

Appendix A : Description of Computing Modules

A.1 Level-1

CS1101 Programming Methodology

The aim of this module is to introduce students to the discipline of computing and to the problem solving process. The module stresses on good program design and programming styles, and structured program development using a high-level programming language. Some basic concepts in procedural abstraction, structured programming and top-down design with stepwise refinement will be introduced. Topics to be covered include: algorithm design process, program development/coding/debugging, programming concepts in a high-level language including program structure, simple data types and structured types, and various control structures (sequencing, loops, conditionals, etc.), and linear data structures, such as arrays and linked-lists. The utility of recursion will also be highlighted using a variety of sorting algorithms. Laboratory work is essential in this course.

CS1101S Programming Methodology

The aim and topics for this module are similar to those of CS1101. However, students taking this S-option will be given advanced assignments. To support such advanced study into selected topics, extra recitation classes will be scheduled. Advanced students, as determined by the School, can subscribe this S-option.

CS1102 Data Structures and Algorithms

The aim of this module is to give a systematic introduction to data structures and algorithms for constructing efficient computer programs. Emphasis is on data abstraction issues (through ADTs) in the program development process, and on efficient implementations of chosen data structures and algorithms. Commonly used data structures covered include stacks, queues, trees (including binary search tree, heap and AVL trees), hashing tables, and graphs; together with their corresponding algorithms (tree and graph traversals, minimum spanning trees). Simple algorithmic paradigms, such as generate-and-test (search) algorithms, greedy algorithms and divide-and-conquer algorithms will be introduced. Elementary analyses of algorithmic complexities will also be taught. Laboratory work is essential in this course.

CS1104 Computer Organization

This course aims to familiarize students with the fundamental building blocks of computer systems. Students will learn the basic design of digital logic circuits. They will be exposed to the register-level architecture of a computer system. The basic building blocks of a computer system like CPU, memory, and I/O units are discussed. Students will gain a better understanding on how a high-level language program actually works inside a computer. Topics to be covered include: Binary system; Boolean algebra and logic gates; simplification of Boolean functions; adders, subtractors, and multiplexers; flip-flop and memory; registers and counters; basic organization and von Neumann model; memory organization; input/output; CPU structure and organization; control unit; parallel organization - multiprocessing and vector computation; RISC architecture; and comparison between RISC and CISC; overview of assembly language programming; representation of numeric and character data, types of instruction operators and operands; arithmetic and logic instructions; string and bit operations; arrays and addressing modes; branching and loops; procedures; input and output at the assembly level.

CS1105 Computing and Society

This module explores the social, ethical and professional issues of computing. Topics include 1) history of computing: hardware, software, networks; 2) social implications of

computing, networked communication, internet; 3) privacy and computing technologies; 4) methods and tools of ethical arguments; 5) professionalism and ethical responsibility; 6) risk and liability of critical systems, examples, risk assessment, management; and 7) introduction to intellectual property.

CS1231S Discrete Mathematics (Accelerated)

The module aims to introduce students to the basic discrete mathematical concepts and the results that are used in almost all areas of the school curriculum. The students are exposed to rigorous mathematical proof techniques in many branches of discrete mathematics. The module compresses the two successive modules on Discrete Mathematics (CS1231 and CS1232) into one module. It provides an accelerated path for students with strong mathematics background to attain the knowledge in this area.

CS1231 Discrete Mathematics I

The module aims to introduce students to the basic discrete mathematical concepts and the results that are used in almost all areas of the school curriculum. The students are exposed to rigorous mathematical proof techniques in many branches of discrete mathematics. Topic includes: Proofs: Statements and Logical Connectives: truth table, conjunction, disjunction, negation, conditional, biconditional, compound statement, tautology, contradiction, implication, equivalence. Quantification: universal and existential quantification, negation of quantified statements, counterexamples, multiple quantification. Mathematical Reasoning: rules of inference, direct proof, proof by contradiction, proof by cases, constructive proof, inductive proof. Relations: Sets. Natural numbers, integers, and rational numbers. Cartesian products. Binary Relations. Compositions. Binary relations on a set. Reflexivity, symmetry and transitivity. Transitivity as composition. Equivalence relations and partitions. Partially and totally ordered sets. Mappings : Domain, codomain and range. Composition of mappings. Surjectivity and injectivity. Equality of mappings. Identity map. Inverse mappings. Bijection and one-to-one correspondence. Graphs: Basic definitions. Sum of degrees is twice the number of edges. Euler's formula for planar graphs. Paths and the Konigsberg bridge problem. Trees and spanning trees. Rooted tree as a directed graph and a partially ordered set. Terminology for rooted trees. Binary relations as directed graphs. Partially ordered sets as directed acyclic graphs. Undirected graphs as symmetric relations. Connectedness as transitive closure of a relation. Equivalence relations, partitions and connected components of a graph. Number of paths and matrix multiplication. Connectedness and multiplication of boolean matrices.

CS1232 Discrete Mathematics II

The second module continues to introduce students to the basic discrete mathematical concepts and the results that are used in almost all areas of the school curriculum. Topic includes: Combinatorics: Permutation and combination. Pigeonhole Principle. Inclusion-Exclusion Principle. Combinatorics on previous topics: number of relations on a set, number of injections from one finite set to another, number of graphs with n vertices, height of a tree, etc. Countability. Countability of binary strings. Diagonalisation: There are uncountably many sets of binary strings. Countability of rational numbers and uncountability of reals. Subsets of countable sets are countable. An infinite countable set has an uncountable power set. Probability: Sample space. Event. Elementary results. Sampling with and without replacement. Conditional probability. Multiplication, Total Probability and Bayes' Theorems. Independent events. Discrete random variables. Density functions. Joint and marginal density functions. Independent random variables. Mean and variance. Basic results on mean and variance. Chebyshev's Inequality. Uniform, Bernoulli, binomial, geometric and Poisson distributions. Poisson and Normal approximations.

CS1240 New Media Art

In the past few decades there have been rapid changes in our perceptions on creativity and the work of art. Simultaneously we observe how the most recent developments in

information, communication, interface and experiential technologies have radically affected our lives. One of the main notions that bring contemporary art and such technologies together is that of interactivity. This course seeks to critically explore this crucial element of new media art with reference to its historic precedents and contemporary manifestations. The different notions of interactivity exemplified and enabled by the new media arts are explored - specifically digital imaging, video and animation; web-based interactivity; human-machine interfaces; technological embodiments; biotechnological arts; virtual reality; artists' software; the aesthetics of programming and; new media exhibition strategies.

CS1305/GEM1501M Problem Solving for Computing

This module aims to introduce students the basics of critical thinking and problem solving, particularly, in relation to the discipline of computing. The module covers: what is problem solving, problem statement & representations (natural language, mathematical notation, logical formulation, pictorial representation, graph models), stages in problem solving (understand, plan, execute, analysis); paradigms in problem solving, what is thinking, thinking as a skill, perception and common errors in thinking, and critical thinking and reasoning.

A.2 Level-2

CS2102 Introduction to Database Systems

The aim of this module is to provide students with the knowledge and understanding of basic issues and techniques in manipulating large volumes of data stored on secondary storage. The module covers manipulation of data stored on secondary storage, physical organization of data, access methods that facilitate data retrieval, concepts of database management systems in manipulating large volume of shared data, principals of DBMS, particularly the relational database management systems and their use in application development, SQL language, and new developments in non-conventional data processing techniques.

CS2102S Introduction to Database Systems

The aim and topics for this module are similar to those of CS2102. However, students taking this S-option will be given advanced assignments. To support such advanced study into selected topics, extra recitation classes will be scheduled. Advanced students, as determined by the School, can subscribe this S-option.

CS2103 Software Engineering

This module is a continuation of CS1101/S/C Programming Methodology and CS1102 Data Structures and algorithms. It also serves to prepare the students for CS3214/S Software Engineering Project. It introduces the necessary conceptual and analytical tools for systematic and rigorous development of software systems. It covers four main areas of software development, namely object-oriented analysis, object-oriented design, implementation, and testing, with emphasis on the design and implementation of software modules that work cooperatively to fulfil the requirements of a system. Tools and techniques for software development, such as Universal Modeling Language (UML), program specification, and testing methods, will be taught. Major software engineering issues such as modularization criteria, program correctness, and software quality will also be covered. Hands-on practices of analysis, design, programming, and testing are essential in this module. After taking this module, students should be able to put all that they have learned in CS1101/S/C, CS1102, and CS2103 into practice in CS3214/S Software Engineering Project.

CS2104 Programming Language Concepts

A small number of concepts underline the hundreds of programming languages that have been designed and implemented. This module introduces the concepts that serve as a basis for programming languages. It aims to provide the students with a basic understanding and

appreciation of the various essential programming language constructs, programming paradigms, evaluation criteria and language implementation issues. The module covers concepts from imperative, object-oriented, functional, logic, constraints, and concurrent programming. These concepts are illustrated by examples from varieties of languages such as Pascal, C, Java, Smalltalk, Scheme, Haskell, Prolog, Awk/Perl/Snobol, and Concurrent Pascal. The module also introduces various implementation issues, such as pseudo-code interpretation, static and dynamic semantics, abstract machine, type inferencing, etc.

CS2105 Computer Networks I

This module gives students a foundation in the study of communication networks. It assumes no prior knowledge of data communication. The emphasis is on the basic principles and concepts. Essential data communication knowledge required in the use and understanding of computer networks is covered without resorting to mathematical approach. While discussing computer networks, more emphasis is placed on architecture such as local area networks, layering, characteristics of protocols like flow control and error control that are common across all layers. Wherever possible the module provides practical information regarding products, vendors, selection criteria and integration issues. The module is associated with laboratory experiments to augment the concepts taught in the class. The data communication part includes: basic concepts of data communication, fundamental limits, encoding and modulation, multiplexing, error detection and control. The communication networks covers: Concept of layered architecture, ISO model, message transmission techniques, basics of terminal protocols like polling and flow control, data link layer, introduction to LANs, CSMA/CD and Ethernet. Other medium access mechanisms like token ring (including FDDI) and token bus; practical aspects of LAN including selection, cost and performance considerations, and integration. Network interconnection - bridges, internetworking with routers, IP and ARP protocol; practical aspects in integration of LANs, TCP and ISO transport services, network applications and services, network monitoring, management and security issues are also dealt with.

CS2106 Operating Systems

The aim of this module is to introduce students to basic programs of the computer system such as assemblers, macro processors, linkers, compilers, and operating systems that are essential for programming. This module covers machine structure, assembly language programming, macros, linkers, regular expressions and lexical analysis, context free grammars and syntax analysis, syntax directed translation and code generation, processes and concurrency, mutual exclusion, process communication and synchronization, deadlocks, scheduling, memory management, file management, and I/O management.

CS2250 Information Systems Theory and Practice

The aim of this course is to provide students with a general background on the uses of information systems in organizations and the managerial aspects of such systems and to promote an awareness of the economic, social and ethical implications of such systems on society and IS professional. Topics include: general systems concepts, data and information, framework of information systems in organizations, introduction to transaction processing systems, management information systems, electronic data interchange and executive information systems, controlling and managing the implementation change process of information systems, end user computing, social relationships in electronic communities, economic and organizational dimensions of computerization, social control and privacy, ethical issues and professional responsibilities.

CS2250S Information Systems Theory and Practice

The aim and topics for this module are similar to those of CS2250. However, students taking this S-option will be given advanced assignments. To support such advanced study into selected topics, extra recitation classes will be scheduled. Advanced students, as determined by the School, can subscribe this S-option.

CS2251 Business Finance

The aim of this module is to introduce students to the basic concepts and tools in Finance. Students will learn about the financial environment facing companies and the financial decision making process that confronts company management. The emphasis will be on the application of these concepts and tools to make sound financial judgment for a company. The module covers financial concepts and tools, fixed asset investing, long-term financing, short-term financial management, and international financial management.

CS2301 Business and Technical Communication

The module surveys the kinds of business and technical communication needed by Information Systems and Computer Science students. The module is designed to sharpen students' oral and written skills in business and technical communication. The technical communication component will emphasize documentation, writing user's manuals and instructions, and the proposal process. Students will also need to become aware of the importance of the interactive nature of communication. After completion of this module, students will be able to analyze communication situations according to the models presented in lectures, on videotapes, or in the course text or handouts, and discuss the relevant principles. More important, the course will help students put the communication principles and skills they have mastered into practice in stimulated real-world situations. The course uses half-size tutorial groups to facilitate discussion and to provide more opportunities for practice. This module covers theory of communication, interpersonal communication, oral communication, written communication, the job process, and technical communication.

CS2271 Introduction to Embedded Systems

The aim of this module is to introduce student the design trade-off and technologies for the creation of embedded systems. Topics include: Introduction to the embedded systems; FPGAs, DSP, and embedded microprocessors; designing and programming FPGAs; programming with a hardware description language; high-level programming of FPGAs.

A.3 Level-3

CS3103 Computer Networks II

The aim of this module is to provide the basic knowledge in network interconnection, protocols, and network based application development. Students will be able to analyze networking requirements, ask proper networking questions, and know where to seek answers to those questions. This laboratory- based module will explore many alternatives for connecting LANs and introduces basic components like hubs, switches and routers. It provides an opportunity for students to wire their own LANs in the laboratory and interconnect LANs using hubs and routers. It heavily uses Ethernet and TCP/IP protocols to illustrate how networking and Internet connections are achieved. The LAN technology is revised and reinforced specifically with respect to Internet protocols and client/server based architecture. Interprocess communication through socket programming and server design issues are also covered. Client-server application development using client-serve programming tools like RPC will be discussed.

CS3106 Independent Project

This project module provides students an opportunity to undertake a substantial project work over a period of 6 months. Students may work individual or in groups on projects proposed by staff. At the end of the project, the students must submit a report describing the details of the project.

CS3107 Industrial Attachment

The main aim of this module is to expose students to the IT industry over a period of 6 months. The attachment will give them a good opportunity to apply what they have learnt at the University on a real-life industrial problem. The experience they gained can become useful to their future studies at university and to their careers in industry. It also enables the student to develop the necessary social, technical and communication skills to work effectively in industry. Students may work individual or in groups on projects proposed by staff. At the end of the project, the students must submit a report describing the details of the project.

CS3208 Undergraduate Research in Computing I

The module (together with CS3209) is part of the UROP (Computing) project. The project provides an opportunity for student to undertake a substantial research project under the supervision of faculty members of the School of Computing. Through this research collaboration, the student will get to experience at first hand the challenges and exhilaration of research, discovery and invention. This module should be followed by CS3209 to complete the UROP (Computing) project.

CS3209 Undergraduate Research in Computing II

The module follows CS3208 and completes the requirements of the UROP (Computing) project. Please see CS3208 for description.

CS3210 Compiler Writing

This module introduces some techniques for program analysis and run-time organization for language implementation. This module covers (i) the general program analysis techniques, (ii) the use of lexer- and parser-generators, (iii) the implementation of run-time systems and interpreters and (iv) code generation basics. A toy language may be used to show the implementation of typical languages such as Pascal or C. Each assignment will build up upon previous assignment until a full-compiler is developed. Since most students may not be designing new languages in industry, the module should also be relevant to general language processing and tool construction, and possibly 4GL languages.

CS3211 Parallel and Concurrent Programming

A concurrent system consists of a set of processes that execute simultaneously and that may collaborate by communicating and synchronising with one another. Examples of concurrent systems are parallel programs that describe sets of collaborating processes. This module introduces the design, development and debugging of parallel programs. It will build on the concurrency concepts gained from the Operating System module. It covers concepts and modeling tools for specifying and reasoning (about the properties of) concurrent systems and parallel programs. It also covers principles of performance analysis, asynchronous and synchronous parallel programming, and engineering concurrent systems and parallel programs.

CS3212 Programming Languages

This module provides the students with theoretical knowledge and practical skill in design and implementation of programming languages. It discusses the theory behind the fundamental programming paradigms (imperative, functional, logic, and object-oriented) and behind basic programming language concepts such as binding, scope, parameter-passing mechanisms and types. It introduces the language processing techniques of interpretation and compilation. A discussion of virtual machines highlights that program execution almost always uses both, often in a multi-level hierarchical architecture. The course covers automatic memory management as a feature of programming systems and its implementation.

CS3214 Software Engineering Project

This project module trains students to undertake a substantial project work on software development. It enables students to consolidate and apply what they have learned in their three-semester programming courses. Students are required to work (in team) through a complete Systems Development Life Cycle, while completing a large-scale software project. The workload is approximately two months (full-time) effort. It differs from CS3214S in its emphasis on the development of a business information system, focusing on requirement analysis, user-interface and database design.

CS3214S Software Engineering Project

This project module trains student to undertake a substantial project work on software development. It enables students to consolidate and apply the skills they have developed in their three-semester programming courses. Students are required to work in team through a complete Systems Development Life Cycle, while completing a large-scale software project. The workload is approximately two months (full-time) effort. It differs from CS3214 in its emphasis on the development of software tools, from the design of the software architecture down to detail data structures, and algorithmic aspect of software development.

CS3220 Computer Architecture

Although computer systems employ a range of performance-improving techniques, intense efforts have been made to improve present performance, often leading to the development of completely new type of computer systems. Many of such design techniques involve the use of parallelism, in which more than one operation is performed simultaneously. Parallelism can be achieved by using multiple functional units at various levels within the computer system. The objective of this module is concerned with design techniques involving the use of parallelism to improve the performance of computer systems. The module is divided into three parts. Part I consider the fundamental methods to improve the performance of single processor systems. Topics include the design principle of instruction set, memory hierarchy, pipeline design techniques, RISC and vector computer. In Part II, multi-processor systems using shared memory are examined in detail, and Part III, multi-processor systems that did not use shared memory.

CS3221 Advanced Operating Systems

The aims of this module are to explore operating systems concepts not covered in CS2106 by addressing both new topics and discussing in-depth the implementation of familiar concepts. The topics will include process scheduling, synchronization, IPC, distributed system, concurrency control in distributed & non-distributed systems, load distribution, advanced file systems, storage management, protection, reliability, security, and case study of the implementation of 'real' operating systems.

CS3222 Microprocessor Technologies and Systems

The aim of this module is introduce students to semiconductor technologies, including MOS, PMOS, NMPOS, CMOS, etc. design and implementation of VLSI chip and their fabrication process. Topics on design, architecture and programming of microprocessors and interfacing peripherals will be covered.

CS3223 Database Management Systems

This module studies concepts and implementation related to database management systems (DBMSs) in depth and some concepts and techniques for modern applications. We first cover the physical implementation of relational data model, which includes storage management, access methods, query processing, and optimization. Then we study issues and techniques dealing with multi-user application environments, namely, transactions, concurrency control and recovery. The third part covers object-database systems that are useful extension of relational databases to deal with complex data types. The last part

covers database technologies required for modern decision support systems, including data warehousing, data mining and knowledge discovery, on-line analytical processing, etc.

CS3224 Architecture of Internet

The aim of this course is to provide a solid grounding in the architecture of the Internet and the world-wide web. It introduces concepts, issues, design and implementation of the underlying networking protocols, issues of server design, scalability issues and security issues. At the end of this course, the students should have the expertise and competence to design, implement and deploy complete internet-based systems.

CS3230 Design and Analysis of Algorithms

This module is to teach students different techniques of designing and analyzing algorithms. In this, module students learn about the framework for algorithm analysis, for example lower bound arguments, average case analysis, and the theory of NP-completeness. In addition, students are exposed to various algorithm design paradigms. The module serves two purposes: firstly, to improve the students' ability to design algorithms in different areas, and secondly, to prepare students for the study of more advanced algorithms. The module covers lower and upper bounds, recurrences, basic algorithm paradigms (such as prune-and-search, dynamic programming, branch-and-bound, graph traversal, and randomized approaches), amortized analysis, NP-completeness, and some selected advanced topics.

CS3231 Automata Theory and Formal Languages

This module serves as an introduction to (1) some standard formal models of computation so as to develop an understanding of what can and cannot be computed by various devices, (2) some techniques in computer science (e.g. nondeterminism, diagonalization, simulation and reduction), (3) the mathematical formulation of objects in computer science so as to study their properties. The module covers regular languages and finite automata, context-free languages and pushdown automata, Turing machines, Church's Thesis and unsolvability.

CS3232 Systems Modeling and Simulation

This module provides students with the methodology and techniques that are required for the planning and design of computer simulation models. At the end of the module, the students should be able to carry out a study of a system using simulation. Topics include: overview of ways to study a system; simulation modeling; concepts, components and organization of discrete-event simulation; random number and random variate generators; input data collection; modeling and analysis; model verification and validation; output analysis; design of simulation experiments; examples of systems models from science and business; and overview of parallel discrete-event simulation. A simulation language will be covered in detailed, with a large simulation exercise to be carried out.

CS3233 Competitive Programming

This modules aims to prepare students in competitive problem solving in computing -- covering techniques for attacking, solving, and writing computer programs for challenging computational problems. It also covers algorithmic and programming language toolkits used in problem solving supported by the solution of representative or well-known problems in the various algorithmic paradigms. The course will be a hands-on course with weekly problem sets to be solved.

CS3234 Logic and Formal Systems

The course aims to cover both classical and non-classical logics focusing on their deductive and algorithmic aspects. This module introduces mathematical logic as a means for specifying, verifying and reasoning about computer programs. Its emphasis, in contrast to other similar logic courses, is on how logic can be used to represent computational problems, how these representations can be proved correct and how they can be executed

on a computer. Topics covered include classical logic theories (6 hours), logic programming (10 hours), modal logic (6 hours), and an introduction to non-standard logics (4 hours). Treatment of propositional calculus, predicate calculus, and temporal logic are fully covered with emphasis on their specification, verification, deductive and algorithmic aspects.

CS3235 Computer Security

With the widespread use of computers and Internet as well as electronic commerce, computer security becomes more and more important. The idea of introducing this module is to give students basic knowledge of computer security. This module covers the following topics: threats to computer systems, network security fundamentals, security in a layered protocol architecture, authentication in computer systems, access control, intrusion detection, security architecture and frameworks, lower layers security protocols, upper layer security protocols, electronic mail and EDI security, directory systems security, Unix systems security, security evaluation criteria.

CS3236 Scientific Computing

This module introduces numerical methods and symbolic methods for handling scientific problems. It provides students hands-on experience in using existing software tools for performing numerical analysis and symbolic computation. Topics covered include: fixed precision and errors, exact computation and costs, matrix and non-linear numerical algorithms, algebraic manipulation techniques, usage and programming of numerical and computer algebra systems.

CS3240 Human-Computer Interaction

This course is intended for students in computing disciplines whose work interacts with user interface issues in the design of software systems. The course stresses the importance of user-centered design and usability in the development of software applications and systems. Students will be taken through the analysis, design, development, and evaluation of user interfaces. They will acquire hands-on design skills through a graphical user interface design project. The course also emphasizes the importance of taking into account contextual, organizational, and social factors in system design.

CS3241 Introduction to Computer Graphics

This module teaches some graphics hardware devices, review the mathematics related to the understanding and discuss the fundamental areas of computer graphics. After the course, students are expected to understand the basic computer graphics terminology, concepts and be able to design and implement simple 2D and 3D interactive computer graphics related programs. As an enrichment part of the course, students are introduced the state-of-the-art development in computer graphics by viewing for example, interesting video clips and experimenting with demo program made available in our course web.

CS3242 Hypermedia Technologies

CS3242S Hypermedia Technologies (project-emphasis)

This course introduces digital multimedia technologies and systems, XML and other web based information encoding standards, digital libraries and information accesses on the WWW. As part of the course, the students need to complete at least one large-scale group project on developing digital media systems. At the end of the course, students should have: (a) good knowledge of digital multimedia, XML and WWW; (b) the experience to develop a large-scale systems-oriented digital media project; and (c) the competent to take up senior year projects and research in multimedia, digital library and electronic publishing.

CS3243 Foundations of Artificial Intelligence

The module introduces students to the basic concepts in search and knowledge representation as well as to a number of sub areas of artificial intelligence to allow them to have a good foundation and overview of the discipline. The emphasis of the module is in

covering the essential concepts in AI. The module covers Turing test, blind search, iterative deepening, production systems, heuristic search, A* algorithm, minimax and alpha-beta procedures, predicate and first-order logic, resolution refutation, nonmonotonic reasoning, assumption-based truth maintenance systems, inheritance hierarchies, the frame problem, certainty factors, Bayes' rule, frames and semantic nets, planning, learning, natural language, vision, and expert systems and LISP.

CS3244 Machine Learning and Neural Networks

This module introduces basic concepts and algorithms in machine learning and neural networks. Students who have taken this module are expected to be (1) familiar with the theories and paradigms of computational learning; (2) capable of implementing basic learning systems; (3) knowledgeable about the sources of computational learning materials (literature, web sites, etc.) and (4) equipped with basic skills for further research and/or development. The module starts with discussing motivation and background for computational learning. The main reason for studying computational learning is to make better use of powerful computers to learn knowledge (or regularities) from the raw data. The ultimate objective is to build self-learning systems to relieve human from some of already-too-many programming tasks. This will be a very long journey. Hopefully, this module will introduce a few more believers of computational learning to join the journey. In general, there are two camps of computational learning drawing inspirations from different sources: symbolic and connectionist. Both will be covered in such details that students will be able to create learning systems themselves. Essential theories and fundamental techniques will be presented in a down-to-earth manner. Basic math, probability theory and statistics will be used only when it is necessary in explaining the concepts.

CS3245 Decision Making Processes

The module introduces rational decision making techniques and tools based on probability theory and utility theory, and some common biases people exhibit when make decisions. The focus is on comparing actual decisions to those specified by the normative theory, with a view of improving them. The module covers the introduction to basic concepts and techniques in descriptive, normative, and prescriptive decision theory and game theory. Examples of complex, decision situations in business, medicine, law, and general daily life. Analysis of theories and models for decision making under uncertainty, risk, and adversity. Discussion of judgmental biases and corrective procedures.

CS3246 Computer Animation

Computer animation is applied extensively in many fields from fantasy entertainment to science, engineering, medicine and military. The newest 3D interactive devices, together with powerful graphics card (PC) and engine (Workstations) technologies make it possible to interactively animate a complex model. The proposed module will explore systematically the computer animation techniques: interactive devices, mobile data structure and soft object modeling, various motion control and deformation techniques, techniques for animation of natural phenomena, collision detection and animation systems.

CS3247P Speech and Language Processing

This is a project-based course aims to provide students with hands-on experience through project development by applying the latest technologies in speech and language processing. The course covers the following areas: Basic knowledge on human language: Human voice and human languages, phonemes, syllabuses, words form and meaning, printed fonts, handwriting, part-of-speech, sentences, paragraphs and text. Language processing technique includes: techniques and algorithms for speech recognition, dynamic time wrapping(DTW), Hidden Markov Modelling(HMM), speech feature vectors, vector quantizations(VQ), speech synthesis, PSOLA technique, morphological analysis, word segmentation, part-of-speech and parsers, word spotting, sentences understanding, representation of sentence in logic, text retrieval, text knowledge extraction. The teaching of

the course will be algorithm oriented and theories are introduced using program examples. The mastering of the technologies through practical experiences is the main approach. Part of the course materials will be composed by the students through a seminar series. Vendors in speech and language technologies will be invited to share with the students their R&D experiences. Students will spend 2/3rd of their time on project work on speech and language applications with commercial values.

CS3250 Management Support Systems

The module introduces students to the use of computer-based systems in support of managerial decision in organizations. Topics include: evolution of management support systems, decision making and decision makers, modeling, development of DSS, data- and model-management in DSS, organizational DSS, EIS, GDSS, data warehousing and mining, integration and implementation issues. MAGNUS, a simulated decision environment and software such as SAS, What's Best, DPL, @RISK are used to support lectures and illustrate applications.

CS3251 Technology Strategy and Management

The aim of this module is to understand the theory and practice of business strategy as applied to technology-oriented (and in particular, IT-oriented) products and services. It provides students with a broad and in-depth understanding of the theory and practice of technology strategy and management. These will be applied to information technology related products and services. The module covers strategy planning and implementation, change management, information politics, and intellectual property. Case studies form a major part of this model.

CS3252 Management Science

This module introduces students to some of the basic concepts and methods of management science and operations research careers. There is a strong focus on models - how they are created, how they are used, what kinds of insights they provide -and on the critical importance of managerial judgment in utilizing those insights. Computer applications, including the use of spreadsheets and of many popular special-purpose software packages, are integrated throughout the module. The main topics to be covered include linear programming, decision making under uncertainty, inventory management, queuing model, and simulation for complex systems.

CS3253 Management of Information Systems

The course covers the essentials in management of information systems in an organizational setting. The main topics include: information systems planning, management of systems development and maintenance, implementation management, end-user computing, data centre operations, information systems control, evaluation of information systems, acquisition of IS resources, and management of IS personnel.

CS3260 Telecommunications for Business

Telecommunications encompasses the transmission of voice, data, video, and multimedia through local and wide area networks. This course aims to analyze how telecommunications can be employed to reduce costs and meet new customer needs. It begins from the basic economics of technology and networks to develop a telecommunications strategy and policy for network management. The course will include case studies of particular industries such as banking and finance, manufacturing, and logistics and transportation. It will also introduce the telecommunications environment in Singapore and the region.

CS3261 IT Marketing

This module introduces students to the principles of marketing with the emphasis on the IT industry. The second focus is the application of IT in marketing. The substantive topics covered include the concept of marketing and marketing environment, consumer behaviour,

market analysis and targeting, product design, pricing, distribution and sales force management, advertising and promotion, and international marketing. Case studies and examples will be drawn from the IT industry. The application of IT to marketing will also be emphasized.

CS3262 Investment Technology

This module aims to introduce students to different investment instruments and the related technologies. The objective of the module is to present the students with the basic paradigms of modern financial investment theory, to provide a foundation for analyzing risks in financial markets and study the pricing of financial securities. Topics will include the calculation of risk and return, market efficiency, choice under uncertainty and portfolio theory, asset pricing (CAPM), bonds and term structure, futures and forward contracts, option pricing, and risk management. The module will examine in detail the rationale, structure, characteristics and use of various investment instruments. Throughout the module, the functions and operations of the various financial institutions that utilize these instruments will be briefly touched upon.

CS3263 Financial Markets

This module builds upon previous modules in Economics and Finance and focuses on familiarizing the students with the context of global and regional financial markets. The financial markets covered include money markets, capital markets, Euro/Asia-markets, foreign exchange markets and futures markets. First, the economic and institutional justifications for these markets will be discussed in terms of various theories of asset demand and financial intermediation. Subsequently, the module will examine in more detail the rationale, characteristics and use of various financial instruments traded in these markets. Throughout the module, the functions and operations of the various financial institutions that operate in these markets will be briefly touched upon.

CS3264 ERP Systems

A typical business organisation has a number of resources. They include: the employees, their skills and competencies; the business processes, procedures and organisational structure; and the computer systems that support the business. The efficiency and effectiveness of an organisation in carrying out its business can be enhanced if managers and employees are given the support to plan, monitor and control the business. Enterprise Resource Planning (ERP) aims to provide organisation with such a support by maximising the use of all the resources in an organisation. In this course, students will be taught the rationale for having ERP, ERP functionality (such as manufacturing, finance, distribution and human resource management), ERP and information technology, ERP systems and ERP implementation (this includes planning, product selection, implementation and optimisation).

CS3265 Economics of e-Business

We are living in a "New Economy" with e-business. E-business means not only "selling products electronically" but also digitalization of many conventional business processes: financing, advertising, and managing human resources. These process-related changes significantly impact intra-business organization, business-to-business relationships, and business-to-consumer interactions. Even though technology advances breathlessly, the ideas, the concepts, and the models of economic principles are durable. The economic analyses, such as differential pricing, bundling, signaling, licensing, lock-in, or network effects can directly applied to e-business economy. This course aims to give students economic insights to understand e-business and to make better decisions in e-business.

CS3266 e-Commerce Technologies

This module is a hands-on education on the stage of the art technologies peculiar to e-commerce. Students will learn the fundamentals as well as the applications of e-commerce

technologies, such as e-commerce security systems, e-commerce payment systems, supply chain systems, e-commerce agents and e-commerce client-server systems.

CS3281 Programming in UNIX

This module aims to train students to be professional in dealing with UNIX systems. Topics include: C programming: Variables, types, operators, expressions, control flow, functions, function arguments, recursion, pointers, address arithmetic, arrays, structures, standard input/output. Unix system interface: file/directory manipulation, system data files, Unix processes, process control, signals, interprocess communication (pipe, FIFO), terminal I/O. Unix tools: shell programming (Bourne shell), programming tools (Xemacs, gcc, make, ddd debugger), regular expressions and text utilities (grep, awk, sed).

CS3282 Systems Programming and Administration

This course will train students to become junior system programmers. System administration constitutes the major part of most system programmers work. The course will cover UNIX system. It will possibly covers LINUX in detail, and with some references to Windows NT. The topics are generally applicable to most types of computer systems. Topics covered include typical system programming and system administration; script programming, such as Perl and shell scripts, will also be covered.

CS3283 GUI Programming

This module aims to teach the nuts and bolts of GUI programming. At the end of the course, students will acquire practical knowledge in Windows programming and techniques of programming interactive systems. Topics include Windows programming, Motif, Tck/TI programming.

A.4 Level-4

CS4101 Honours Project

The students work on the individual honours years research project throughout the honours year. The project may be proposed internally or jointly between staff member and an industrial partner. Towards the end of the honours year studies, the student is required to submit a report describing the project work, and give an oral presentation before a panel of examiners. The workload is approximately four months (full-time) efforts.

CS4102 Technical and Management Training

The aim of this module is to provide students with further technical and management experience. Students will get the opportunities to manage computer laboratories, as well as conduct and manage practical sessions and tutorial groups.

CS4210 Constraint and Logic Programming

This module covers elements of contemporary concepts in the design and implementation of constraint programming languages. Programming concepts will include imperative and logic programming with constraints, parallel and concurrent constraint programming. The implementation section will be an overview of major techniques, presented at a level that enhances programming, as opposed to a level purely to enhance performance. Practical assignments will be done using ILOG, CLP(R) and a concurrent CP system.

CS4211 Advanced Software Engineering

This module introduces students to problems that occur in large-scale software production. The module examines technical and managerial aspects of software development life cycle. A methodological approach and automation of software production are stressed. After the module, students should be prepared to play an active role throughout all the phases of team projects and should understand project control mechanisms. This module focuses on

technical and project management aspects of software development and maintenance in team environments. It covers concepts of software development life cycle, project planning and control, software requirement analysis, software design principles and methods, software quality assurance, reuse and maintenance methods. Formal approaches to project planning and software specification are covered. Modern CASE based methods for software development and maintenance are emphasized.

CS4220 Computer Systems and Server Interfacing

The aim of the module is to provide the students with technical knowledge about how to interface various devices to a computer, using the PC as an example. Both software and hardware aspects are included. The students will learn the basic techniques of interfacing both analog and digital devices to the PC, and to develop software to drive them. A practical module that covers servers and computer systems interfacing including device drivers, application programming interfaces (APIs), dynamic linking, interrupt programming, system communication and synchronization. The lectures consist of four main parts. The first part introduces the concept of computer interfacing and discusses interfacing issues at the digital electronics level, covering topics such as diodes, transistors, TTL and CMOS. The second part covers interfacing to ISA bus and discusses topics such as address decoding, bus drivers and ISA bus cycles. The third part covers digital interfacing, which includes simple I/O ports, handshaking, interfacing parallel and serial I/O, and digital signal conditioning. The fourth part covers analog interfacing, which includes sensors, analog signal conditioning, digital-to-analog conversion and analog-to-digital conversion.

CS4221 Database Design

The aim of this module is to provide students with the knowledge necessary to design relational databases and object oriented databases. The module covers normalization theory: functional, multivalued and join dependency, normal forms, relational database schema design using decomposition method and synthesizing method, eg. Bernstein's Algorithm and LTK's Algorithm; entity-relationship approach: normal form entity-relationship Diagram, convert entity-relationship diagrams to normal form entity-relationship diagrams, translate entity-relationship diagrams to relational, network, and hierarchical database schemas; schema integration: view integration and database integration, schema conflict resolution; nested relations: normal form nested relations, nested relations design using decomposition method and entity-relationship approach; object-oriented databases: object-oriented DBMS concepts, inadequacies in object-oriented data models, inheritance conflict resolution, translate relational database schemas and entity-relationship diagrams to object-oriented database schemas.

CS4222 Advanced Networking: Protocols Design and Implementation

The module covers: protocol design considerations, protocol engineering and implementation issues, case studies of protocol design and implementation, performance evaluation – modeling & performance measurement; multimedia networking and introduction to high performance networks (sonet, atm, gigabit ethernet, etc.). Lab work include mini projects on protocol design, modeling and simulation, high speed network programming.

CS4230 Computational Complexity

The aim of this module is to study measures of difficulty of problem solving, and to introduce some techniques in theoretical computer science such as nondeterminism, diagonalization, simulation, padding, reduction, randomization and interaction. The module covers: space and time complexity, tape compression, linear speedup, Savitch's theorem, translation lemma, Gap theorem, NP-completeness, probabilistic complexity classes, approximation algorithms, and interactive protocols.

CS4231 Parallel and Distributed Algorithms

This module studies the different models of parallel computation, as well as different parallel algorithms. Topics on parallel algorithms include models of computation, selection, merging, sorting, searching, generating permutations and combinations, matrix operations, numerical problems, computing fourier transforms, graph theory, computational geometry, decision and optimization. Topics on distributed algorithms include algorithms such as mutual exclusion, deadlock detection, leadership election, distributed consensus, atomic commitment for achieving consistent global states, fault-tolerance and self-stability.

CS4232 Performance Analysis of Computer Systems

The aim of this module is to provide students a working knowledge of computer performance evaluation and capacity planning. They will be able to identify performance bottlenecks, to predict when performance limits of a system will be exceeded, and to characterize present and future workload to perform capacity planning activities. The module covers: performance analysis overview; measurement techniques and tools including workload characterization, instrumentation, and benchmarking; analytical modeling techniques including operational analysis, stochastic queuing network analysis and performance of client-server architecture; simulation modeling; and capacity planning.

CS4233 Cryptographic Techniques

Cryptographic techniques are the basic tools for building secure systems and are essential to electronic commerce. This module is to introduce the basic cryptographic techniques. It covers the following topics: foundations of cryptography, classical ciphers, introduction to block and stream ciphers, private-key block ciphers, stream ciphers, the idea of public-key cryptography, knapsack systems, RSA system, hash algorithms, authentication, data integrity and nonrepudiation, key management, authentication codes, secret sharing.

CS4234 Combinatorial and Graph Algorithms

This module presents advanced material on the design and analysis of combinatorial algorithms with emphasis on efficient algorithms and data structures. This module is meant for students who intend to (i) do research in computer science in general, and algorithm design in particular, or (ii) do advanced application/software development in other areas of computer science. The module covers a wide range of standard combinatorial and graph algorithms, including advanced data structures commonly used in these algorithms. Some of the topics that may be covered include, advanced data structures, graph algorithms, matching and network flow, theory of NP-Completeness, combinatorial algorithms, geometric algorithms, mathematical programming, probabilistic algorithms and Meta-Heuristic search methods.

CS4240 Advanced Computer Graphics & Virtual Reality (current)

The aim of this module is to provide a general treatment of graphics modeling, interactive 3D graphics and virtual reality, and visualization. The module covers: (a) graphics modeling: mathematics of 3D graphics; rendering and ray tracing; polygonal, parametric surface and CSG models; and modeling natural phenomena; (b) interactive 3D graphics and virtual reality: 3D interactions and devices; immersive and non-immersive VR systems; modeling of virtual world; and applications; and (c) visualization: visualizing scalar data in 1D, 2D and 3D; visualization systems and their applications.

CS4240 Virtual Reality and 3D Interaction (to replace current CS4240)*

The module will cover advanced 3D interactive techniques by focusing on a set of selective subjects: fundamentals of virtual reality, immersing devices (HMD, Gloves, magnetic trackers, stereo glasses and other force and multi-user systems, techniques for real time or fix frame rate simulation such as scene/object culling and representations of level of details (LOD) and image based rendering.

CS4241 Multimedia Information Systems

This course introduces techniques for analysis, representation and retrieval of multimedia information. The media to be considered include images, audio and videos. At the end of this course, the students should have the expertise and competence to design and implement retrieval software for multimedia data. In this course, we will discuss various attributes characterizing the multimedia data. The attributes to be discussed are text, color, texture and shapes. For each attribute, we will discuss its representation scheme, similarity-based retrieval model, iterative refinement technique, and other representation and retrieval models. We will discuss the use of these attributes to retrieve images, audio and video. Finally, we will discuss a framework for multimedia information retrieval and directions of the future work.

CS4242 Reasoning under Uncertainty

The aim of this module is to introduce essences of uncertainty in the real world situations. Reasoning based on probability theory and fuzzy theories to cope with typical real world situations are studied. This module is divided into two parts. The first part covers probabilistic reasoning and Bayesian networks, and the second part covers fuzzy sets, fuzzy logic and approximate reasoning. The emphasis is on both theory and application (in control, decision making, pattern recognition, etc.)

CS4243 Computer Vision and Pattern Recognition

This module is the study of methods for computers to understand and interpret the contents in the images. It teaches mainly on low-level visual processing. Topics include image formation, edge detection, pattern recognition, texture analysis, stereo matching, motion, optical flow, and region segmentation. Optional topics may include Fourier analysis and filtering.

CS4244 Knowledge-Based Systems

This is a module containing both the theory and practice of building knowledge-based systems. The aim of this module is to prepare students so that they can design and build knowledge-based systems to solve real-world problems. The module starts with motivations, background and history of knowledge-based system development. The main content has five parts: rule-based programming language, uncertainty management, knowledge-based systems design, development and life cycle, efficiency in rule-based language and knowledge-based systems design examples.

CS4245 Computer-based Learning And Instructional Technologies

This course teaches students how to design, develop and use computer-based technologies to support effective instruction and student learning. The course has two main parts. The first part deals with epistemological foundations of learning and with pedagogy. Pedagogical approaches to be covered include, for example, active learning, constructivist learning, collaborative learning and problem based learning. This part also addresses principles of instructional design for lesson planning and organization. The second part of the course deals with the design, development and appropriate use of computing technologies for instruction and learning. It deals with educational technologies including interactive learning environments, tutoring systems, simulation-based learning environments and computer-mediated communication. This part also addresses the design and use of electronic media to support instructions in situations involving multimedia-based learning and Web-based teaching. Students will be required to complete a realistic educational technology design and development project using an appropriate authoring tool.

CS4246 Text Processing on the Web

Large quantity of information is available on the web and the amount is increasing every day. There is strong need to develop appropriate tools to process and manage such information

effectively. Many such tools are now available, ranging from search engines, to systems to classify and summarize information. The aim of this module is to introduce the concepts and techniques for the analysis, representation, retrieval, classification and summarization of unstructured textual information. At the end of this course, the students should have the expertise and competence to design and implement text processing and mining systems, and search engines on the web. Topics covered include: text encoding, text retrieval, text classification, text summarization, information access including multi-lingual, multi-modal and multi-media access, applications and future trends.

CS4247 Image Synthesis and Computer Animation*

The aim of this module is to provide a general treatment of image synthesis and computer animation. On image synthesis, sampling, shading and display aspects of computer graphics will be covered. Topics include local and global illumination methods with emphasis on radiosity and distributed ray tracing, volume rendering, texture generation and rendering, strategies for anti-aliasing and photo-realism.

On computer animation, the major animation techniques will be systematically explored. Topics include interactive devices, mobile data structure and soft object modeling, various motion control and deformation techniques, techniques for simulation of natural phenomena, collision detection and animation systems.

CS4248 Natural Language Processing*

This module deals with computer processing of human languages, emphasizing a corpus-based empirical approach. The topics covered include: Linguistic essentials. Basic techniques and algorithms: Hidden Markov model, Viterbi algorithm, supervised learning algorithms. Words: part-of-speech tagging. Syntax: noun phrase chunking, named entity tagging, parsing (top down, bottom up, probabilistic). Semantics: word sense disambiguation. Pragmatics: discourse, co-reference resolution. Applications: text categorization, text summarization, language identification, information extraction, question answering, machine translation.

CS4249 Game Development*

This course will introduce techniques for electronic game design and programming. The possible topics include game history, game design, game development environments, interactive fiction, game shell and engine, game programming (managing the frame loop, blitting and page flipping, sprite animation, clipping, and scaling), multi-player game, game production industry. Students can enhance the learning from the course projects.

CS424A Multimedia and Internet-based Learning Environments*

This course teaches students how to design and develop multimedia and Internet-based learning environments to support effective online learning and training. The course has two main parts. The first part addresses the issue of pedagogy in learning and training. The second part deals with different types of educational technologies, such as interactive learning environments, tutoring systems, and simulation-based learning environments. It will also address the design, development, and appropriate use of computing technologies for instruction and learning. Special emphasis will be given to multimedia and Internet-based learning environments. Students will be required to complete a realistic multimedia or Internet-based educational technology design and development project using an appropriate authoring tool.

CS424B Design of Advanced User Interfaces*

As computers become embedded and pervasive, the design of their interface has become increasingly specialized to meet specific task needs while remaining subject to the overall requirement of usability. This course will expose students to a broad range of advanced and novel interfaces that are having an impact both at work and in play. The course will focus

especially on the design of such interfaces and emphasize the importance of usability and task fit. It will be conducted as a seminar course. Students will be required to read critically and extensively and contribute to class discussion. They will also be required to complete a significant review or design project. The types of interfaces covered will be selected from the list below.

- Auditory and Haptic Interfaces
- Assistive Technology Interfaces
- Gaming
- Interfaces
- Interfaces for Kids at Work and Play
- Augmented Reality Interfaces
- Collaborative and Groupwork Interfaces
- Personal and Wearable Computing Interfaces
- Intelligent User Interfaces
- Virtual Reality Interfaces
- Visualization Interfaces

CS4250 IS Research Methodologies

This module introduces a broad spectrum of essential methodologies of MIS research, including qualitative research, laboratory experiments, survey research, and mathematical modeling. It will discuss applications of the methods in MIS research and an evaluation of their effectiveness.

CS4251 Strategic IS Planning

This module covers strategic planning to link information needs and technology support to organizational objectives. The module covers: development of strategic planning process for information resources, identification of strategic issues, alignment of strategic plans, plan format, implementation, and evaluation.

CS4252 Control, Audit and Security of Information Systems

The aim of this module is to provide an in-depth study of information systems security in business organizations. The topics include: basic principles and functions of secure systems reviewed, management policy plans and programmes discussed.

CS4260 Electronic Commerce: Theory and Practice

The global data highway offers dramatic new business opportunities as well as new ways to run existing businesses. This new technology will be harnessed by organizations to help them to achieve competitive advantage, to transform relationships with customers, suppliers and business partners, to empower global business, and to rebuild their organizations. Students taking this module learn about the convergence of the communications, computer, entertainment, and publishing industries and develop multimedia applications using Netscape, the Internet, and a variety of related tools.

CS4261 Forecasting and Time Series Analysis

This module introduces students to basic techniques in forecasting, focusing primarily on time series data. An introduction to the theory and methods of modeling dynamic relationships among several interrelated time-series data from the fields of business and economics. The focus of the module will be on the use of Box Jenkins Analysis techniques but other approaches (such as fuzzy logic, neural network, technical indicators) will be considered. The module will also consider in some detail the implementation, validation and on-going maintenance of the forecasting models. Data in business, economics, the environment, and other scientific fields are often collected in the form of multivariate time series. Analysis of time series makes it possible to study the dynamic leading/ lagging relationships among the series and improve predictive efficiency of the components. This module discusses the modeling and analysis of such series via ARIMA models. Both the

theory/methods as well as applications are stressed. The module will be in two parts; first the basic concepts of time series such as stationarity, seasonality, invertibility, the memory function, autoregressive and moving average models will be presented. The Box Jenkins approach for developing ARIMA models will be discussed. Models for forecasting macro-economic, industry, firm level data will be developed and discussed. The second part of the module will discuss the computer-based implementation and organizational management of forecasting models.

CS4262 Financial Trading and Visualization Technology

The aim of this module is to emphasize financial analysis, strategy and implementation: How do we value positions in financial instruments? What risks are associated with the security? How should we manage a portfolio of different security classes? How do we develop useful financial modeling information systems? The course will have two basic elements. First, course work based on the same text used in CS3261. Topics include: bond and equity valuation and risk management, derivatives, international investment and asset allocation. The second element of the course will be a group project to develop an effective financial modeling tool. Projects will involve financial modeling and systems development, as well as writing and presenting a project report.

CS4263 Risk Management

As the world becomes more volatile, the need for risk management has become critical for both financial service firms and non-financial corporations. From derivatives to total quality management, from insurance to outsourcing, these are all techniques to manage the risks that organizations face. This course will discuss the objectives of risk management, firms' measurement of their risks, the techniques (both financial and non-financial) they use to manage the risks and the systems and organizational practices they must have in place to prevent disasters.

CS4264 Case Studies in E-Commerce

Students will be able to integrate earlier knowledge and skills in this module. Through case studies of e-commerce success and failure, students will examine factors vital for e-commerce. Strategy, management, and technology issues will be included. Cases will cover a broad spectrum from the traditional products (such as books and office supplies) to high-tech products (such as internet communication and financial services). The module will examine both business to customer and business to business environments.

CS4265 Advance Topics in E-Commerce

As e-commerce is a fast developing phenomenon, this module will cater for state of the art topics in e-commerce. The content is expected to change from year to year. Possible topics include virtual organizations, advance payment systems, evolution of e-commerce due to new technologies, and other specialized topics such as logistic and global e-commerce organization.

CS4271 Critical Systems and their Verification

Motivation: To understand and use the technique of formal verification applied to the production of mission critical software systems.

CS4272 Hardware-software Co-design

Motivation: An advanced course on embedded systems. The aim of this course is to introduce the student to the fundamental issues in hardware/software codesign including issues in system design, various conceptual models that can be used to capture system behaviour, system partitioning and estimation, and synthesis of software and hardware.

CS4273 Sensors and Actuators

Motivation: This subject aims to introduce students to the concepts of modern sensors and actuators. The theory and application of these devices will be studied.

CS4274 Mobile Computing

Motivation: To study the issues and technology involved in mobile computing, including mobile IP, security, algorithms, performance and programmability issues, for notebook PCs, PDAs, WAP protocol and applications, and Internet appliances.

CS4275 Speech Processing

Motivation: Techniques specific to speech processing, recognition, and generation will be studied.

Note:

***: New modules to be planned and their contents are subject to changes.**

A.5 Level-5

CS5201 Foundation Module I

This module covers the essence of basic programming modules, algorithms, and databases (CS1101+CS2103 and CS1102+CS2102). It includes basic concepts in software and algorithm design, program development/coding/debugging, program structure, simple data types and structured types, control structures (sequencing, loops, conditions etc.), procedure abstraction, structured programming, top-down design, testing and verification, recursion, link lists, data structures (stacks, queues, binary trees) and their applications, use of abstract data types, in terms of data structures and algorithms. It covers basic algorithms for sorting and searching, including binary search, tree search, hashing, graph transversal, minimum spanning trees, Dijkstra's shortest path algorithm, iterative, greedy, divide and conquer and traversal algorithms. It also covers complexity of algorithms. The module also covers principle of DBMS, database management system, relational databases, storage of data on secondary storage, physical organization of data, and various access methods.

CS5202 Foundation Module II

This module combines the essence of basic computer organization, networking and operating system modules (CS1103+ CS1104 and CS2105+CS2106). It covers logic design: data representations, basic logic and digital circuits, combinatorial and sequential circuits, PAL, PLA and logic programming. Basic computer organization: local and system buses, memory system, input/output, serial and parallel data IO, direct memory access and interrupt, CPU structure and organization, RISC and CISC, various types of CPUs (parallel and vector processors, digital signal processors.) Communication network: concept of layered architecture, ISO model, message transmission technique, terminal protocols, and data link layer. Introduction to LAN, CSMA/CD and Ethernet, token ring and token bus, network interconnection - bridges, routers, IP and ARP protocol, TCP and ISO Transport services. Operating system and system software: language translators, linkers and loaders, multi-tasking and time-sharing, file systems, process management, memory management and device management.

CS5211 Design & Implementation of Software Tools

This course looks at tools used in the design and implementation of software projects. The emphasis of the course is on the design and implementation of software design tools, rather than on their usage. Two major categories of CASE tools are reviewed: literate programming systems as an example of lower CASE tools, and graphical integrated CASE Tools, as an example of upper CASE tools. Examples of tools are taken mainly from a UNIX environment. Java and Perl languages will be used for creating examples. Hands-on

sessions will be arranged to give students access to standard UNIX and Java environments. The desired target environment should include: UNIX SVR4, UNIX utilities (yacc, lex, m4, make), the Free Software Foundation's (FSF) GNU packages (emacs, RCS, CVS), and Flexor (or other WEB/LPS systems).

CS5212 Software Project Management

This module examines the managerial aspects of the software production process: from its initial feasibility stage to its maintenance phase. It covers topics such as feasibility studies, cost estimation and control, quality and operational integrity reviews, project scheduling and control techniques and methods, and productivity and quality metrics. Of particular interest will be the management of cross-cultural and cross-border software teams. Students who are certified IT Project Managers will be given credit for this module.

CS5221 Parallel Computer Systems

This module aims to give students an overview on the state-of-the-art technological advancements in the field of parallel processing, in particular, the importance of shared models of parallel computing that lead to specific types of parallel languages and hardware designs. The module is divided into four parts comprising theoretical foundation, technologies, parallel architecture and parallel software. Topics include: parallel computer models; program and network properties, principles of performance analysis, processors and memory technologies, multiprocessor and multicomputer architectures; multithreaded and dataflow architectures, parallel programming models, languages and compilers, parallel program development and environments, and operating systems for parallel computers.

CS5222 Advanced Processor Architectures

The aim of this module is to study the hardware and software issues involved in the design of modern processor architectures. The aim is to introduce the state-of-the-art technology that enables the kind of performance we now see in modern microprocessors. The focus is on three main types of processor designs, namely long instruction word, super scalar and vector processors. The module will start with a brief survey of current advances in VLSI technology, a brief recap of the important ideas in computer architecture and the challenges involved. Then each of the three-processor architectures is discussed in detail. In particular, the architectural issues, implementation and compiler optimizations needed to exploit the design are discussed.

CS5223 Distributed Systems

The aim of this module is to provide students with basic concepts and principles of distributed systems, and to augment their understanding with examples from practical systems. The module provides insight into the distributed operating systems, distributed file systems and shared data. The module is taught in seminar style, and several case studies are included.

CS5224 High-speed Networks & Multimedia Networking

The module explains the motivation of high-speed networks and provides an in-depth discussion on the challenges in designing such networks, from transmission system and network point of views. Emerging new network technologies such as ATM, HIPPI, and a few others will be addressed. The challenges of network systems and middlewares to support multimedia data transmissions and applications are identified and discussed, other system supports such as operating systems for continuous real-time data and end-to-end hosts/network QOS will also be presented. Design issues of distributed multimedia systems will be identified, related industry efforts such as CORBA and IMA's MSS will be studied. Finally, a brief overview of related R&D in Singapore will be presented.

CS5225 Parallel & Distributed Database Systems

This module will concentrate on the issues in management of large volume shared data in parallel and distributed environment, such as the efficient storage techniques, the query processing and optimization strategies, concurrency control and transaction management.

CS5226 Database Administration and Performance Tuning

This module is concerned with the performance related database administration issues. The topics include: an overview of query optimization techniques, physical data base design, system configuration, buffer management, performance analysis and tuning techniques.

CS5227 Database Design

(See CS4221)

CS5231 Cryptographic Techniques and Data Security

This module introduces the main cryptographic methods for communication and computer system security. The topics include: symmetric cyphers, public key cryptography, stream ciphers and block cyphers, digital signature, message authentication, operation system security, access control, entry authentication and key distribution mechanisms, network security. The module will use case studies for illustrating relevant topics, and cover international standards that implement the concepts.

CS5232 Formal Specification and Design Techniques

The primary role of the formal specification is to provide a precise and unambiguous description of a computer system. A formal specification allows the system designer to verify important properties and detect design error before system development begins. The objective of this course is to study various formal specification and design techniques for modeling

- * object-oriented systems
- * real-time distributed systems
- * concurrent reactive systems

The course will focus on the state-based notations Z/Object-Z, event-based notation CSP/Timed-CSP. Graphical modeling notations, such as StateChart and UML (Unified Modelling Language) will also be addressed.

CS5234 Combinatorial and Graph Algorithms

(See CS4234)

CS5241 Multilingual Information Processing

This module focuses on the problems and solutions of configuring existing computer systems for multi-lingual processing. The module covers: introduction to internal codes, ISO646, ISO10646 and national code standards such as China, Japan, Korean, Vietnam, Thai, Malaysia, Indonesia and India, problems and solutions of inputting large character sets such as CJK (Chinese, Japanese and Korea) character set, font design, video display and printing of multi-lingual character sets, internal code conflicts and incompatibility, hardware and software design for multi-lingual processing, multi-lingual operating systems, compilers, application systems and user interface designs, introduction to existing systems, start-of-the-art, future development. This module introduces the processing of natural languages using rule-based and statistical approaches. Both the basic theories and essential algorithms will be covered.

CS5242 Advanced Neural Networks

This module examines advanced research topics in two major aspects of neural networks' functionality: problem solving and modeling. Topics covered under problem solving include classification, clustering, content-addressable memory, reinforcement learning, control, time series, etc. Topics covered under modeling include Grossberg networks (instars, outstars,

cooperative-competitive networks, etc.) data encoding, knowledge representation, modeling behaviour and cognitive functions, etc.

CS5243 Reasoning under Uncertainty
(See CS4242)

CS5244 Text Processing on the Web
(See CS4246)

CS5251 Integration of IS & Business

This module examines the high level CEO/CIO concerns of information systems within the wider scopes of the corporations. The module includes: introduction to information systems in organizations from the general manager's perspective, managerial and strategic uses of information systems, overview of enabling technologies, how information systems are developed and managed, long-range planning for information systems investment and employment, study of information technology in Singapore's business environment, and individual and team projects.

CS5252 Global Project Co-ordination

The aim of this module is to teach students how to address the challenges of managing and coordinating a global project to deliver results under tight time constraints. Students will learn approaches for global project management along with concepts, frameworks, and diagnostic instruments that will help them to understand mutual similarities and differences, form an effective global team, accomplish the objectives established for a global project, and carry out project management in cross-cultural settings. As part of this module, students from NUS and Stanford University will form joint teams to work on real-life global projects provided by government organizations or private companies in North America or the Asia-Pacific. They will have to apply the knowledge taught in this course to help them overcome cultural, time zone, and geographical differences. They will work on their global projects through various forms of information technology (e.g., telephone, video-conferencing, fax, electronic mail and tools on the World Wide Web). The experience of working with a global team on a global project will be valuable to students in an increasingly globalized business environment.

CS5253 Knowledge Systems and Management in Organizations

Students will learn how organizations are managing knowledge - the collective knowledge and experience of their employees and departments. Students will also learn the various systems that are employed to manage knowledge. Technologies such as data mining and Intranet in support of knowledge management will be covered.

CS5254 Information Technology Policies

This course covers policymaking and evaluation for information technology. Topics range from the information technology industry to social, educational and economic uses of IT, such as the Internet, E-commerce, and use of computers in schools. Students will learn how policies are made and implemented. They will also learn how to evaluate the long-term impact of policies.

CS5255 Computer Mediated Communications

Computer and communications technologies are changing the ways in which individuals and groups communicate. The impact goes beyond one-to-one communications, to the formation and operation of virtual and semi-virtual groups and work environments. The module examines the mediation of such technologies on verbal and nonverbal communications, feedback, intrapersonal communications, interpersonal communications, small group communications, organizational communications, and communication goals. Technologies include basic media should as email, phone, fax, chat board, bulletin board, computer

conferencing, and video conferencing. In addition, integrated systems such as group support systems and negotiation support systems will be used for advance illustrations.

CS5261 Telecommunications and Inter-organizational Networking

Rapid advancements in telecommunications technology and the convergence of computing and telecommunications have created unique opportunities for organizations to derive competitive advantage. This module will provide students with a broad and in-depth understanding of the impact of telecommunications technology on organizations. The topics covered include: adoption/diffusion of telecommunications technology, telecommunications technology strategy, telecommunications applications in supply chain management, manufacturing, sales & marketing, etc, inter-organizational networking, convergence, and national/international telecommunications policies.

CS5262 IT and Supply Chain Management

The aim of this module is to teach students how to deploy information technology to enable and facilitate supply chain management among organizations. Key topics covered in this module include overview of a supply chain, coordination difficulties confronting organizations, pitfalls and opportunities in supply chain management, tradeoffs between inventory and service, and performance measurement for a supply chain. Students will learn about the role that information technology plays in supply chain network design, global supply chain management, the interface between manufacturing and distribution, and supplier management. The module will also explore the approaches (e.g. strategic alliances) and the tools for designing and redesigning products and processes for supply chain management as well as current industry initiatives for supply chain management.

CS5263 IT and Entrepreneurship

The aim of this module is to teach students how to start and sustain global entrepreneurial efforts with the assistance of information technology. Students will be equipped with the marketing skills needed to launch and lead high growth, high technology ventures within rapidly changing industry environments. They will be taught how to market new products to new customers using new information technology, sometimes in a new company. The module covers marketing challenges facing high technology entrepreneurs who expand internationally early in the life of their company. Students will learn from numerous cases of global entrepreneurial efforts. They will also work in teams on a global entrepreneurial project to cultivate their entrepreneurial leadership and teamwork skills, and to reinforce their ability to deploy new information technology in support of high growth, high technology ventures.

CS5264 Decision Making Technologies

Students will learn about modern decision technologies that can support decisions in the financial, operational, marketing and strategic areas. Examples include neural networks, genetic algorithms, intelligent agents, and data mining. It will highlight the latest effective use of such technologies for decision-making.

CS5265 Advanced Techniques in Financial Engineering

The aim of this module is to offer students an insightful look into financial engineering field that is sweeping the world of corporate, bank and investment finance, bring them the professional guidance on identifying risk exposure, developing new products, applying equity and equity related instruments, and building hybrid securities. The module is divided into three parts comprising the conceptual tools of financial engineering, the physical tools of financial engineering and financial engineering processes and strategies. Topics include: measuring return and risk, speculation, arbitrage and market efficiency; swaps, multiperiod options, fixed income securities and debt market innovations, equity and equity-related instruments, hybrid securities; asset and liability management, hedging and related risk management techniques, arbitrage and synthetic instruments.

CS5266 Computer-based Financial Engineering

This course will follow a structured approach to study quantitative modelling applications to financial planning. On completion of this module, students will be able to understand the role of computers in analysing the financial operations of a business and in decision making process. They will be able to appreciate the problems involved in the design and implementation of computerized financial models; recognize the ways in which computer-based financial models may be used by practitioners and researchers. Performance evaluations of commercially available financial modelling software will be covered. Hands-on experience in designing, coding, testing, and presenting financial decision models will be stressed using some available software tools.

A.6 Level-6

CS6201 Software Re-engineering & Reuse

This module is based around reading of papers on software re-engineering and reuse. Topics of program understanding, reverse engineering, domain modeling, design for and with reuse will be covered. The objective is to familiarize students with principles, practicalities and key research issues in areas of software re-engineering and reuse. The business context of re-engineering and reuse are emphasized. Issues of implementing reuse in a company are discussed and relations between software re-engineering methods and software reuse are examined.

CS6202 Advanced Topics in Programming Languages & Systems

This module discusses the contemporary concepts in the design and implementation of major programming languages and systems. It aims to provide students with advanced technical knowledge in evaluating, designing, and implementing an efficient and expressive programming language/system. Topics are selected from a group of contemporary issues that have substantial impact in the development of programming languages/systems, either in terms of performance efficiency or programming expressivity. These include, but not restricted to, computational models, program semantics, concurrency theory, garbage collection techniques, program analysis, type inference, program calculation and transformation, run-time profiling, implementation models, meta-programming, etc. A subset of the languages Smalltalk, C++, Java, Eiffel/Sether, ML, Haskell, and CCP may be used as examples.

CS6203 Advanced Topics in Database Management Systems

This module covers the topics in data base management systems with current research and industrial interests and importance. Examples of topics include multimedia data management, object-oriented database technology, data warehousing and data mining, integrating of heterogeneous and legacy systems.

CS6204 Combinatorial & Graph Algorithms

This module presents advanced material on the design and analysis of combinatorial algorithms with emphasis on efficient algorithms and data structures. This module is meant for students who intend to (i) do research in computer science in general, and algorithm design in particular, or (ii) do advanced application/software development in other areas of computer science. The module covers a wide range of standard combinatorial and graph algorithms, including advanced data structures commonly used in these algorithms. Some of the topics that may be covered include, advanced data structures, graph algorithms, matching and network flow, theory of NP-Completeness, combinatorial algorithms, geometric algorithms, mathematical programming, probabilistic algorithms and Meta-Heuristic search methods.

CS6205 Advanced Modeling & Simulation Techniques

As simulation is increasingly applied to more complex applications, exploiting efficiencies in model design and model execution becomes a challenging task. The aim of this course is to provide students with the ability to model, simulate and analyse complex systems in a reasonable time. This course is divided into three parts and covers advanced techniques in simulation model design, model execution and model analysis. A selection of model design techniques such as conceptual models, declarative models, functional models, constraint models, and multi-models will be discussed. Model execution techniques include discussion of serial and parallel discrete-event simulation algorithms. For model analysis, topics include input-output analysis, variance reduction techniques and experimental design.

CS6206 Advanced Topics in Human Computer Interaction

This module covers advanced topics in human computer interaction that are of current research or application interests. Its aim is to examine both the theoretical bases that underlie the design of interfaces and advanced technologies for human computer interactions. A wide range of topics may be covered including psychological theories, organizational behavior, virtual reality, augmented reality, computer-supported cooperative work, etc. The module illustrates where and when the theories are applicable, demonstrates the solutions using a combination of scientific theory understanding and engineering modeling. It also illustrates advanced technologies that form part of the solutions. The exact topics to be taught will depend on the lecturers teaching the module.

CS6207 Natural Language Processing

The module will discuss various aspects of natural language processing. Topics include the natural language problem, stages of language analysis, syntax, transition networks, Chomsky hierarchy and context-sensitive grammars, combining syntax and semantics, role of knowledge in language understanding, and applications of natural language understanding.

CS6208 Advanced Topics in Artificial Intelligence

This module covers advanced topics in artificial intelligence that are of current research or application interests. A wide range of topics may be covered including soft computing (fuzzy logic, genetic algorithms, etc.), data mining, machine learning, image and video processing, artificial life, robotics, etc. The exact topics to be taught will depend on the lecturers teaching the module.

CS6209 Advanced Cryptography

This is a follow-up of the module "Cryptographic techniques". It will give a systematic treatment to the following topics: mathematical foundations, information theory and cryptographic systems, design and analysis of block ciphers, pseudorandom numbers and sequences, design and analysis of stream ciphers, identification and entity authentication, key management techniques, Rabin public-key encryption, McEliece public-key encryption, design and analysis of hash functions, cryptographic protocols, and efficient implementations.

CS6301 Case Study Research

Students will get a first hand qualitative research experience in the information systems area. This is a practical module in applying the theories of case study research methodology, which is different from the case study method of teaching. Lectures will cover in-depth the advantages and pitfalls of case study. Students will design, conduct and discuss their case studies.

CS6302 Quantitative Research

This module will go in-depth into information collection and analysis for quantitative IS research. It will cover instrument development and validation, and advance statistical

analyses. It will be practice-oriented, whereby students are expected to design and execute quantitative studies.

CS6303 Information Systems Theories

This course aims to provide participant with in-depth treatment of theoretical pursuits pertaining to several streams of IS research. These may include media richness theory, group support systems, adoption/diffusion of technology, decision support systems, Internet commerce, IT & education, to name a few. A major thrust, which also serves as an integrating component of the course, consists of treatment with fundamental, foundational, and other related issues of IS research in general.

CS6304 Economics of Information Systems

Ever since the beginning of research into information systems, economics has been recognized as one of the underlying disciplines. Economics has made many contributions to the understanding of information systems. Some examples include theories of information value (decision theory or game theory) and empirical (econometrical) methodologies, which help to understand the implementation and use of information systems, economics of network, and IT contribution to productivity. The objective of this course is to make graduate students familiar with economics methodologies and aware of economics issues in information systems.

CS6210 Special Topics in Computer Science I

(Will be available when offered)

CS6211 Special Topics in Computer Science II

(Will be available when offered)

A.7 Modules for Minor Programmes

IT1001/GEM1511K Introduction to Computing

This module aims to provide basic IT understanding for a student who has no or little knowledge of computing. It is structured to be the course for the student who either plans to take only one course in computing in her entire undergraduate studies or wants to equip herself to do further more specialized computing studies. The module tries to be broad by touching on most aspects of computing. However, there will also be some technical depth in standard introductory computing topics. The lectures will be intensely complemented by Web exploring activities.

IT1002/IF2206 Introduction to Programming

The aim of this module is to introduce students to programming and abstraction methods as espoused in a modern programming language such as Java.

This introductory course on Java introduces object abstraction and object-oriented implementation. The concept of objects and object communication will be reinforced via the rich API library for input/output functionality and graphical user-interface components. Abstraction techniques allow non-trivial programs to be implemented incrementally and with control on complexity.

Laboratory sessions will equip students with hands-on experience in Web pages and Java applets. Projects and assignments will expose students to programming and the use of Java constructs.

IT2001 Network Technology and Applications

The objective of the module is to provide technological background in telecommunication, data communication and Internet technology to non-computer science students. It covers

the basic concepts in communication and networking, and looks at Internet and telecommunication in detail. It also deals with some common applications in all these areas and looks at the possible convergence of various communication technologies. The impact on social and business areas as a result of the wide spread use of the fast changing communication technologies are also addressed.

IT2002 Database Technology and Management

The aim of this module is to provide students with practical knowledge and understanding of basic issues and techniques in data management, with sufficient theory to understand the reasons for these techniques. Topics include conceptual (entity relationship model) and logical design (relational model) of database models, relational database management (data definition, data manipulation, SQL, visual interactive query interfaces), and their use in application development (in particular, data extraction from DBMS to spreadsheets application and data extraction to Web applications). Projects in developing a database within an application form an essential component of this module.

IT3001 Hypermedia Applications

The use of multimedia and hypertext is widespread in computer applications. This course shows how such systems may be built and applied strategically in an organization.

While the Internet and in particular the Web has used such technology, the majority of such content remains static. This course will teach students about hypermedia systems and how the next generation systems with dynamic content can be implemented. In addition, both client and server centred solutions will be investigated.

This course will expose students to front-end Web techniques, back-end Web processing, and database connectivity. Search and indexing methods will also be explained. The collection of these methods will form the core in many E-commerce sites.

This is very much a hands-on implementation course, and builds on the prerequisite introduction to Programming, Networking and the Database courses.