systems, communications network optimization involving cut saturation algorithm for topological design of packet switched, communication networks algorithm for access facility location problem, dimensioning schemes, mesh topology optimization including capacity assignment and branch exchange, mesh network topology optimization and routing algorithm.

CPEN 617 Communication Networks Design

The communication networks design course examines the design issues for communication networks and the trade-offs. Topics include types of communication networks, shortest path, maximum flow, and minimum cost problems including novel polynomial time algorithms, routing algorithms and protocols, protocol processing, queuing theory, switching fabrics, network processors, network development life cycle, network design and analysis, network protection and restoration design, multi-layer network design, data to support network design, structured enterprise network design, hierarchical tree network design, network optimization, traffic flow analysis, analysis of data loss and delay in networks, and network reliability issues.

CPEN 618 Digital Communications

The digital communications course investigates the modern trends in generating digital signal for propagation and processing. Topics include information transmission fundamentals including capacity, entropy, Shannon theorem, and source coding, basics of stochastic processes, design of baseband and passband digital communication systems, rate distortion theory, advanced digital

modulation and demodulation techniques, performance measures, channel coding and trellis coded modulation, synchronization, inter-symbol interference (ISI) and equalization techniques, and concepts for modern digital communication including spread spectrum signals for digital communications, multiple access systems, time division multiple access, code division multiple access, and frequency division multiple access..

CPEN 619 Wireless and Mobile Communication Systems

The wireless and mobile communication course examines the design and implementation of wireless and mobile communication systems. Topics include wireless radio communications, cellular networks, satellite networks, wireless local area networks, wireless personal area networks, elements of wireless communication systems, modeling of wireless multipath fading channel and parameters, coherent and non-coherent reception, spread spectrum communication, multiple access, anti-jamming and interference management, frequency re-use, sectorization, multiple access techniques such as TDMA, CDMA, and OFDM, capacity of wireless channels, error performance evaluation over radio links, mobile IP, ad-hoc networks, wireless network security, and future of wireless communications.

CPEN 621 Communication Network Management

The network management course covers modern network management models and issues. Topics include communication networks management architecture, homogenous and non-homogeneous network management systems, modern tools for managing network, management network reference models, remote network management, configuration for data collection, network management implementation, network monitoring and reconfiguration, network management application development, operational issues in managing heterogeneous networks.

CPEN 622 Mobile Computing Systems

The mobile computing course is concerned with methods and principles for the development of systems whose components show forms of mobility across networks which requires knowledge about the domain that the movement is taking place. Topics include delivery of connectivity to mobile nodes, languages that provide facilities for code migration, computational models that include the notion of locality, and design methods supporting the development of new kinds of network applications, communication protocols, application-support software, and characteristics of wireless communication medium, security, location-aware applications, and algorithms for the implementation of basic system services.

CPEN 623 Optical Fibre Communication Systems

The optical fibre communication systems course examines the techniques associated with signal transmission and detection process in optical medium. Topics include physics of optical fibre, fiber properties of dispersion, attenuation, and nonlinear effects on data transmission, electro-optical conversion devices for signal generation and detection, modulation techniques and

implications, circuit considerations, overall system considerations including coupling, transmitter design, receiver design, noise properties of fiber, and multichannel transmission issues, coherent modulation properties of laser diodes, homodyne and heterodyne detection, light-wave networks such DWDM, FDM, TDM, and CDM, and their relative merits, optical network access, optical interconnection, and topological issues in optical switching.

CPEN 624 Optical Devices

The optical device course examines the optoelectronic devices and their properties that facilitate optical communications. Topics include identification of optical components in photonic systems and subsystems, operation principles of lasers and LED, modulation dynamics, single frequency lasers, fundamental AM and FM noise properties, laser line-width requirements, tunable semiconductor lasers, quantum well lasers, electro-optic modulators and switches, optical filters, couplers, isolators, detectors, integrated optoelectronic circuits, semiconductor optical amplifiers, Erbium optical fiber amplifiers, low coherence sources diodes, and tunable optical filters.

CPEN 626 Wireless Communication Security

The wireless communication security course examines security treats and design of security features necessary to protect and control wireless communication for reliable operation. Topics include wireless network architecture and components, wireless network systems security and privacy issues, wireless network threats and sources, security requirements and implementation framework, security policies, security requirements for switching, access network, transport network elements and mediation devices, network security techniques, security protocols and services, network security system design model including identification, authentication, system access control, resource access control, data integrity, audit, security administration, and data confidentiality, network attacks and counter measures, intrusion and extraction detection, incidence response and forensic analysis, security implementation for securing wireless network infrastructure. Example to be drawn from cellular, wireless LAN, mobile, wireless mesh, ad-hoc (MANET), RFID, sensor networks, and vehicular networks.

CPEN 627 Adaptive Signal Processing

The adaptive signal processing course provides introduction to relevant signal processing and basics of pattern recognition. Topics include discrete random processes, linear prediction, digital wiener filtering, digital adaptive filter structures including LMS adaptive algorithm, properties of LMS adaptive filter, normalized and finite effect and adaptive beam-forming, performance analysis of LMS algorithms, stability criteria of evaluation, and modified LMS algorithms, frequency-domain adaptive filter, least squares adaptive filters, sub-band adaptive filter, infinite impulse response filter and algorithms, lattice structure and algorithms, applications using adaptive signal processing techniques in adaptive noise cancellation in speech communication and adaptive system identification among others, practical implementations and issues in adaptive signal processing and current trends ad research in adaptive signal processing.

CPEN 628 Multimedia Signal Processing

The multimedia processing course provides focuses on multimedia signal representation, data compression and information retrieval. Topics include multimedia signal representation of data, audio, speech, image, and graphics, analog video, data transformation techniques such as Fourier, *z*, and wavelets, Shannon entropy theory, data sampling and quantization, sub-sampling and up-sampling of data, multimedia data compression techniques including lossless encoding methods including Huffman, entropy, arithmetic, run-length, lossy encoding such as transform encoding, wavelet based zero-tree, differential encoding, and vector quantization, compression standards - JPEG, MPEG, multimedia data retrieval including techniques for statistical pattern recognition and probability density estimation, introduction to content based data retrieval and multimedia data fusion.

3.4.3 Automation Engineering Courses

CEPN 631 Applied Optimization Methods

The Applied optimization methods course examines the optimization theory and techniques for practical engineering problems. Topics include classification of optimization problems, linear programming, nonlinear unconstrained optimization, nonlinear constrained optimization including inequality and equality constraints, Lagrange multiplier method, and Kuhn-Tucker conditions and solution methods, dynamic programming, random search algorithms and search methods for optimization, convex optimization methods, and application examples from different engineering disciplines.

CPEN 632 Industrial Controls

The industrial controls course present an overview of advanced controller design strategies for multivariable industrial processes, starting from PID control structure to the more advanced H-infinity design technique. Topics include feedback control systems, industrial processes and need for feedback, industrial control system components such as actuators, sensors, and controllers, classical control strategies, process modeling, PID control, state feedback, nominal feedback and performance of feedback control systems, H-optimal control uncertainty modeling for robust control, robust closed loop stability and performance, robust H control, controller technologies such as PLC, DCS, PC-based control, Matlab based control, Labview based control, and dedicated hardware for controller implementations.

CPEN 633 Control Systems Design

The control systems design course examines the basic issues and theoretical foundation in the analysis and design of computer control systems for industrial applications. Topics include

signals and sampled data systems, zero-order hold equivalent, linear systems theory, control system modeling, dynamic systems analysis and feedback control, controller design methods, system stability analysis using Jury's test, Nyquist criterion, and Lyapunov method, observability, reachability and controllers, performance analysis, robust control, output feedback, separation theorem, optimal control, and adaptive control systems.

CPEN 634 Programming for Industrial Automation

The programming for industrial automation course focuses on the programming mechanisms for modern devices in the control operations in industry. Topics include functional block diagrams, control system software for PLC and SCADA, programming techniques for PLC, computer based controllers, microcontroller, digital computer interface including isolated and non-isolated digital I/O, ADC, DAC, and engineering applications in selected industry in Ghana.

CPEN 635 Robotics Systems

The robotic system course focuses on the design and programming of robotic systems and issues in current research in robotics. Topics include basic components of robotic systems, planning, control of realistic robotic systems, review of issues in robotics programming, robotic programming languages, classifications of robots, basic components, motion classification, control and sensing uncertainty, motion constraints, analysis of friction for assembly and grasping tasks, sensing systems for hands, environmental perception from sparse sensors for dexterous hands, grasp planning and manipulation.

CPEN 636 Communication in Industrial Automation

The communication in automation course examines modern communication topology and architecture employed in industrial automation systems. Topics include communication components, principles of communication in industrial automation, architecture and topology of network communication, communication protocols as used in industrial automation in wired and wireless communication such as TCP/IP, RS-232, RS-485, Fieldbus, DNP3.0, Modbus, Zigbee, Bluetooth, and IDRA, error detection and control, troubleshooting, and introduction to security in industrial automation systems.

CPEN 637 Human-Computer Interaction

The human computer interaction course provides key approaches to the design, development, and evaluation of human-computer interfaces, with an emphasis on usability, interaction paradigms, computer-mediated human activities, and implications to society. Topics include foundation of HCI and technologies, HCI paradigms and history, nature of human computer interaction, use and context of computers, human characteristics including human information processing, language and communication interaction, and ergonomics, computer system and interface architecture, development process including design approaches, implementation

techniques and tools, evaluation techniques, user interface software and error handling, multimedia systems, interaction design for new environment.

CPEN 638 Machine Learning

The machine learning course examines the field of machine learning with a focus on how to construct computer programs that automatically improve with experience. Topics include exponential family distributions, Bayesian networks, Bayesian inference, maximum likelihood, maximum entropy, mixture models, EM algorithm, graphical models, hidden Markov models, variational methods, linear classifiers, regression, generalization bounds, support vector machines, kernel methods and transduction, machine learning applications of detecting fraudulent card transactions, learning users reading preferences, and autonomous vehicles that learn to drive.

3.4.4 Software Engineering Courses

CPEN 641 Advanced Operating Systems

The advanced operating system course examines the structural aspects of operating system and how these provide support for general purpose, embedded, and real-time operating environments. Topics include survey of early systems, structural design of operating system including process model, inter-process communication, synchronization mechanisms, resource management, CPU scheduling, I/O scheduling, file systems, virtual machines, protection issues, implementation issues of modern operating systems, performance analysis, deadlock detection, recovery and avoidance, operating system for distributed and current systems, review of current research in operating systems.

CPEN 642 Real-Time Software and Systems

The real-time software and systems course provides a comprehensive view of real-time systems with theory, techniques and methods necessary for effective design and development of real-time computing system. Topics include fundamental concepts, terminology, real-time characteristics and issues, real-time hardware including processors, memory and transducers, operating systems and tasks, utilization and response time, periodic and aperiodic task scheduling, synchronization and blocking, resource access, rate monotonic analysis, priority servers, real-time system development process, real-time system requirements analysis, modeling techniques, architecture design, design patterns, performance analysis, verification and validation, testing strategies, system safety and reliability, languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems.

CPEN 643 Software Engineering

The software engineering course examines the concepts of system hierarchical relationships and the role of system engineers. Topics include software engineering for modern enterprise application and performance critical systems, software life cycle, software engineering process, requirements and software requirements analysis, software design, software architecture including trade-off analysis, enterprise architecture, service-oriented architecture, COTS architecture, and RAD, software implementation, software integration for systems such as enterprise application integration and COTS integration, software verification and transition, software validation, operation and maintenance, software quality assurance.

CPEN 644 Software Testing

The software testing course focuses on the techniques and processes for testing software reliability, reliability models, and techniques to improve and predict software reliability. Topics include defining necessary reliability, testing fundamentals including issues and relationships of testing to other activities, test levels ranging from target of the tests, objectives, component testing, integration, system and acceptance testing, testing techniques including specification-based, coded-based, fault-base, usage-based, and nature of application, test-related measures for system under test and evaluation of the tests performed, and test process.

CPEN 645 Software Design

The software design course examines the general software design concepts and design process and enabling techniques. Topics include key issues in software design, software structure and architecture styles including human computer interface design, software design quality analysis and evaluation, software design notations, software design strategies and methods including heuristic and formal methods and component-based design.

CPEN 646 Software Measurements and Quality

The software measurements and quality assurance course provides an in-depth evaluation of the verification and validation process throughout the development lifecycle of software. Topics include software quality fundamentals, software engineering culture and ethics, value and costs of quality, quality models and characteristics, quality improvement, application quality requirements, and defect characterization, software quality management process, quality assurance, software quality management techniques, and software quality measurement, verification and validation including system and software verification and validation, and independent verification and validation, verification and validation techniques including testing, demonstrations, traceability, analysis, inspections, peer review, walkthrough, and audits.

CPEN 647 Systems Engineering

The systems engineering course examines the methods, tools, and validation techniques for the analysis, specification and prototyping of software systems. Topics include basics of systems engineering, system design constraints, design and requirements allocation, eliciting requirements, analysis, concepts exploration and evaluation, design process, defining concepts, architecting systems, prototyping systems, conceptual modeling of systems and validation, designing tests, analysis of risks and failures, acceptance tests, considering users, deployment and maintenance of systems, and practical considerations for software engineering of the world wide web.

CPEN 648 Software Maintenance

The software maintenance course examines the principles and techniques used for the maintenance of software systems. Topics include nature of maintenance, need for maintenance, components of maintenance costs, and categories of maintenance, key issues in software maintenance such as technical issues relating to testing, impact analysis, and maintainability, management issues, maintenance cost estimation, and software maintenance measurement, maintenance process including process models, maintenance activities, unique activities, and supporting activities, techniques for maintenance such as program comprehension, reengineering, and reverse engineering

CPEN 649 Enterprise Application Integration

The enterprise application integration course provides the techniques on how to design and deploy large-scale systems and understand the trade-offs and implications of supporting the critical backbone of modern enterprises. Topics include enterprise architecture frameworks including the Zachman enterprise framework, open group architecture framework, and enterprise architecture cube methodology, enterprise oriented service architecture design and implementation, unique aspects of enterprise architecture and development, security for large enterprise systems, reliability for distributed long running transactions, standards for intra and extra organization system integration, deployment and fault tolerance of systems.

CPEN 686 Software Architecture Systems

The software architecture systems course examines the principles and techniques for the architectural design of complex systems using well-founded architectural paradigms. It considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. Topics include overview of software architecture, architectural drivers, structures

and views, data flow systems, data flow styles, call-return systems, client-server and tiered architecture, middleware, event based systems, shared information systems, techniques and methods for the architecture, design by selection, architecture evaluation, product lines, using UML for design representation, formal specification and analysis, architecture conformance, performance, availability, service oriented architecture and web services, security, usability, organizational alignment, global distributed development, platforms, and research directions in software architecture systems.

3.4.5 Networks Engineering Courses

CPEN 651 High-Speed Networks

The high speed data networks course focuses on the advances in LAN, MAN, and ATM. Topics include high speed data networks models, approaches to design and management of networks, high speed transmission networks and switching technologies, FDDI, DQDB, SMDS, Frame Relay, ATM networks, and SONET, congestion control and traffic management, performance modeling, queuing theory, routing algorithms, data compression, and applications demanding high-speed communication, multicasting for teleconferencing, and mobile computing.

CPEN 652 Advanced Topics in Wireless Networks

The advanced topics course examines topical issues in networking with focus on wireless networking technologies, protection and the next generation networking. Topics include wireless networking services and technologies, requirements and challenges for wireless data network design, access technologies, developments in wireless networks such as WiFi (IEEE 802.11), bluetooth, wireless USB, Ultra wideband, sensor networks such as zigbee, wide area networks such as WiMAX (IEEE 802.16) and 3G/4G cellular networks, mobility management, handoff, protocol adaptations for wireless networking including mobile IP, WAP, mobile TCP, wireless resources management, including packet scheduling power management and ad-hoc routing, issues of mobile data network security, emerging mobile data architectures and services, quality of service, issues of mobile data application, wireless cache invalidation, multimedia transport over wireless, and location dependent services.

CPEN 653 Network Protocols and Services

The network protocols and services course examines the principles behind communication network protocols, standards, performance analysis, and implementation of both existing and emerging network. Topics include fundamental of data communication networks and protocol architectures, network performance metrics, principles of network protocol design, error detection and correction, flow control and congestion, delay and throughput models, QoS, service support and application interface, LAN and WAN and protocols, LAN and WAN

interconnections, IP addressing, TCP, UDP, high-speed bulk transfer protocols, routing in data networks and protocols such as BGP and OSPF, network services, DNS and BIND, network and protocol design to support multi-media and multicasting connections, network management and SNMP, protocol implementation models, network application security.

CPEN 654 Multimedia Networks and Storage

The multimedia networks and storage course covers a broad range of topics in the frontier of multimedia networking systems with focus on transmission techniques and protocols, massive storage architectures and data security. Topics include concepts of multimedia systems, resource management issues in distributed/networked multimedia systems, QoS routing and multicasting, traffic shaping, task and message scheduling, internet QoS, adaptive multimedia applications over internet, operating system support for multimedia, characteristics of multimedia data, storage architecture and scalable media servers, processor architectures for multimedia, compression techniques, synchronization techniques, jitter management, error control and loss recovery, video-on-demand, voice-over-IP, wide area caching systems and techniques, encryption and group key management.

CPEN 655 Distributed Networks

The distributed networks course provides the concepts underlying the architecture and operations of distributed networks. Topics include distributed network architectures and processing, communication primitives, resource sharing, event ordering and synchronization, distributed deadlocks and management, naming, load balancing, distributed network operating systems and languages, distributed databases, fault tolerance and recovery strategies, file service, protection issues, design issues, distributed office information systems, and related applications.

CPEN 656 Computer Network Security

The computer network security course examines the treatment of network security for secure data operation. Topics include principles and practice of network related security threats and solutions, mathematical principles of cryptography and data security, conventional and modern encryption algorithm techniques, secure communication protocols, public and private key encryption, remote access security, authentication, digital signatures, internet protocol security architecture, firewalls, VPNs, and PKI architecture, intrusion detection systems, electronic mail security, routing protocol security, wireless network security, traffic analysis and alert tools, modern applications relating to digital cash and secure distributed computing, and operational aspects of network security and management.

CPEN 657 Wireless Sensor Networks

The wireless sensor networks course examines the fundamental issues of sensor network and design of collections of smart sensors that are networked to form self-configuring pervasive computing systems. Topics include introduction to ad-hoc and senor network including challenges and unique constraints, wireless communication characteristics, ad-hoc wireless networks, media access control protocols, routing protocols, networking sensors including unique features, deployment techniques, sensor tasking and control, and transport layer and security protocols, sensor network platforms and tools including sensor network programming challenges, operating systems, and middleware devices, applications of ad-hoc and sensors networks and future trends including ultra wide band radio communication and wireless fidelity systems, and applications such as embedded sensor networks and pervasive computing.

CPEN 658 E-Commerce Technologies

The e-commerce technologies course examines the principles and design of secured e-commerce applications deployment over the world-wide-web systems. Topics include fundamentals of e-commerce infrastructure and implementation, social, ethical and legal considerations in e-commerce, developing application for the world-wide-web, application protocols, e-commerce models, connection and session objects, authentication services, internet security including firewalls, viruses, hacking, design issues of e-commerce, web servers, integrating database services, data transactions between database servers and servers using XML.

3.4.6 Information Systems Engineering Courses

CPEN 661 Information Security

The information security course examines the design and implementation of information security system that assures content confidentiality. Topics include introduction to confidentiality, integrity, availability, authentication techniques and models, controls and protection models, security kernels, secure programming, audit, intrusion, detection and response, operational security issues, physical security issues, personal security, policy formation and enforcement, access controls, information flow, legal, privacy and social issues, identification and authentication in local and distributed systems, classification and trust modeling, risks and vulnerabilities, risk assessment, database security, encryption, host based and network based security issues, secure network design, implementation and transition issues, and techniques for responding to security breaches.

CPEN 662 Pattern Recognition

The pattern recognition course describes various methods and techniques that are used in pattern recognition. Topics include Bayes decision theory, description of patterns, feature extraction and classification, classification models, non-parametric pattern classification techniques, parameter estimation, pattern classification using linear discriminant functions, uncertainty in pattern recognition, fuzzy sets, perception algorithms and its extensions, learning of rules for pattern recognition, learning discriminates, unsupervised learning and clustering algorithms, feature extraction and algorithms, neural network techniques including Hopfield, feed forward model, and training of neural networks, structural recognition techniques, and other pattern recognition methods and applications.

CPEN 663 Cryptography and Analysis

The cryptography course focuses on the mathematical concepts and techniques behind modern information encryption and network technologies. Topics include survey of classical and modern encryption techniques and algorithms, encryption theory and foundations, cryptographic and crypto-analysis techniques, one-way functions, pseudo-random function, encryption system modeling, authentication protocols, public-key cryptosystems, notions of security, zero-knowledge proofs, multi-party cryptographic protocols, security policies, legal and ethical issues, practical applications of encryption.

CPEN 664 Artificial Intelligence

The artificial intelligence course focuses on the issues and principles and techniques of artificial intelligence. Topics include knowledge representation, organization and manipulation of the world and how to reason logically with the knowledge, concepts of inconsistency, uncertainty, probabilistic reasoning, structured knowledge, logic programming, computational and statistical learning theory, machine learning including supervised, unsupervised and reinforcement learning, decision making including search oriented problem solving, planning, games, Markov and decision processes, planning and temporal reasoning, inference and theorem proving, reasoning under uncertainty, search and information retrieval, principles of intelligent agents, speech and natural language processing involving parsing, machine translation, and information extraction, speech recognition, computer vision, and robotics

CPEN 665 Neural Networks

The neural networks course examines models of computation that learn tasks from examples of desired input and output behavior for various applications. Topics include basic concepts behind neural network models, biological neuron model, neural network architectures, feed-forward, feed-back, Hopefield models, adaptation and learning in neural networks including perceptron,

iterative learning, multilayer network with hidden layers, back-propagation, convergence and speeding up algorithms, supervised Hebbian learning, Widrow-Hoff learning, associative learning, competitive learning, self-organizing neural networks, neural network training and testing techniques including setting of training parameters, preparing training data, training the network, and testing of the network, neural network applications to speech, robotics, face and pattern recognition, implementation process using electronics and optical.

CPEN 667 Advanced Database Systems

The database system course examines the principles of the design of systems that can manipulate and retrieve data from large databases using high level formal languages. Topics include data base development lifecycle, data modeling, database architectures, database design theory, data acquisition, models for database systems, data integration and cleaning, query processing, concurrency control and transaction management, data search and recovery, distributed and parallel data management in cluster computing and peer-to-peer, web pages, sensor networks and RFID, data storage, inference and data mining, data security and privacy, declarative data-intensive systems, data visualization, query optimization and stream algorithms, current trends in development of database systems.

CPEN 668 Data Compression

The data compression course examines the theoretical foundation of compression techniques and algorithms for lossy and lossless data compression as well as signal modeling and its extensions to data compression and applications to multimedia data compression. Topics include basics of signal encoding and decoding for compression, lossy and lossless compression, communication building blocks, and fixed and variable rates, quantization theory including uniform quantization, distortion and bit rate, high rate quantization theory and elementary distortion rate theory, architecture for data compression including signal models and spectral analysis, coding forms, entropy and variable quantization, lossless coding algorithms such as Huffman, arithmetic, universal lossless, adaptive and predictive coding algorithms, distortion and similarity measures, lossy coding algorithms such as scalar quantization algorithm, and vector quantization coding algorithm, speech and audio compression techniques, image and video compression techniques, compression standards and formats.

CPEN 669 Speech Processing and Recognition

The speech processing and recognition course covers the fundamentals of speech recognition and voice interfacing with machines. Topics include overview of discrete statistical signal analysis, acoustic aspects of speech and hearing, voice interfacing and issues, speech technologies like recognition, synthesis, and compressed audio transmission, automated speech processing, digital models of speech production, short-time processing in time and frequency domains, waveform encoding and linear predictive coding of speech, estimation of fundamental speech parameters,

digital speech processing and phonetic feature extraction, identifying words from pronunciations, syntax and semantics in speech understanding, task constraints and natural language, alternative speech recognition system structures, voice interfacing projects, and strategies for achieving user satisfaction, automatic speech recognition and enhancement.

CPEN 672 Data Mining

The data mining course provides background information on the design and use of data mining algorithms and applications in data mining on the web, computational biology and various medical applications. Topics include models, methods and processes of data mining including search and querying, data dredging and fishing, discrete structures involving item-set mining, concept lattices, condensed representation, frequent pattern mining, customized data structures for speeding up data mining algorithms, attribute-value learning techniques including decision tree, decision lists, classification and regression trees, association rules, and rule-based mining, relational mining techniques, probabilistic techniques including conditional independence and its modeling, representational complexity, Bayesian networks, and probabilistic models for query approximation, sequences and order, compositional data mining, mining chains of relations, integrated query and mining languages, paradigms for interfacing with database systems, and application in bi-informatics, personalization, information retrieval, web modeling, filtering and text processing.

CPEN 674 Computer Vision

The computer vision course involves the development of algorithms and software that have the potential to mimic a biological organism's ability to see. Topics include the physics of vision and its computational modeling, mathematical techniques for representing and reasoning with curves, surfaces, and volumes, image formation and sensing, camera model, thin lens model, lighting and reflectance, image capture and processing including edge finding, corner detection, image segmentation and texture analysis, image reflectometry involving color, image irradiance, and reflectance map, image analysis techniques such as convolution, filtering, noise, derivatives, and smoothing, scale space and SIFT, motion estimation and optic flow, 3D vision including shape from shading and shape from texture and defocus, geometric camera calibration, homographies, structure from motion, epipolar geometry and estimating of fundamental matrix, and dense stereo correspondence.

3.4.7 Bio-Computing Courses

CPEN 673 Biomedical Signal Processing

The biomedical signal processing course provides an application-intensive approach to biomedical signal processing and application of mathematical tools. Topics include technologies for signal acquisition such as MRI, EEG, ECG, and sonar, architecture of bio-sensors and design,

signals and systems theory, Fourier analysis, sampling theorem, discrete signal processing, noise characteristics of biosignals such as biologic, sensor, electronics and digital processing noise, linear and adaptive filtering, wavelet transforms, denoising, compression, classification and feature extraction applications, practical considerations in medical device design as relates to signal processing such as scalability, robustness, testability, algorithm complexity and regulatory issues.

CPEN 674 Digital Image Processing

The digital image processing course examines the properties of digital images and the method of processing. Topics include 2-D sequences and systems, separable systems, properties of digital images, image formation, sampling, time and frequency representation of images, transformation techniques including Fourier, z transform, difference equations, and wavelets transform, human visual system including perception, vision properties, color, and sensors, image enhancement, image restoration, geometrical image modification, filtering, and edge detection, binary image processing, morphological image processing, halftoning and edge detection, image coding and compression models for loss-free, lossless, and lossy compressions, motion estimation and compensation, compression standards and formats.

CPEN 675 Theory of Computations

The theory of computations course provides the fundamental complexity theory and models useful for solving computational problems. Topics include basic computational theory, computational models including nondeterministic alternating and probabilistic machines, Boolean circuits, complexity classes related to models of computing including NP, polynomial hierarchy, BPP among others, complete problems, interactive proof systems and probabilistic proofs, randomized algorithms, structural complexity and complexity hierarchy.

CPEN 676 Algorithms for Computational Biology

The algorithms for computational biology course provide the background knowledge useful for the design of algorithms for analysis of biological systems. Topics include vector geometry, matrix algebra and recursive relationship, algorithm concepts and optimization, basic biological techniques for predicting interactions, databases, graph algorithm libraries, network topological properties, phylogenetic profiles, predicting function including integer programming, modularity, partitioning heuristics, spectral partitioning and dense sub-graph detection, network searching and alignments, speeding-up searches and color coding, random models of biological networks including duplication model, small world, preferential attachment models, evolving modularity, generating random graphs, dynamic networks, linear programming algorithm, semi-definite, side chain packing, and phylogenetic trees and reassortment detection algorithm.

CPEN 677 Bioinformatics

The bioinformatics course provides computational methods and development of algorithms to address problems in molecular biology. Topics include molecular genetics of DNA, RNA and protein, cellular organization, modern biochemical techniques such as cloning and DNA sequencing, bioinformatics problems, bioinformatics database, representing and retrieval of sequences, sequence comparison with dot matrices and dynamic programming, statistics of pattern appearance, multiple sequence alignment, sequence database searching, learning machine basics, phylogenetic tree construction and algorithms, representing and finding sequence features, RNA and protein structure prediction, gene prediction and annotation, gene finding, retrieving and displaying macromolecular structures, microarrays and gene expression analysis models and technologies, biomolecular computing.

CPEN 678 Mathematical Neurobiology

The mathematical neurobiology course provides insight to the elements of neurophysiology and neuroanatomy for the development of quantitative models of nerve cell and brain phenomena and to develop and analyze several different mathematical models in neurobiology. Topics include difference equations, dynamical systems theory, ordinary differential equations and partial differential equations, linear membrane and cable theory, Rall's equivalent cylinder model of the nerve cell, determination of active membrane properties using linear theory, action potentials including Hodgkin-Huxley (HH) model and FitzHugh-Nagumo (FHN) model, asymptotic and computational determination of the action potential using the FHN equations, bursting phenomena in excitable cells, nonlinear waves of spreading cortical depression, and rotating waves in excitable media.

CPEN 679 Advanced Algorithm Design

The algorithm design course provides the basic concepts and principles to examine and design efficient algorithms for a variety of computational problems and applications. Topics include dynamic programming, methods of algorithm design and analysis including data structures, network flows, matching, and linear programming, ellipsoid algorithm, probabilistic algorithm techniques, approximation algorithms for NP problems, geometric algorithms, number theoretic algorithms, on-line computation, and parallel computing.

CPEN 682 Analysis of Genomic Data

The analysis of genomic data course examines the approach for the analysis and display of large scale biological data sets using various algorithms and machine learning techniques. Topics

include clustering techniques for gene expression and protein data analysis, machine learning techniques, biological networks, joint learning from multiple data sources, visualization issues for large scale biological data sets.

MASTER OF PHILOSOPHY (MPHIL) IN COMPUTER ENGINEERING

1.0 Introduction

The programme of the Department is structured along three thematic or research focus areas:

(d) Computer and intelligent systems
(e) Control and automation systems
(f) Communications and networks systems

12.0 Graduation Requirements

To graduate with MPhil Degree in Computer Engineering, a candidate will be expected to have successfully taken and passed a minimum total of **60 credits** consisting of course work (both core and elective), seminars, and graduation thesis. The graduation requirements are summarized as follows:

1	Core courses	15 credits
2	Elective courses	9 credits
3	Seminar I	3 credits
4	Seminar II	3 credits
5	MPhil Thesis	30 credits
	Total	**60 credits**

In addition to the satisfactory completion of the course work, a candidate will be required to make a formal defense of the thesis. *Prior to graduation, the candidate will be expected to have submitted at least one (1) extended abstract originating from the research to a conference.*

3.0 Course Structure

A summary of the courses required under the MPhil is as follows:

3.1 MPhil Core Courses – Year I

Semester I

- CPEN 601 Engineering Research Methods – 3 credits
- CPEN 603 System-On-Chip Design – 3 credits

- CPEN 605 Probability and Random Processes – 3 credits

Semester II

- CPEN 602 Engineering Project Management – 3 credits
- CPEN 604 Real Time Computing Systems – 3 credits
- CPEN 684 Advanced Engineering Mathematics – 3 credits
- CPEN 610 Seminar I – 3 credits

3.2 MPhil Elective Courses – Year I

Candidates will be expected to select a minimum of four (**4**) elective courses (12 credits) from any of the under-listed specialization area of interest. Candidates have the option to select courses across the various specialization disciplines based on recommendations from academic supervisors or Department. However, to provide adequate theoretical foundation in any preferred research or specialization area, it is recommended that candidates select not less than 4 elective courses from that area of specialization.

3.2.1 Computer Systems Elective Courses

Semester I - Elective Courses

- CPEN 607 VLSI System Design – 3 credits
- CPEN 609 Microprocessor Systems Design – 3 credits
- CPEN 611 Parallel Computing Systems – 3 credits

Semester II - Elective Courses

- CPEN 606 Computer System Testability – 3 credits
- CPEN 608 VLSI System for Signal Processing – 3 credits
- CPEN 612 Reconfigurable Systems – 3 credits

3.2.2 Telecommunications Systems Elective Courses

Semester I - Elective Courses

- CPEN 613 Communication Policy and Management – 3 credits
- CPEN 615 Information Theory and Coding – 3 credits

- CPEN 617 Communication Networks Design – 3 credits
- CPEN 619 Wireless and Mobile Communication Systems – 3 credits
- CPEN 621 Communication Network Management – 3 credits
- CPEN 623 Optical Fibre Communication Systems – 3 credits
- CPEN 627 Adaptive Signal Processing – 3 credits

Semester II - Elective Courses

- CPEN 614 Error Detection and Control – 3 credits
- CPEN 616 Communication Networks Algorithms – 3 credits
- CPEN 618 Digital Communications – 3 credits
- CPEN 622 Mobile Computing Systems – 3 credits
- CPEN 624 Optical Devices – 3 credits
- CPEN 626 Wireless Communication Security – 3 credits
- CPEN 628 Multimedia Signal Processing – 3 credits

3.2.3 Automation Engineering Elective Courses

Semester I - Elective Courses

- CPEN 631 Applied Optimization Methods – 3 credits
- CPEN 633 Control Systems Design – 3 credits
- CPEN 635 Robotic Systems – 3 credits
- CPEN 637 Human Computer Interaction – 3 credits

Semester II - Elective Courses

- CPEN 632 Industrial Controls – 3 credits
- CPEN 634 Programming for Industrial Automation – 3 credits
- CPEN 636 Communication in Automation – 3 credits
- CPEN 638 Machine Learning – 3 credits

3.2.4 Software Engineering Elective Courses

Semester I - Elective Courses

- CPEN 641 Advanced Operating Systems – 3 credits
- CPEN 643 Software Engineering – 3 credits
- CPEN 645 Software Design – 3 credits
- CPEN 647 Systems Engineering – 3 credits
- CPEN 649 Enterprise Application Integration – 3 credits

Semester II - Elective Courses

- CPEN 642 Real-Time Software and Systems – 3 credits
- CPEN 644 Software Testing – 3 credits
- CPEN 646 Software Measurements and Quality – 3 credits
- CPEN 648 Software Maintenance – 3 credits
- CPEN 686 Software Architecture Systems – 3 credits

3.2.5 Networks Engineering Elective Courses

Semester I - Elective Courses

- CPEN 651 High Speed Networks – 3 credits
- CPEN 653 Network Protocols and Services – 3 credits
- CPEN 655 Distributed Networks – 3 credits
- CPEN 657 Wireless Sensor Networks – 3 credits

Semester II - Elective Courses

- CPEN 652 Advanced Topics in Wireless Networks – 3 credits
- CPEN 654 Multimedia Networks and Storage – 3 credits
- CPEN 656 Computer Network Security – 3 credits

- CPEN 658 E-Commerce Technologies – 3 credits

3.2.6 Information Systems Engineering Elective Courses

Semester I - Elective Courses

- CPEN 661 Information Security – 3 credits
- CPEN 663 Cryptography and Analysis – 3 credits
- CPEN 665 Neural Networks – 3 credits
- CPEN 667 Advanced Database Systems – 3 credits
- CPEN 669 Speech Processing and Recognition – 3 credits

Semester II - Elective Courses

- CPEN 662 Pattern Recognition – 3 credits
- CPEN 664 Artificial Intelligence – 3 credits
- CPEN 668 Data Compression – 3 credits
- CPEN 672 Data Mining – 3 credits
- CPEN 674 Computer Vision – 3 credits

3.2.7 Bio-Computing Elective Courses

Semester I - Elective Courses

- CPEN 673 Biomedical Signal Processing – 3 credits
- CPEN 675 Theory of Computations – 3 credits
- CPEN 677 Bioinformatics – 3 credits
- CPEN 679 Advanced Algorithm Design – 3 credits

Semester II - Elective Courses

- CPEN 674 Digital Image Processing – 3 credits
- CPEN 676 Algorithms for Computational Biology – 3 credits

- CPEN 678 Mathematical Neurobiology – 3 credits
- CPEN 682 Analysis of Genomic Data – 3 credits

3.3 MPhil Core Courses – Year II

Semester I and Semester II

- CPEN 620 Seminar II – 3 credits
- CPEN 650 MPhil Thesis – 30 credits

3.4 Description of Core Courses – MPhil Year I

CPEN 601 Engineering Research Methods

The engineering research methods course highlights on the principle and developmental process for conducting effective research and documentation. Topics include research process, nature of contribution of research to theory development in the discipline, development of research proposals, design of questionnaire and interviewing techniques, content analysis, research report writing, quantitative and qualitative research, measurement strategies, sources of data and collection procedures, literature survey, statistical evaluation of data and testing, interpretation and presentation of results, experimental research design forms and development processes, use of statistical software packages.

CPEN 602 Engineering Project Management

The engineering project management course explores the theoretical, practical and strategic development management tools necessary to manage a project. Topics include scope and value of project, project clarity and goals, systems engineering, management processes and strategies, various functional areas in project management including project planning, organizing, monitoring and control, integration, communication and reporting, risk management, human resource management, procurement management, engineering economics including for-profit and not-for profit decision-making, uncertainty, and multiple attribute decisions.

CPEN 603 System-On-Chip Design

The system-on-chip design course examines the tools and techniques for modeling, designing, verification, and implementation of system-on chip designs on a single chip using FPGAs. Topics include emerging trends in system-on-chips, concepts of system-on-chips, architectures of networks on chip and multi-core organization, design flow process and IP reuse, FPGA design, software design, embedded processor architecture, hardware/software co-design, high-

level synthesis, scheduling system, system performance analysis, testing, ASIP design, reconfigurable computing, and case studies. Completion of a substantial design project will be part of the course.

CPEN 604 Real Time Computing Systems

The real-time systems course examines technologies used for real-time systems and networks for systems such as multimedia, telecommunication management, and smart manufacturing. Topics include overview of real-time systems, design and implementation issues, system interfacing concepts, real-time scheduling paradigms, resource management issues in uniprocessor and multiprocessor real-time systems, embedded software design constraints, feedback control real-time scheduling, performance management, reliability, software timing and functional validation, supporting applications from real-time wireless sensor networks, distributed real-time systems, and real-time networks.

CPEN 605 Probability and Random Processes

The probability and random processes course provides in-depth analysis of the statistical tools for engineering applications. Topics include basic probability, conditional probability, Bayes' theorem, PDF and CDF, random variables, transformations, expected values, moments, characteristic functions, limit theorem, random processes, wide sense stationary processes, spectral density, Markov processes and Markov chains, Gaussian, Poisson and shot noise processes, and elementary queuing analysis.

CPEN 610 Seminar I

The seminar I course focuses on the development of the professional presentation skills as well as problem solving skill of candidates in the discipline through special seminars. Some of the areas to cover include introduction of ideas, methods, and techniques to improve the content and presentation of scientific seminars. As part of the course, candidates will provide a title and an abstract for a seminar, compose and present a seminar, compose and present feedback on other delivered seminars. Candidates will be involved in informal group studies on special problems, group participation in comprehensive design problems, or group research on complete problems for analysis and experimentation. Each candidate will give at least one oral presentation and also submit a full write up of the presentation for assessment.

CPEN 684 Advanced Engineering Mathematics

The advanced mathematics course provides the necessary applied mathematical and analytical tools useful for solving practical engineering problems. Topics include first ordinary differential equations and solutions, second order differential equations and higher order differential equations, series solution of ordinary differential equation including power series method, Bessel functions, Legendre function, and hyper-geometric functions, linear algebra and calculus

including matrices, eigen-values eigen-vectors, vector differential calculus, divergence and curl vector fields, vector integral calculus including Green's theorem and Stoke's theorem, Laplace transforms, Fourier analysis of differential equations, partial differential equations including basic concepts, vibrating strings, D'Alembert solution, wave equation and heat equation.

3.5 Description of Elective Courses – MPhil Year I

3.5.1 Computer System Courses

CPEN 606 Computer System Testability

The computer system testability course examines fault models and testing techniques, errors, failures, reliability and availability techniques in digital systems. Topics include designing techniques for reliable systems, redundancy management, fault modeling, fault detection, fault location and reconfiguration, testing, design for testability, self-checking circuit, fail-safe circuit, system-level fault diagnosis, fault-tolerant communication, fault tolerant multiprocessor systems, reliable software design, low-overhead high-availability techniques, and evaluation methods.

CPEN 607 VLSI Systems Design

The VLSI systems design course examines the concepts behind the development of digital systems and their testing techniques. Topics include trends in VLSI development, architectures of VLSI, design methodologies, circuit design using structured systems, CMOS and MOS device modeling, design of CMOS combinational and sequential circuits, noise and signal integrity, design techniques for system power reduction, interconnect analysis and timing issues, clocking and synchronization, testing and verification, programmable ASICs and design methodologies, ASIC architecture and programming methodologies, routing techniques, fault analysis and design testability. Completion of a substantial design project will be part of the course.

CPEN 608 VLSI System for Signal Processing

The VLSI system for signal processing course focuses on the hardware implementation of signal processing systems on SoC (system-on-chip) used for communications, compression, encryption, and coding applications. Topics include signal processing algorithms, principles of datapath design, FIR and IIR filter architectures, communication systems including OFDM and multirate signal processing, fast transforms and algorithms including FFT, DCT, Wavelet transform, and Walsh-Hadamard transform, computer arithmetic methods including Galois fields, residue number systems, distributed arithmetic, canonic signed digit systems and reduced adder graph algorithms.

CPEN 609 Microprocessor Systems Design

The microprocessor systems design course explores the architectures for microprocessors and the supporting components for application. Topics include microprocessor components, design, analysis and performance of microprocessor architectures, comparison of design paradigms for architectures such as CISC, RISC, and DSP, instruction level parallelism, bus timing analysis, design considerations for high-performance systems, execution problems, memory architectures and performance, benchmarking and optimization, parallel architectures and processing, systolic and data flow architectures, multiprocessor performance and iterations, power dissipation, support software, and simulation tools.

CPEN 611 Parallel Computing Systems

The parallel computing systems course examines modern parallel and distributed systems design, engineering and evaluation. Topics include parallel systems design concepts, architectural evolution of parallel systems, technological driving forces of parallel systems, programming algorithms and models, communication primitives, programming and compilation techniques, multiprogramming workloads and methodology, latency avoidance techniques, cache-coherency, protocols, directories, and memory consistency models, message passing protocols, storage management, and deadlock, network interface, protection, events, active messages, latency tolerance techniques, pre-fetching, multithreading, dynamic instruction scheduling, and software techniques, network design and synchronization.

CPEN 612 Reconfigurable Systems

The reconfigurable systems course focuses on the design and implementation of high-performance computing machinery using configurable computing technology. Topics include introduction to configurable computing and developments, performance metrics for configurable systems, architectures for configurable computing, FPGA architectures, spatial computing architectures, adaptive network architectures, systolic and bit serial architectures, contemporary configurable systems, hardware/software co-design for computing systems, pipeline, caches, configurable computing operating systems, and adaptive computing machines and applications.

3.5.2 Telecommunications System Courses

CPEN 613 Communication Policy and Management

The communication and policy and management course provides the necessary policy frame work, standards and management of telecommunication systems. Topics include ICT industry and developmental issues, overview of the telecommunication systems including fixed, mobile, internet, and cable systems, telecommunications services and delivery, communications policy and regulation, role of ITU and challenges, radio frequency management, allocation of spectrum, regulations for the use of spectrum, common carriers, competition and compliance, long term

policy planning, and telecommunications management including internal and external views of telecommunication management, and telecommunication network management model.

CPEN 614 Error Detection and Control

The error detection and control course examines error detection in communication and recording systems and control measures for reliable digital transmission and storage. Topics include signal detection in white and colored noise, random waveform, matched filtering, m-ary signal detection, nonparametric detection, error control coding including major classes of codes that important in practice such as binary linear block codes, Reed Muller codes, Galois fields, linear block codes over a finite field, cyclic codes, BCH and Reed Solomon codes, convolutional codes and trellis decoding, message passing decoding algorithms, trellis based soft decision decoding of block codes, turbo codes, and low density parity check codes.

CPEN 615 Information Theory and Coding

The information theory and coding course provides the fundamental background on the Shannon theory and their application. Topics include information theory, encoders and decoders for digital data in noisy channels, linear block coding, cyclic coding, BCH coding, convolutional coding, burst error correcting codes, Huffman code and universal code, channel capacity, differential entropy and Gaussian channels, multi-user information theory including broadcast and multiple access channels, rate distortion including quantization, proof of achievability and converse rate distortion, performance of block and convolutional coding in noisy channels.

CPEN 616 Communication Network Algorithms

The communication network algorithms course provides the methodologies and algorithms used for designing and optimizing communications networks with focus on the algorithmic aspects of network design. Topics include modeling networks as graphs, graph algorithms for finding minimum spanning trees, shortest paths, and matroids, topological design including selecting terminal concentrator locations, heuristic algorithms and network topology optimization, algorithms including flow deviation algorithm, Bertsekas-Gallager algorithm, cut-saturation algorithm for distributed computer systems, communications network optimization involving cut saturation algorithm for topological design of packet switched, communication networks algorithm for access facility location problem, dimensioning schemes, mesh topology optimization including capacity assignment and branch exchange, mesh network topology optimization and routing algorithm.

CPEN 617 Communication Networks Design

The communication networks design course examines the design issues for communication networks and the trade-offs. Topics include types of communication networks, shortest path, maximum flow, and minimum cost problems including novel polynomial time algorithms, routing algorithms and protocols, protocol processing, queuing theory, switching fabrics,

network processors, network development life cycle, network design and analysis, network protection and restoration design, multi-layer network design, data to support network design, structured enterprise network design, hierarchical tree network design, network optimization, traffic flow analysis, analysis of data loss and delay in networks, and network reliability issues.

CPEN 618 Digital Communications

The digital communications course investigates the modern trends in generating digital signal for propagation and processing. Topics include information transmission fundamentals including capacity, entropy, Shannon theorem, and source coding, basics of stochastic processes, design of baseband and passband digital communication systems, rate distortion theory, advanced digital modulation and demodulation techniques, performance measures, channel coding and trellis coded modulation, synchronization, inter-symbol interference (ISI) and equalization techniques, and concepts for modern digital communication including spread spectrum signals for digital communications, multiple access systems, time division multiple access, code division multiple access, and frequency division multiple access..

CPEN 619 Wireless and Mobile Communication Systems

The wireless and mobile communication course examines the design and implementation of wireless and mobile communication systems. Topics include wireless radio communications, cellular networks, satellite networks, wireless local area networks, wireless personal area networks, elements of wireless communication systems, modeling of wireless multipath fading channel and parameters, coherent and non-coherent reception, spread spectrum communication, multiple access, anti-jamming and interference management, frequency re-use, sectorization, multiple access techniques such as TDMA, CDMA, and OFDM, capacity of wireless channels, error performance evaluation over radio links, mobile IP, ad-hoc networks, wireless network security, and future of wireless communications.

CPEN 621 Communication Network Management

The network management course covers modern network management models and issues. Topics include communication networks management architecture, homogenous and non-homogeneous network management systems, modern tools for managing network, management network reference models, remote network management, configuration for data collection, network management implementation, network monitoring and reconfiguration, network management application development, operational issues in managing heterogeneous networks.

CPEN 622 Mobile Computing Systems

The mobile computing course is concerned with methods and principles for the development of systems whose components show forms of mobility across networks which requires knowledge about the domain that the movement is taking place. Topics include delivery of connectivity to

mobile nodes, languages that provide facilities for code migration, computational models that include the notion of locality, and design methods supporting the development of new kinds of network applications, communication protocols, application-support software, and characteristics of wireless communication medium, security, location-aware applications, and algorithms for the implementation of basic system services.

CPEN 623 Optical Fibre Communication Systems

The optical fibre communication systems course examines the techniques associated with signal transmission and detection process in optical medium. Topics include physics of optical fibre, fiber properties of dispersion, attenuation, and nonlinear effects on data transmission, electro-optical conversion devices for signal generation and detection, modulation techniques and implications, circuit considerations, overall system considerations including coupling, transmitter design, receiver design, noise properties of fiber, and multichannel transmission issues, coherent modulation properties of laser diodes, homodyne and heterodyne detection, light-wave networks such DWDM, FDM, TDM, and CDM, and their relative merits, optical network access, optical interconnection, and topological issues in optical switching.

CPEN 624 Optical Devices

The optical device course examines the optoelectronic devices and their properties that facilitate optical communications. Topics include identification of optical components in photonic systems and subsystems, operation principles of lasers and LED, modulation dynamics, single frequency lasers, fundamental AM and FM noise properties, laser line-width requirements, tunable semiconductor lasers, quantum well lasers, electro-optic modulators and switches, optical filters, couplers, isolators, detectors, integrated optoelectronic circuits, semiconductor optical amplifiers, Erbium optical fiber amplifiers, low coherence sources diodes, and tunable optical filters.

CPEN 626 Wireless Communication Security

The wireless communication security course examines security treats and design of security features necessary to protect and control wireless communication for reliable operation. Topics include wireless network architecture and components, wireless network systems security and privacy issues, wireless network threats and sources, security requirements and implementation framework, security policies, security requirements for switching, access network, transport network elements and mediation devices, network security techniques, security protocols and services, network security system design model including identification, authentication, system access control, resource access control, data integrity, audit, security administration, and data confidentiality, network attacks and counter measures, intrusion and extraction detection, incidence response and forensic analysis, security implementation for securing wireless network infrastructure. Example to be drawn from cellular, wireless LAN, mobile, wireless mesh, ad-hoc (MANET), RFID, sensor networks, and vehicular networks.

CPEN 627 Adaptive Signal Processing

The adaptive signal processing course provides introduction to relevant signal processing and basics of pattern recognition. Topics include discrete random processes, linear prediction, digital wiener filtering, digital adaptive filter structures including LMS adaptive algorithm, properties of LMS adaptive filter, normalized and finite effect and adaptive beam-forming, performance analysis of LMS algorithms, stability criteria of evaluation, and modified LMS algorithms, frequency-domain adaptive filter, least squares adaptive filters, sub-band adaptive filter, infinite impulse response filter and algorithms, lattice structure and algorithms, applications using adaptive signal processing techniques in adaptive noise cancellation in speech communication and adaptive system identification among others, practical implementations and issues in adaptive signal processing and current trends ad research in adaptive signal processing.

CPEN 628 Multimedia Signal Processing

The multimedia processing course provides focuses on multimedia signal representation, data compression and information retrieval. Topics include multimedia signal representation of data, audio, speech, image, and graphics, analog video, data transformation techniques such as Fourier, z, and wavelets, Shannon entropy theory, data sampling and quantization, sub-sampling and up-sampling of data, multimedia data compression techniques including lossless encoding methods including Huffman, entropy, arithmetic, run-length, lossy encoding such as transform encoding, wavelet based zero-tree, differential encoding, and vector quantization, compression standards - JPEG, MPEG, multimedia data retrieval including techniques for statistical pattern recognition and probability density estimation, introduction to content based data retrieval and multimedia data fusion.

3.5.3 Automation Engineering Courses

CEPN 631 Applied Optimization Methods

The Applied optimization methods course examines the optimization theory and techniques for practical engineering problems. Topics include classification of optimization problems, linear programming, nonlinear unconstrained optimization, nonlinear constrained optimization including inequality and equality constraints, Lagrange multiplier method, and Kuhn-Tucker conditions and solution methods, dynamic programming, random search algorithms and search methods for optimization, convex optimization methods, and application examples from different engineering disciplines.

CPEN 632 Industrial Controls

The industrial controls course present an overview of advanced controller design strategies for multivariable industrial processes, starting from PID control structure to the more advanced H-infinity design technique. Topics include feedback control systems, industrial processes and need

for feedback, industrial control system components such as actuators, sensors, and controllers, classical control strategies, process modeling, PID control, state feedback, nominal feedback and performance of feedback control systems, H-optimal control uncertainty modeling for robust control, robust closed loop stability and performance, robust H control, controller technologies such as PLC, DCS, PC-based control, Matlab based control, Labview based control, and dedicated hardware for controller implementations.

CPEN 633 Control Systems Design

The control systems design course examines the basic issues and theoretical foundation in the analysis and design of computer control systems for industrial applications. Topics include signals and sampled data systems, zero-order hold equivalent, linear systems theory, control system modeling, dynamic systems analysis and feedback control, controller design methods, system stability analysis using Jury's test, Nyquist criterion, and Lyapunov method, observability, reachability and controllers, performance analysis, robust control, output feedback, separation theorem, optimal control, and adaptive control systems.

CPEN 634 Programming for Industrial Automation

The programming for industrial automation course focuses on the programming mechanisms for modern devices in the control operations in industry. Topics include functional block diagrams, control system software for PLC and SCADA, programming techniques for PLC, computer based controllers, microcontroller, digital computer interface including isolated and non-isolated digital I/O, ADC, DAC, and engineering applications in selected industry in Ghana.

CPEN 635 Robotics Systems

The robotic system course focuses on the design and programming of robotic systems and issues in current research in robotics. Topics include basic components of robotic systems, planning, control of realistic robotic systems, review of issues in robotics programming, robotic programming languages, classifications of robots, basic components, motion classification, control and sensing uncertainty, motion constraints, analysis of friction for assembly and grasping tasks, sensing systems for hands, environmental perception from sparse sensors for dexterous hands, grasp planning and manipulation.

CPEN 636 Communication in Industrial Automation

The communication in automation course examines modern communication topology and architecture employed in industrial automation systems. Topics include communication components, principles of communication in industrial automation, architecture and topology of network communication, communication protocols as used in industrial automation in wired and wireless communication such as TCP/IP, RS-232, RS-485, Fieldbus, DNP3.0, Modbus, Zigbee,

Bluetooth, and IDRA, error detection and control, troubleshooting, and introduction to security in industrial automation systems.

CPEN 637 Human-Computer Interaction

The human computer interaction course provides key approaches to the design, development, and evaluation of human-computer interfaces, with an emphasis on usability, interaction paradigms, computer-mediated human activities, and implications to society. Topics include foundation of HCI and technologies, HCI paradigms and history, nature of human computer interaction, use and context of computers, human characteristics including human information processing, language and communication interaction, and ergonomics, computer system and interface architecture, development process including design approaches, implementation techniques and tools, evaluation techniques, user interface software and error handling, multimedia systems, interaction design for new environment.

CPEN 638 Machine Learning

The machine learning course examines the field of machine learning with a focus on how to construct computer programs that automatically improve with experience. Topics include exponential family distributions, Bayesian networks, Bayesian inference, maximum likelihood, maximum entropy, mixture models, EM algorithm, graphical models, hidden Markov models, variational methods, linear classifiers, regression, generalization bounds, support vector machines, kernel methods and transduction, machine learning applications of detecting fraudulent card transactions, learning users reading preferences, and autonomous vehicles that learn to drive.

3.5.4 Software Engineering Courses

CPEN 641 Advanced Operating Systems

The advanced operating system course examines the structural aspects of operating system and how these provide support for general purpose, embedded, and real-time operating environments. Topics include survey of early systems, structural design of operating system including process model, inter-process communication, synchronization mechanisms, resource management, CPU scheduling, I/O scheduling, file systems, virtual machines, protection issues, implementation issues of modern operating systems, performance analysis, deadlock detection, recovery and avoidance, operating system for distributed and current systems, review of current research in operating systems.

CPEN 642 Real-Time Software and Systems

The real-time software and systems course provides a comprehensive view of real-time systems with theory, techniques and methods necessary for effective design and development of real-time computing system. Topics include fundamental concepts, terminology, real-time characteristics and issues, real-time hardware including processors, memory and transducers, operating systems and tasks, utilization and response time, periodic and aperiodic task scheduling, synchronization and blocking, resource access, rate monotonic analysis, priority servers, real-time system development process, real-time system requirements analysis, modeling techniques, architecture design, design patterns, performance analysis, verification and validation, testing strategies, system safety and reliability, languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems.

CPEN 643 Software Engineering

The software engineering course examines the concepts of system hierarchical relationships and the role of system engineers. Topics include software engineering for modern enterprise application and performance critical systems, software life cycle, software engineering process, requirements and software requirements analysis, software design, software architecture including trade-off analysis, enterprise architecture, service-oriented architecture, COTS architecture, and RAD, software implementation, software integration for systems such as enterprise application integration and COTS integration, software verification and transition, software validation, operation and maintenance, software quality assurance.

CPEN 644 Software Testing

The software testing course focuses on the techniques and processes for testing software reliability, reliability models, and techniques to improve and predict software reliability. Topics include defining necessary reliability, testing fundamentals including issues and relationships of testing to other activities, test levels ranging from target of the tests, objectives, component testing, integration, system and acceptance testing, testing techniques including specification-based, coded-based, fault-base, usage-based, and nature of application, test-related measures for system under test and evaluation of the tests performed, and test process.

CPEN 645 Software Design

The software design course examines the general software design concepts and design process and enabling techniques. Topics include key issues in software design, software structure and architecture styles including human computer interface design, software design quality analysis

and evaluation, software design notations, software design strategies and methods including heuristic and formal methods and component-based design.

CPEN 646 Software Measurements and Quality

The software measurements and quality assurance course provides an in-depth evaluation of the verification and validation process throughout the development lifecycle of software. Topics include software quality fundamentals, software engineering culture and ethics, value and costs of quality, quality models and characteristics, quality improvement, application quality requirements, and defect characterization, software quality management process, quality assurance, software quality management techniques, and software quality measurement, verification and validation including system and software verification and validation, and independent verification and validation, verification and validation techniques including testing, demonstrations, traceability, analysis, inspections, peer review, walkthrough, and audits.

CPEN 647 Systems Engineering

The systems engineering course examines the methods, tools, and validation techniques for the analysis, specification and prototyping of software systems. Topics include basics of systems engineering, system design constraints, design and requirements allocation, eliciting requirements, analysis, concepts exploration and evaluation, design process, defining concepts, architecting systems, prototyping systems, conceptual modeling of systems and validation, designing tests, analysis of risks and failures, acceptance tests, considering users, deployment and maintenance of systems, and practical considerations for software engineering of the world wide web.

CPEN 648 Software Maintenance

The software maintenance course examines the principles and techniques used for the maintenance of software systems. Topics include nature of maintenance, need for maintenance, components of maintenance costs, and categories of maintenance, key issues in software maintenance such as technical issues relating to testing, impact analysis, and maintainability, management issues, maintenance cost estimation, and software maintenance measurement, maintenance process including process models, maintenance activities, unique activities, and supporting activities, techniques for maintenance such as program comprehension, reengineering, and reverse engineering

CPEN 649 Enterprise Application Integration

The enterprise application integration course provides the techniques on how to design and deploy large-scale systems and understand the trade-offs and implications of supporting the critical backbone of modern enterprises. Topics include enterprise architecture frameworks including the Zachman enterprise framework, open group architecture framework, and enterprise

architecture cube methodology, enterprise oriented service architecture design and implementation, unique aspects of enterprise architecture and development, security for large enterprise systems, reliability for distributed long running transactions, standards for intra and extra organization system integration, deployment and fault tolerance of systems.

CPEN 686 Software Architecture Systems

The software architecture systems course examines the principles and techniques for the architectural design of complex systems using well-founded architectural paradigms. It considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. Topics include overview of software architecture, architectural drivers, structures and views, data flow systems, data flow styles, call-return systems, client-server and tiered architecture, middleware, event based systems, shared information systems, techniques and methods for the architecture, design by selection, architecture evaluation, product lines, using UML for design representation, formal specification and analysis, architecture conformance, performance, availability, service oriented architecture and web services, security, usability, organizational alignment, global distributed development, platforms, and research directions in software architecture systems.

3.5.5 Networks Engineering Courses

CPEN 651 High-Speed Networks

The high speed data networks course focuses on the advances in LAN, MAN, and ATM. Topics include high speed data networks models, approaches to design and management of networks, high speed transmission networks and switching technologies, FDDI, DQDB, SMDS, Frame Relay, ATM networks, and SONET, congestion control and traffic management, performance modeling, queuing theory, routing algorithms, data compression, and applications demanding high-speed communication, multicasting for teleconferencing, and mobile computing.

CPEN 652 Advanced Topics in Wireless Networks

The advanced topics course examines topical issues in networking with focus on wireless networking technologies, protection and the next generation networking. Topics include wireless networking services and technologies, requirements and challenges for wireless data network design, access technologies, developments in wireless networks such as WiFi (IEEE 802.11), bluetooth, wireless USB, Ultra wideband, sensor networks such as zigbee, wide area networks such as WiMAX (IEEE 802.16) and 3G/4G cellular networks, mobility management, handoff, protocol adaptations for wireless networking including mobile IP, WAP, mobile TCP, wireless

resources management, including packet scheduling power management and ad-hoc routing, issues of mobile data network security, emerging mobile data architectures and services, quality of service, issues of mobile data application, wireless cache invalidation, multimedia transport over wireless, and location dependent services.

CPEN 653 Network Protocols and Services

The network protocols and services course examines the principles behind communication network protocols, standards, performance analysis, and implementation of both existing and emerging network. Topics include fundamental of data communication networks and protocol architectures, network performance metrics, principles of network protocol design, error detection and correction, flow control and congestion, delay and throughput models, QoS, service support and application interface, LAN and WAN and protocols, LAN and WAN interconnections, IP addressing, TCP, UDP, high-speed bulk transfer protocols, routing in data networks and protocols such as BGP and OSPF, network services, DNS and BIND, network and protocol design to support multi-media and multicasting connections, network management and SNMP, protocol implementation models, network application security.

CPEN 654 Multimedia Networks and Storage

The multimedia networks and storage course covers a broad range of topics in the frontier of multimedia networking systems with focus on transmission techniques and protocols, massive storage architectures and data security. Topics include concepts of multimedia systems, resource management issues in distributed/networked multimedia systems, QoS routing and multicasting, traffic shaping, task and message scheduling, internet QoS, adaptive multimedia applications over internet, operating system support for multimedia, characteristics of multimedia data, storage architecture and scalable media servers, processor architectures for multimedia, compression techniques, synchronization techniques, jitter management, error control and loss recovery, video-on-demand, voice-over-IP, wide area caching systems and techniques, encryption and group key management.

CPEN 655 Distributed Networks

The distributed networks course provides the concepts underlying the architecture and operations of distributed networks. Topics include distributed network architectures and processing, communication primitives, resource sharing, event ordering and synchronization, distributed deadlocks and management, naming, load balancing, distributed network operating systems and languages, distributed databases, fault tolerance and recovery strategies, file service, protection issues, design issues, distributed office information systems, and related applications.

CPEN 656 Computer Network Security

The computer network security course examines the treatment of network security for secure data operation. Topics include principles and practice of network related security threats and

solutions, mathematical principles of cryptography and data security, conventional and modern encryption algorithm techniques, secure communication protocols, public and private key encryption, remote access security, authentication, digital signatures, internet protocol security architecture, firewalls, VPNs, and PKI architecture, intrusion detection systems, electronic mail security, routing protocol security, wireless network security, traffic analysis and alert tools, modern applications relating to digital cash and secure distributed computing, and operational aspects of network security and management.

CPEN 657 Wireless Sensor Networks

The wireless sensor networks course examines the fundamental issues of sensor network and design of collections of smart sensors that are networked to form self-configuring pervasive computing systems. Topics include introduction to ad-hoc and senor network including challenges and unique constraints, wireless communication characteristics, ad-hoc wireless networks, media access control protocols, routing protocols, networking sensors including unique features, deployment techniques, sensor tasking and control, and transport layer and security protocols, sensor network platforms and tools including sensor network programming challenges, operating systems, and middleware devices, applications of ad-hoc and sensors networks and future trends including ultra wide band radio communication and wireless fidelity systems, and applications such as embedded sensor networks and pervasive computing.

CPEN 658 E-Commerce Technologies

The e-commerce technologies course examines the principles and design of secured e-commerce applications deployment over the world-wide-web systems. Topics include fundamentals of e-commerce infrastructure and implementation, social, ethical and legal considerations in e-commerce, developing application for the world-wide-web, application protocols, e-commerce models, connection and session objects, authentication services, internet security including firewalls, viruses, hacking, design issues of e-commerce, web servers, integrating database services, data transactions between database servers and servers using XML.

3.5.6 Information Systems Engineering Courses

CPEN 661 Information Security

The information security course examines the design and implementation of information security system that assures content confidentiality. Topics include introduction to confidentiality, integrity, availability, authentication techniques and models, controls and protection models, security kernels, secure programming, audit, intrusion, detection and response, operational security issues, physical security issues, personal security, policy formation and enforcement, access controls, information flow, legal, privacy and social issues, identification and authentication in local and distributed systems, classification and trust modeling, risks and

vulnerabilities, risk assessment, database security, encryption, host based and network based security issues, secure network design, implementation and transition issues, and techniques for responding to security breaches.

CPEN 662 Pattern Recognition

The pattern recognition course describes various methods and techniques that are used in pattern recognition. Topics include Bayes decision theory, description of patterns, feature extraction and classification, classification models, non-parametric pattern classification techniques, parameter estimation, pattern classification using linear discriminant functions, uncertainty in pattern recognition, fuzzy sets, perception algorithms and its extensions, learning of rules for pattern recognition, learning discriminates, unsupervised learning and clustering algorithms, feature extraction and algorithms, neural network techniques including Hopfield, feed forward model, and training of neural networks, structural recognition techniques, and other pattern recognition methods and applications.

CPEN 663 Cryptography and Analysis

The cryptography course focuses on the mathematical concepts and techniques behind modern information encryption and network technologies. Topics include survey of classical and modern encryption techniques and algorithms, encryption theory and foundations, cryptographic and crypto-analysis techniques, one-way functions, pseudo-random function, encryption system modeling, authentication protocols, public-key cryptosystems, notions of security, zero-knowledge proofs, multi-party cryptographic protocols, security policies, legal and ethical issues, practical applications of encryption.

CPEN 664 Artificial Intelligence

The artificial intelligence course focuses on the issues and principles and techniques of artificial intelligence. Topics include knowledge representation, organization and manipulation of the world and how to reason logically with the knowledge, concepts of inconsistency, uncertainty, probabilistic reasoning, structured knowledge, logic programming, computational and statistical learning theory, machine learning including supervised, unsupervised and reinforcement learning, decision making including search oriented problem solving, planning, games, Markov and decision processes, planning and temporal reasoning, inference and theorem proving, reasoning under uncertainty, search and information retrieval, principles of intelligent agents, speech and natural language processing involving parsing, machine translation, and information extraction, speech recognition, computer vision, and robotics

CPEN 665 Neural Networks

The neural networks course examines models of computation that learn tasks from examples of desired input and output behavior for various applications. Topics include basic concepts behind

neural network models, biological neuron model, neural network architectures, feed-forward, feed-back, Hopefield models, adaptation and learning in neural networks including perceptron, iterative learning, multilayer network with hidden layers, back-propagation, convergence and speeding up algorithms, supervised Hebbian learning, Widrow-Hoff learning, associative learning, competitive learning, self-organizing neural networks, neural network training and testing techniques including setting of training parameters, preparing training data, training the network, and testing of the network, neural network applications to speech, robotics, face and pattern recognition, implementation process using electronics and optical.

CPEN 667 Advanced Database Systems

The database system course examines the principles of the design of systems that can manipulate and retrieve data from large databases using high level formal languages. Topics include data base development lifecycle, data modeling, database architectures, database design theory, data acquisition, models for database systems, data integration and cleaning, query processing, concurrency control and transaction management, data search and recovery, distributed and parallel data management in cluster computing and peer-to-peer, web pages, sensor networks and RFID, data storage, inference and data mining, data security and privacy, declarative data-intensive systems, data visualization, query optimization and stream algorithms, current trends in development of database systems.

CPEN 668 Data Compression

The data compression course examines the theoretical foundation of compression techniques and algorithms for lossy and lossless data compression as well as signal modeling and its extensions to data compression and applications to multimedia data compression. Topics include basics of signal encoding and decoding for compression, lossy and lossless compression, communication building blocks, and fixed and variable rates, quantization theory including uniform quantization, distortion and bit rate, high rate quantization theory and elementary distortion rate theory, architecture for data compression including signal models and spectral analysis, coding forms, entropy and variable quantization, lossless coding algorithms such as Huffman, arithmetic, universal lossless, adaptive and predictive coding algorithms, distortion and similarity measures, lossy coding algorithms such as scalar quantization algorithm, and vector quantization coding algorithm, speech and audio compression techniques, image and video compression techniques, compression standards and formats.

CPEN 669 Speech Processing and Recognition

The speech processing and recognition course covers the fundamentals of speech recognition and voice interfacing with machines. Topics include overview of discrete statistical signal analysis, acoustic aspects of speech and hearing, voice interfacing and issues, speech technologies like recognition, synthesis, and compressed audio transmission, automated speech processing, digital

models of speech production, short-time processing in time and frequency domains, waveform encoding and linear predictive coding of speech, estimation of fundamental speech parameters, digital speech processing and phonetic feature extraction, identifying words from pronunciations, syntax and semantics in speech understanding, task constraints and natural language, alternative speech recognition system structures, voice interfacing projects, and strategies for achieving user satisfaction, automatic speech recognition and enhancement.

CPEN 672 Data Mining

The data mining course provides background information on the design and use of data mining algorithms and applications in data mining on the web, computational biology and various medical applications. Topics include models, methods and processes of data mining including search and querying, data dredging and fishing, discrete structures involving item-set mining, concept lattices, condensed representation, frequent pattern mining, customized data structures for speeding up data mining algorithms, attribute-value learning techniques including decision tree, decision lists, classification and regression trees, association rules, and rule-based mining, relational mining techniques, probabilistic techniques including conditional independence and its modeling, representational complexity, Bayesian networks, and probabilistic models for query approximation, sequences and order, compositional data mining, mining chains of relations, integrated query and mining languages, paradigms for interfacing with database systems, and application in bi-informatics, personalization, information retrieval, web modeling, filtering and text processing.

CPEN 674 Computer Vision

The computer vision course involves the development of algorithms and software that have the potential to mimic a biological organism's ability to see. Topics include the physics of vision and its computational modeling, mathematical techniques for representing and reasoning with curves, surfaces, and volumes, image formation and sensing, camera model, thin lens model, lighting and reflectance, image capture and processing including edge finding, corner detection, image segmentation and texture analysis, image reflectometry involving color, image irradiance, and reflectance map, image analysis techniques such as convolution, filtering, noise, derivatives, and smoothing, scale space and SIFT, motion estimation and optic flow, 3D vision including shape from shading and shape from texture and defocus, geometric camera calibration, homographies, structure from motion, epipolar geometry and estimating of fundamental matrix, and dense stereo correspondence.

3.5.7 Bio-Computing Courses

CPEN 673 Biomedical Signal Processing

The biomedical signal processing course provides an application-intensive approach to biomedical signal processing and application of mathematical tools. Topics include technologies for signal acquisition such as MRI, EEG, ECG, and sonar, architecture of bio-sensors and design, signals and systems theory, Fourier analysis, sampling theorem, discrete signal processing, noise characteristics of biosignals such as biologic, sensor, electronics and digital processing noise, linear and adaptive filtering, wavelet transforms, denoising, compression, classification and feature extraction applications, practical considerations in medical device design as relates to signal processing such as scalability, robustness, testability, algorithm complexity and regulatory issues.

CPEN 674 Digital Image Processing

The digital image processing course examines the properties of digital images and the method of processing. Topics include 2-D sequences and systems, separable systems, properties of digital images, image formation, sampling, time and frequency representation of images, transformation techniques including Fourier, z transform, difference equations, and wavelets transform, human visual system including perception, vision properties, color, and sensors, image enhancement, image restoration, geometrical image modification, filtering, and edge detection, binary image processing, morphological image processing, halftoning and edge detection, image coding and compression models for loss-free, lossless, and lossy compressions, motion estimation and compensation, compression standards and formats.

CPEN 675 Theory of Computations

The theory of computations course provides the fundamental complexity theory and models useful for solving computational problems. Topics include basic computational theory, computational models including nondeterministic alternating and probabilistic machines, Boolean circuits, complexity classes related to models of computing including NP, polynomial hierarchy, BPP among others, complete problems, interactive proof systems and probabilistic proofs, randomized algorithms, structural complexity and complexity hierarchy.

CPEN 676 Algorithms for Computational Biology

The algorithms for computational biology course provide the background knowledge useful for the design of algorithms for analysis of biological systems. Topics include vector geometry, matrix algebra and recursive relationship, algorithm concepts and optimization, basic biological techniques for predicting interactions, databases, graph algorithm libraries, network topological properties, phylogenetic profiles, predicting function including integer programming, modularity, partitioning heuristics, spectral partitioning and dense sub-graph detection, network searching

and alignments, speeding-up searches and color coding, random models of biological networks including duplication model, small world, preferential attachment models, evolving modularity, generating random graphs, dynamic networks, linear programming algorithm, semi-definite, side chain packing, and phylogenetic trees and reassortment detection algorithm.

CPEN 677 Bioinformatics

The bioinformatics course provides computational methods and development of algorithms to address problems in molecular biology. Topics include molecular genetics of DNA, RNA and protein, cellular organization, modern biochemical techniques such as cloning and DNA sequencing, bioinformatics problems, bioinformatics database, representing and retrieval of sequences, sequence comparison with dot matrices and dynamic programming, statistics of pattern appearance, multiple sequence alignment, sequence database searching, learning machine basics, phylogenetic tree construction and algorithms, representing and finding sequence features, RNA and protein structure prediction, gene prediction and annotation, gene finding, retrieving and displaying macromolecular structures, microarrays and gene expression analysis models and technologies, biomolecular computing.

CPEN 678 Mathematical Neurobiology

The mathematical neurobiology course provides insight to the elements of neurophysiology and neuroanatomy for the development of quantitative models of nerve cell and brain phenomena and to develop and analyze several different mathematical models in neurobiology. Topics include difference equations, dynamical systems theory, ordinary differential equations and partial differential equations, linear membrane and cable theory, Rall's equivalent cylinder model of the nerve cell, determination of active membrane properties using linear theory, action potentials including Hodgkin-Huxley (HH) model and FitzHugh-Nagumo (FHN) model, asymptotic and computational determination of the action potential using the FHN equations, bursting phenomena in excitable cells, nonlinear waves of spreading cortical depression, and rotating waves in excitable media.

CPEN 679 Advanced Algorithm Design

The algorithm design course provides the basic concepts and principles to examine and design efficient algorithms for a variety of computational problems and applications. Topics include dynamic programming, methods of algorithm design and analysis including data structures, network flows, matching, and linear programming, ellipsoid algorithm, probabilistic algorithm techniques, approximation algorithms for NP problems, geometric algorithms, number theoretic algorithms, on-line computation, and parallel computing.

CPEN 682 Analysis of Genomic Data

The analysis of genomic data course examines the approach for the analysis and display of large scale biological data sets using various algorithms and machine learning techniques. Topics include clustering techniques for gene expression and protein data analysis, machine learning techniques, biological networks, joint learning from multiple data sources, visualization issues for large scale biological data sets.

3.6 Description of Core Courses – MPhil Year II

CPEN 620 Seminar II

The seminar II course emphasizes on the development of the skill of candidates to enable them reach the research frontier of the discipline. As part of the course, scholarly articles will be selected from recent publications or book chapters to develop a good understanding and provide sufficient background to enable the formulation of novel hypotheses and experimental testing. Some of the areas to cover include identification of problems addressed by a study, relevant background material from scientific literature to clarify current state of knowledge on the topic, method and approaches followed by the study, in-depth analysis of presented results, evaluation of the importance of the results and their implication, evaluation of the significance of the study, its merits and short-comings. Each candidate will be required to give a scientific presentation on one or more selected papers published in a peer-reviewed journal. As part of the course, each candidate will be expected to give a formal presentation on the research proposal the candidate intends to work on for the thesis as well as progress report on the research.

CPEN 650 MPhil Thesis

The MPhil thesis involves a candidate working closely under the guidance of an approved graduate supervisor or supervisors for one year to investigate an approved original project idea from a selected field of specialization, and writing a thesis. The investigation will conform to the principles of research and will include the relationship of the proposed idea to previous related work reported in literature, significance of the study, the merits, short-comings and potential applications. The thesis will be evaluated based either on the academic contribution or contribution to the relevant industrial application. The contributions and results obtained from the investigation will be synthesized and compiled into a publication-quality research paper.