1.3.2 Description of courses

M.Sc. (Bioinformatics)

Core courses

BI6101 Introductory Biology
AUs: 3
Prerequisites: None
Semester 1
With an emphasis on an integrative and systems approach to learning all about the functional basis of life, the aim of this course is to create a framework of biological knowledge essential to the study of bioinformatics. Regardless of background, this module will infuse the learner with an appreciation of life's inner workings, and perhaps allow even those familiar with biology, the opportunity to re-discover the extraordinary unity within the diversity of life. It begins with the fundamental building blocks of life, molecular and cell biology, then on through biochemistry, genetics, developmental biology and human physiology, and finally to life at the macro level in ecology and evolutionary theory.

Lectures are liberally supplemented with videos, interactive multimedia and hands-on practical sessions. The practical sessions provide the opportunity for experiential learning by illustrating the concepts taught using real-life examples. Wherever relevant, the role information technology plays in the investigation, analysis, modelling and manipulation of life will be highlighted.

BI6102 Introductory Bioinformatics
AUs: 3
Prerequisites: CSC 103, CPE 103/ SC104 or equivalent
CSC 102/CPE 102/SC103 or equivalent
Semester 1
This course covers basic bioinformatics concepts, databases, tools and applications. Introduction: cell biology's central dogma, biological technologies for collecting and storing genomic sequence data; methods of computational biology; Genomic and proteomic resources: information networks, DNA sequence databases, cDNA libraries of expressed genes, protein sequence and structure databases, Human Genome Project; Sequence and structure analysis tools: dynamic programming for sequence alignment, pairwise and multiple alignment techniques, predication of RNA secondary structures, homology modelling for 3D protein structure, clustering and classification, visualisation techniques; Applications in genomics and proteomics: discovery of evolutionary relationships, gene hunting, EST and microarray data analysis for disease diagnoses, drug discovery, genetic engineering. Case studies and hands-on sessions are conducted during the course to prepare the participants for their individual thesis projects.

BI6103 Computational Biology
AUs: 3
Prerequisites: BI6101 and BI6102 or equivalent
Semester 2
Mathematical foundations: sets and sequences; probability theory; Bayes' theorem; random variables; probability distributions; information theory; sequence alignment by information minimization, mutual information (MI), characterization of splice sites with MI; Probabilistic models of sequences: model selection: parameter estimation: constrained optimization; Lagrange theory; prior models; die models of sequences given data/counts; dice models for pairs/ multiple sequences; random and match models and log-odds ratios for alignment; Markov models of sequences, modeling CpG islands; protein structure prediction: GOR approaches; artificial neurons; gradient-decent learning; multilayer neural networks; back-propagation algorithm; PHD method; protein tertiary structure prediction; precision-recall trade-off; ROC curves; cross-validation; bias-variance trade-off; gene expression data analysis: hierarchical clustering; k-means algorithm, self-organizing feature maps; support vector machines; feature selection: T-test, SVM-RVE; graphical models; gene regulation networks; structure and parameter learning;; Hidden Markov models and gene structure prediction: forward algorithm; backward algorithm; Viterbi algorithm; expectation minimization (EM); Baum-Welch algorithm; Baldi-Chauvin approach; VEIL; GENESCAN; profile HMM; statistical mechanics: Boltzmann-Gibbs distribution; Metropolis-Hastings algorithm; simulated annealing; H-P lattice models of proteins; local MSA with Gibbs sampling; prediction of gene features: signal selection; recognition of translation initiation sites and transcription start sites; promoter finders; Promoter 2.0, NNPP, Promoter Inspector, Grail's Promoter, DIANA-TIS, LVQ for TATA Recognition; Netstart; recognition of protein features: recognition of transmembrane helices; turn propensity scale for TM helices; hydrophobicity approach;

TMHMM – a HMM approach; ENSEMBLE; topography prediction; subcellular localization; secretory pathway; compartments and sorting; PSORT-B; TargetP; SCL-BLAST, adaptation of protein surfaces; SubLoc; motif recognition; profile analysis; word counting method; graphical approaches.

BI6104 Biostatistics
AUs: 3
Prerequisites: CSC103, CPE 103/SC104 or equivalent
Semester 1
Knowledge of biostatistical methods is fundamental to the planning, execution, and analyses of biomedical experiments. It is also required for the planning of observational studies and for mathematical modelling of biological phenomena. This core course aims to provide students with sufficient knowledge of biostatistics to handle biomedical projects. Coverage includes: Introduction to biostatistics, analyze univariate, bivariate and multivariate data; Introduction to probability and probability distributions, sampling distributions, point and interval estimations, confidence intervals; Hypothesis testing, testing hypotheses involving means and proportions, examining relationships using correlation and regression, sample size and power estimation; Concepts and methods of design of experiments, simple comparative experiments such as concepts of randomisation and blocking, factorial and fractional factorial designs, analysis of variance and multiple comparisons techniques, non-parametric techniques, multiple linear regression; Well-designed experiment can lead to efficient variable estimation, however, many data are collected without proper design, we will cover statistical learning theory for data mining and regression, and fundamental of classification using Support Vector Machines.

BI6105 Advanced Biology
AUs: 3
Prerequisites: BI6101
Semester 2
Part A: DNA and genes dynamics
DNA, genes (replication, recombination repair, genomes, gene clusters and repeats), mRNA (transcription and operons), proteins (synthesis, genetic code and localization), nucleus (transcription initiation, regulation, nucleosomes, nuclear splicing) and cells (protein trafficking, signal transduction, cell regulation, gradients and cascades).

Part B: Biochemistry
Protein function; Enzymes & enzyme catalysis; Enzyme kinetics; Regulation of enzyme activity; Metabolic pathways; Energetics of metabolism; Control of metabolic pathways; Role of membranes; Metabolic network in higher organisms; Analysis & modeling of metabolic control = doorway to bioinformatics.

BI6106 Algorithms for Bioinformatics
AUs: 3
Prerequisites: BI6102
Semester 1
This course covers key algorithms that are commonly used within bioinformatics. It includes sequence alignment: scoring matrices and global pairwise sequence alignment; algorithmic techniques for: string matching, suffix trees; sequence alignment using dynamic programming, optimisation of multiple sequence alignments, evolutionary trees, map assembly, combinatorial approaches to sequencing, and parallel processing for compute-intensive algorithms. Unsupervised learning algorithm such as K-mean, SOM will also be covered.

Project Dissertation
AUs: 6
Prerequisites: NIL
Semester 1 and 2
Each student must submit a research dissertation. The aim of the project is to offer students to develop algorithms and application in bioinformatics under the supervision of an academic staff.

Elective courses

BI6121 High Performance Computing for Bioinformatics
AUs: 3
Prerequisites: BI6101 and BI6102 or equivalent
Semester 2

This course covers practical programming methods and skills for development of bioinformatics software, especially with high performance computing (HPC) systems. Introduction: bioinformatics data processing, algorithm design for sequence and structure analysis, programming language, bioinformatics software packages and toolkits; Infrastructure of HPC systems: client / server architecture, compute cluster, resource management system; Parallel and distributed programming: Amdahl's law, message passing interface, parallel programs for genomic sequence and structure data analysis; Imaging and visualisation: visualizing 3D protein structures, interactive 3D graphics programming. Case studies and hands-on sessions are conducted in the BioInformatics Research Centre to help the participants for their individual thesis projects.

BI6122 Biological Systems Modelling
AUs: 3
Prerequisites: BI6101 and BI6102 or equivalent
Semester 2
This course deals with engineering modeling of biological structures and systems at a molecular and cellular level, for understanding their functional processes and characterizing normal and disordered states. It includes structure of biomolecules and cell, biomolecular mechanics, cell mechanics and adhesion, biological molecular dynamics, biological graph theory, nonlinear physics of DNA, mechanics of cytoskeleton filaments, molecular basis of muscle contraction, and motility-to-peristaltic flow.

BI6123 Methods and Tools of Proteomics
AUs: 3
Prerequisites: BI6101 and BI6102 or equivalent
Semester 2
Proteomics, as a rapidly emerging field, has now established itself as a credible approach for furthering our understanding of the biology of whole organisms. Proteomics study and identify protein structure, interactions of protein/protein and protein/DNA and biology of organisms. We will further introduce the newly developed technology for the quantitative analysis of protein expression and function on a genome-wide scale.

BI6124 Medical Informatics
AUs: 3
Prerequisites: BI6102 or equivalent
Semester 2
In recent years, information technology has found very important applications in health care, offering enormous opportunities for the efficient delivery of health care systems. Some of these applications include hospital information systems, computerized patient records, clinical decision support systems, medical image and signals processing, medical knowledge acquisition, and representation and telemedicine.

As research into life sciences intensifies and biological data, especially genomic and proteomic data, are produced at a phenomenal rate, the need to process and link these data with clinical records and disease registries to improve diagnosis, prognosis, treatment strategies, and outcomes will draw upon a whole array of medical informatics tools and applications.

Topics to be covered include: Overview of medical informatics; Hospital information systems and electronic patient records; Standards in health care informatics; Clinical decision making; Clinical decision support; Standards in health care; Image and biosignal processing systems; Coding and classification; Telemedicine; Hospital operational logistics; Performance & cost-effectiveness indicators and activity-based costing and econometrics.

BI6129 Directed Reading
AUs: 3
Prerequisites: NIL
Semester 1 and 2
The course aims to impart detailed knowledge of a highly specialised topic within the field of study of the M.Sc. The directed reading and independent research will involve an in-depth study of an advanced technology/methodology/technique and its application to the area of study, under the guidance of a faculty member. The directed reading course will be chosen in consultation with a supervisor. Admission into the course requires agreement by a proposed supervisor and submission of a proposal to the School (via the programme director) during the first two weeks of the semester in which the course will be taken.

BI6190 Special Topics

AUs: 3
Prerequisites: BI 6101 and BI6102 or equivalent
Co-requisites: BI6105, BI6104
Semester 2

Current issues in genomics and bioinformatics
BI6190 is designed for students who wish to catch up with the latest developments in genomics research, to apply their programming skills to solving actual biological problems, and to become proficient in answering key biological questions in-silico.

It is imperative for computer scientists to maintain relevance to real-world biology. It is equally imperative for biologists in the post-genomic era to be highly competent users of publicly available bioinformatics tools. It is no less important for both camps to be aware of trend-setting current developments in genomics. BI6190 is designed to address all three issues. Students will catch up with the latest developments in genomics: new sequencing technologies, paradigm shifts in our understanding of gene and genome structure and regulation, the micro and macro RNA world, and going beyond textbook comparative genomics in an attempt to compute the genomic basis of what makes humans uniquely human. Students will apply their programming skills to solving actual biological problems, and learn how to obtain answers to key biological questions in-silico through skillful use of genomic resources in the public domain. BI6190 is strongly recommended as an elective course for all students pursuing an M.Sc. in Bioinformatics by coursework.

Other elective courses
Other elective courses within NTU, offered by other schools such as SBS and NIE can be taken by students to tailor to their interests. However, approval must be obtained from the course director for these general electives.

CI6205 Database Systems
AUs: 3
Prerequisites: NIL
Semester 1 and/ 2
Overview of database models: relational and database models; Relational database design: data modelling using the Entity-Relationship diagram and normalisation of relational tables; Relational database definition and manipulation; SQL; Semi structured data representation with XML; Querying XML data with XQuery and XPath; Managing database environments: database administration, transaction processing, concurrency control, client server processing, and security.

M6525 Medical Informatics & Telemedicine
AUs: 3
Prerequisites: NIL
Semester 2
Introduction to Medical Informatics, Introduction to Networking, Object Oriented Design and Modeling, Electronic Medical Records, Derivatives of a Computer Based Patient Record, Nursing Information Systems, Diagnostic Reporting Systems, Standards for Medical System, Terminology and Coding Systems in Medicine, Telemedicine, Medical Imaging, Decision Support, Bioinformatics, Ethics and Confidentiality.

Seminars

There will be a series of seminars on Bioinformatics related research ethics and morality of choices and decisions regarding the recent developments in genetic engineering and medical research.

M.Sc. (Embedded Systems)

Core courses

ES6101 Principles of Embedded Computing Systems
AUs: 3
Prerequisites: NIL
Semester 1
This course will introduce students to embedded systems by providing a detailed overview of the important topics in the field. It will introduce typical examples of embedded systems; real time and safety critical

issues; constraint-driven design; systems integration; hardware-software partitioning and time-to-market considerations.

The course will examine programmable devices, microcontrollers, application specific standard processors; importance of interrupts; reconfigurable logic; system-on-a-chip; finite state machines; dataflow architectures; and distributed embedded systems. Software for embedded systems, including: programming languages and software architectures; interrupt servicing; multi-tasking; task communications and scheduling; verification; hardware-software co-simulation; and real-time operating systems will be introduced.

The course will also review design methodologies, including: techniques for specification; formal models and specification languages for capturing system behaviour; unified modelling frameworks; design analysis; optimisation and implementation; system verification; rapid prototyping; IP-based designs; hardware-software co-design; and quality & performance metrics.

ES6102 Advanced Digital Systems Design
AUs: 3
Prerequisites: NIL
Semester 2
This course will develop the digital hardware design skills necessary for practitioners in the embedded systems field. It will provide a brief overview of logic design concepts before examining, in detail, the design methodologies for complex digital systems, including the use of high-level design languages for rapid development; hardware description languages and tools; FPGA based designs; computer arithmetic in digital systems; energy efficient architectures; signal integrity and clock event horizons. Design for production test strategies will also be examined, including: test structures; automated testing techniques; test coverage and economics of testing; enhancing testability, structured design techniques, scan based design and built in self test.

The course will include a substantial design exercise covering a typical FPGA design flow, including design entry using high level hardware description languages, functional simulation and verification, synthesis, structural simulation and verification, place and route, and target mapping, using the latest commercial FPGA design tools.

ES6103 Embedded Systems Programming
AUs: 3
Prerequisites: NIL
Semester 2
This course will develop the software design skills necessary for practitioners in the embedded systems field. The course will examine the performance needs of embedded systems, including: real-time operation, autonomy; atomicity and data sharing; asynchronous event handling, modularity, flexibility, scalability and robustness; microprocessor-based embedded system elements for digital command and control; integrating sensor/actuator devices and peripherals; commercial real-time operating systems and multi-tasking applications; real-time systems applications; fault tolerance and safety criticality; and long term software operation.

It will introduce techniques for modelling and implementing real-time systems, including: specialised languages, operating systems, timeliness and latency: hard/soft/firm deadlines, scheduling, schedulability analysis, software design with RT-UML; architecture specific considerations; software for distributed real-time systems; embedded programming language requirements; software development tools and environments, implementation and optimisation issues, verification and testing; and defensive design.

ES6104 Embedded Processors & Peripherals
AUs: 3
Prerequisites: NIL
Semester 2
This course will introduce issues relating to embedded processors. This will start with a review of microprocessors, including: processor architectures; programming model; instruction sets; and exception support.

Memory and peripherals for embedded devices will be examined, including: memory and I/O interfacing; parallel I/O; USART, SSC, field buses; timers, watchdog, high-speed I/O modules; display controllers;

DMAs; MMUs, peripheral control processor; memory systems and types; interfacing techniques; performance issues; and power considerations.

The course will also examine aspects of integrated microprocessors, including: selection criteria; on-chip resources; power management; development support; application specific standard processors; and multi-core vs. unified core devices. A case study of a popular RISC such as the ARM processor and emerging technologies will be examined.

ES6105 Digital Signal Processing Systems
AUs: 3
Prerequisites: Knowledge in Digital Electronics and Computer Architecture
Semester 2
This course will introduce students to digital signal processing algorithms and to hardware related implementation issues. It provides an introduction to signals and systems, including: sampling techniques, aliasing, line spectra, symmetry, anti-alias filters; discrete time systems; FIR and IIR filters; windowing techniques, frequency transformations, auto- and cross-correlation; Fast Fourier Transform (FFT), decimation, twiddle functions and butterflies (DIF & DIT) and an introduction to stochastic signal processing techniques.

The course will then examine implementation issues, including: hardware and software structures for FFT implementation and FFT processing rates. It will also examine hardware issues, including: DSP processors; organisation, programming model, and on-chip concurrency; MAC units; pipelining; addressing modes; application specific features such as short/long interrupts, hardware do loops, etc.; dedicated architectures vs. programmable DSPs; multi-DSP implementations; and development tools. Case studies of a number of signal processing implementations will be examined.

Project
AUs: 6
Prerequisites: NIL
Semester 1 and 2
Each student is to carry out an individual research or development project in the area of embedded systems. The project, which carries a weight equal to two normal courses.

Elective courses

ES6125 Wireless Communications
AUs: 3
Prerequisites: Knowledge in Digital Communications and Computer Networks
Semester 1
This course will examine non-wired communications methods for embedded systems. Topics covered will include: a review of wireless communications; TDMA, FDMA and CDMA, GSM and CDMA systems; wireless networks and Bluetooth; wireless subsystem design and implementation. Wireless mobile channels: design of linear and non-linear equalizers, adaptive equalization, structures for equalizers; implementation of channel coders, block, Golay, Reed Solomon, and convolutional coders. DSP processors for filter implementation; digital modulation and demodulation; Costas loop for carrier phase and frequency synthesis. Design of CDMA systems: PN generators; Walsh, Hadamard codes; correlators; data encryption. Bluetooth protocol implementation.

ES6126 Algorithms to Architectures
AUs: 3
Prerequisites: NIL
Semester 2
This course will introduce students to the design techniques, methodologies and tools for the power-delay-area efficient partitioning and mapping of algorithms onto dedicated hardware architectures. Topics covered will include: hardware/software partitioning, concurrency issues, system-level behaviour, global time vs. self-timing, shared state (memory) vs. point-to-point communications, finite vs. unbounded state, and function vs. architecture. System constraints including processing time, size, and cost and space-time tradeoffs in hardware and software will be examined. Fundamental modelling considerations for digital computation, communication, and state including behavioural synthesis and verification techniques will be examined.

ES6129 Directed Reading

AUs: 3
Prerequisites: NIL
Semester 1 and 2
The course aims to impart detailed knowledge of a highly specialised topic within the field of embedded systems. The directed reading and independent research will involve an in-depth study of an advanced embedded technology and its application to embedded systems under the guidance of a faculty member. The directed reading course will be chosen in consultation with a supervisor. Admission into the course requires agreement by a proposed supervisor and submission of a proposal to the School (via the programme director) during the first two weeks of the semester in which the course will be taken.

ES6190 Special Topics - Secure Embedded Systems
AUs: 3
Prerequisites: A first degree in an electronics or computer-related course, and some experience of system design
Semester 2
The course introduces students to the state-of-the-art security techniques, namely models for security and cryptography, and explores the topics related to the implementation of embedded systems with stringent security and assurance requirements. Security techniques shall be studied at the theoretical level and typical attack scenarios examined. Building on the theoretical foundation, techniques and control mechanisms for engineering high assurance embedded systems are examined.

Topics include:
1) Introduction to and concepts of security and assurance
2) Access control mechanisms and policies
3) Contemporary cryptology (constructing and analysing public and secret key cryptosystems, covering RSA, ECC, cryptographic hash functions, DES & 3DES, AES)
4) Side channel attacks
5) Quality and assurance controls for trustworthy systems
6) International standards for security evaluation
7) Research trends in trustworthy systems

ES6191 Special Topics - Advanced Computer Architecture
AUs: 3
Prerequisites: A pass in an undergraduate computer organization, computer architecture or equivalent
Semester 1
This course addresses advanced issues in the design and evaluation of high performance computer architectures with emphasis on architectures for exploiting instruction level parallelism (ILP). Topics include, basic structure of optimizing compilers, instruction scheduling, compiler optimizations for ILP enhancement, superscalar, VLIW, and EPIC architectures, high-performance cache and memory systems, storage systems, and introduction to multiprocessor systems.

ES6191 Special Topics - Advanced Computer Architecture
AUs: 3
Prerequisites: A pass in an undergraduate computer organization, computer architecture or equivalent
Semester 1
This course addresses advanced issues in the design and evaluation of high performance computer architectures with emphasis on architectures for exploiting instruction level parallelism (ILP). Topics include, basic structure of optimizing compilers, instruction scheduling, compiler optimizations for ILP enhancement, superscalar, VLIW, and EPIC architectures, high-performance cache and memory systems, storage systems, and introduction to multiprocessor systems.

ES6192 Special Topics - Embedded Operating Systems
AUs: 3
Prerequisites: Appreciation for C coding
Semester 2
This course examines fundamental methodologies in designing, coding, testing and evaluating embedded operating systems, including case studies and comparisons of operating systems suitable for a range of embedded systems. Students will then concentrate, at a practical level, on one operating system and learn concepts in developing embedded systems using Linux, including the design and implementation of Linux device drivers, and other customizations of the Linux operating-system software. The course will involve hands-on programming and modification of an embedded device running Linux.

M6401 Product Design & Development
AUs: 3
Prerequisites: NIL
Semester 1
A multi-disciplinary approach to product design and development. Product development process and strategies. Need identification and product specifications. Generation and evaluation of ideas and concepts. Product architecture. Product aesthetics and form creation. Product semantics and identity.

General Elective Course
AUs: 3
Prerequisites: Determined by course selected
Semester 1 and/ or 2
Students may take a single general engineering elective course from within the College of Engineering at NTU. It is the students responsibility to ensure that any prerequisites are met and that timetabling issues are resolved. Approval must be obtained from the programme director for these general elective courses.

M.Sc. (Digital Media Technology)

DM6101 Advanced Computer Graphics
AUs: 3
Prerequisites: Basic C/C++ programming, linear algebra and calculus
Semester 1
Description: This course will survey recent rendering techniques in computer graphics as well as fundamental and classical topics that are not usually covered in an undergraduate computer graphics course. Topics include the graphics pipeline and scene graphs, analytical methods in graphics and the implementation of robust geometric algorithms, a survey of both photorealistic and non-photorealistic rendering, as well as recent texture synthesis methods and a survey of the different morphing methods.

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Topics: Geometric and graphical computing - modelling polyhedra, scan-line rendering and ray tracing, shading computations. Elements of an OO scene graph & mapping to the graphics pipeline. Non-photorealistic rendering - computer--generated pen--and--ink illustration. Texture synthesis and mapping - 2D textures, 3D textures. Photo-realistic rendering-ray tracing, global illumination, shadow computation. Morphing techniques - image morphing, solid morphing.

DM6102 Multimedia Information Management
AUs: 3
Prerequisites: NIL
Semester 1
Description: This course focuses on multimedia database management including the fundamental principles underlying the new generation of multimedia databases, and describes how such databases can be designed. It covers information retrieval techniques, multimedia interfaces, memory management, high-speed multimedia, and contains case studies on prototype systems.

Topics: Data modelling: modelling time-based media. Document model issues for hypermedia. Information retrieval techniques: content-based indexing and retrieval. Video and Image Content Representation and Retrieval; Video Segmentation for Video Data management. Multimedia interfaces: visual interfaces to multimedia databases. Visualization of web applications and database structure. Multimedia presentation: composite models. Memory management: codecs, design of large-scale multimedia-on-demand storage servers and storage hierarchies. Prototype systems: image database prototypes. Video database systems - recent trends in research and development activities, third-generation distributed hypermedia systems.

DM6103: Virtual Reality
AUs: 3
Prerequisites: NIL
Semester 1

Description: This course provides an introduction to the current state-of-the-art in virtual reality, helps to set the foundations for a common taxonomy of virtual reality technologies and applications, and introduces the VR software tools commonly available for building VR applications.

Topics: Virtual reality and virtual environments, the historical development of VR, 3D computer graphics for VR systems, geometric modelling for VR systems, a generic VR system, animating the virtual environment, physical simulation, human factors, virtual reality hardware, virtual reality software, virtual reality applications.

DM6104: 2D and 3D Animation
AUs: 3
Prerequisites: NIL
Semester 2
Description: This is an intermediate level course in animation and the focus is on fundamental techniques used in computer animation systems. The approaches, strengths and drawbacks of the classical animation systems based on kinematic and dynamic simulation are explained. Effective animation systems based on advanced approaches such as optimization theory, control theory and machine intelligent paradigms are presented. Prominent commercial animation systems and research tools are discussed. Potential applications of computer animation in entertainment, education, automation and manufacturing for the coming century are discussed and illustrated. At the end of the course, it is expected that the student will be able to produce realistic and fascinating animation sequences using methodologies and implementation skill learned in the course.

Topics: Kinematic and dynamic simulation, rigid multi-body motion, Euler-Newton formulation, lagrange formulation, optimization theory, space-time constraints, simulated annealing, stimulus-response approaches, autonomous agents, behavioural and intelligent models, commercial animation systems and related tools. Movie production: recording techniques - RGB v. NTSC and recording techniques: digital disks, single video frame recording, personal animation recorder, film.

Project
AUs: 6
Prerequisites: NIL
Semester 1 and 2
Each student is to carry out an individual research or development project in the area of digital media. The project carries a weight equal to two normal courses.

Elective courses

DM6121 Human Computer Interaction
AUs: 3
Prerequisites: NIL
Semester 2
Description: The course focuses on both theoretical issues and practical techniques in Human Computer Interaction. The emphasis is to develop good systems designs—systems with interfaces the typical user can understand, predict, and control. The coverage includes development methodologies, evaluation techniques, and user-interface building styles.

Topics: Human factors of interactive software: goals of user-interface design, motivations for human factors in design. Managing design processes: organizational design to support usability, development methodologies, ethnographic observation. Participatory design, direct manipulation and virtual environments. Examples of direct-manipulation systems, visual thinking and icons. Direct-manipulation programming, remote direct manipulation. Menu selection, form fill-In, and dialog boxes. Interaction devices. Keyboards and function keys, pointing devices, speech recognition, digitization and generation, image and video displays. Presentation styles: balancing function and fashion. Error messages, non-anthropomorphic design, colour. Response time and display rate. Expectations and attitudes, user productivity, variability. Expert reviews, usability testing, surveys and continuing assessments. Usability testing and laboratories, surveys, acceptance tests, evaluation during active use. Multiple-window strategies. Computer-supported cooperative work. Asynchronous interactions: different time, different place. Synchronous distributed: different place, same time. Face to face: same place, same time. Hypermedia and the world wide web. Hypertext and hypermedia, information abundant web sites, object-action interface model for web site design.

DM6122 3D Modelling and Reconstruction
AUs: 3
Prerequisites: Basic Engineering Math, computer graphics and programming is helpful
Semester 1
Description: Recent advances in real-time 3D technologies are allowing fully interactive virtual environments to be created and displayed on common desktop and home gaming computers, instead of the expensive research machines of years past. As it becomes feasible for artists and designers to create these rich virtual environments, they need to be aware of both practical and aesthetic issues unique to interactive 3D worlds. It is this course's aim to present the modelling and reconstruction techniques, experiences, and implications of VE development.

Topics: Overview, simple modelling and texturing - VE representation overview, VRML modelling, hierarchical scene graphs, representing geometry, representing material properties, low-poly modelling - common polygonal tools (Maya), optimization, texturing - UV map construction, advanced mapping tools, environments, navigation, lighting - examples from videogames, hiding artefacts. Navigation theory: collision, depth cues, interface design, backgrounds and lighting, animation, sound, interactivity - animation: event model, routing, triggers, timers, engines, key frame animation. Sound: ambient vs. spatialised. Avatars: multi-user, real-time human figure design and uses, virtual community challenges, implications and approaches. Case studies: NTU virtual campus, Singapore urban modelling, high-end military, multi-user VE game environment.

DM6123 Scientific Visualization
AUs: 3
Prerequisites: Basic Engineering Mathematics is helpful
Semester 2
Description: The course will be organized around designing interactive visual solutions for exploring large datasets. The students will learn about techniques that help in designing visualization solutions for specific scientific needs. Each student, sometimes alone and sometimes in a small group, will design and/or realize several visualization approaches during the semester culminating in a final project.

Topics: Visualization overview, coordinate systems, sample theory, navigation, interaction. Perception: light, brightness, contrast, constancy, color theory, components of an effective visualization, 2D scalar visualization methods. Surface extraction: isosurface, convex hull. VolVis: direct volume rendering, MIP, ray casting, texture-based rendering, splatting, transfer functions, methods for time-varying data. FlowVis: design & traditional techniques, texture-based techniques. Information visualization: goals & problems, web-based tools. Case studies: algorithm and program visualization, geographical and weather visualization, financial data visualization, bio visualization, etc.

DM6125 Mobile Game Development
AUs: 3
Prerequisites: Basic familiarity with either C/C++ programming or Java programming language is helpful
Semester 1
Description: This course is an extensive overview of the latest in mobile gaming. Students will learn how to develop interactive games for a variety of mobile devices including cell phones, PDAs and Pocket PCs. The course culminates with the completion of an interactive game on a chosen platform. Knowing how to develop quality games for mobile platforms is becoming increasingly important, as the mobile gaming market continues to explode. Mobile games run on less powerful devices than their PC counterparts with smaller screens and controls designed for telephony – but they are also running on devices that are portable, ubiquitous, and networked. They offer the potential for a whole new style of game. Though communication rich, the environment is media poor in comparison to PC or console games.

Topics: Processor-limited environments, dynamic memory and limited environments, static storage limitations, network and online gaming, the mobile market.

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Topics: Processor-limited environments, dynamic memory and limited environments, static storage limitations, network and online gaming, the mobile market.

DM6127 Introduction to Games Design
AUs: 3
Prerequisites: Basic C/C++ programming, undergraduate-level Math
Semester 2
Description: This course covers fundamental issues related to design and development of game engines, the programming of games and the application of HCI, game play and design to the development of a successful game. The course includes a survey of existing commercial game engines and other "production code," code that is designed to merely work. Students will use a engine that is flexible, extensible, stable, and well-documented, written to be easy to understand and modify, especially to relatively inexperienced students. Students will use SAGE: A Simple Academic Game Engine that provides a series of demos and exercises to develop a functional and working game engine. Using Incremental development students will proceed step by step to develop a game engine.

Topics: Lecture topics will include a survey of game engines, a survey design issues in games development, human computer interaction and its impact on game playability and entertainment, incremental development, plugins for 3d animation software such as Maya and 3DS Max, model importation, Terrain input and rendering, Game engine architecture and Collision detection using axially aligned bounding boxes. Textbook: Introduction to Computer Game Programming with DirectX 8.0 Dr Ian Parberry.

DM6128 Computer Animation and Simulation
AUs: 3
Prerequisites: Basic vector algebra and programming skills
Semester 1
Description: This is an advanced animation subject, designed to teach students the advanced techniques of computer animation and simulation. Topics covered will include advanced animation techniques for keyframing, simulation and dynamics, free-form animation, behavioral and procedural animation, and production scheduling and post-production. Students will be expected to work in teams to complete a large-scale animation project. The animation project must be of "reasonable" size (on the order of implementing a SIGGRAPH paper).

Topics: Software and hardware for animation projects, key frame systems, interpolation, animation languages. Motion control: keyframing and kinematics, motion processing, higher level motion control, particle systems, rigid body dynamics, rigid body. Kinematics - forward and inverse kinematics, physically based, deformable body simulation and animation, shape modification - 2D morphing, 3D shape change; human figure modeling and animation - reaching, walking, facial animation, virtual humans, clothes, hair, artistic anatomy; natural phenomena - modeling plants with L-systems, water, gas, fire. Video review - SIGGRAPH video reviews, demo tapes of commercial computer animation houses, computer animation in the entertainment industry.

DM6129 Directed Reading
AUs: 3
Prerequisites: NIL
Semester 1 and 2
The course aims to impart detailed knowledge of a highly specialised topic within the field of study of the M.Sc. The directed reading and independent research will involve an in-depth study of an advanced technology/methodology/technique and its application to the area of study, under the guidance of a faculty member. The directed reading course will be chosen in consultation with a supervisor. Admission into the course requires agreement by a proposed supervisor and submission of a proposal to the School (via the programme director) during the first 2 weeks of the semester in which the course will be taken.

DM6199 Special Topics in Digital Media Technology
AUs: 3

Prerequisites: NIL
Semester 1 and/ or 2
This course aims to provide a mechanism for providing specialist topics in digital media technology offered by invited visiting professors and practitioners. This course may run in either or both semesters.

General Elective Course
AUs: 3
Prerequisites: Determined by course selected
Semester: 1 and/ or 2
Students may take a single general engineering elective course from within the College of Engineering at NTU. It is the students' responsibility to ensure that any prerequisites are met and that timetabling issues are resolved. Approval must be obtained from the programme director for these general elective courses.

M.Sc. in Information Systems

Foundation Courses

CI6201 Professional Seminar
AUs: 2
Prerequisites: NIL
Semester 1
A series of seminars will be conducted to provide an overview of the areas related to the field of information systems (IS). Speakers will be drawn from academia, industry and professional organisations. Methods and approaches to research and development suitable in the area of IS will be covered and case studies of implementation of IS from industry and academia will be shared.

CI6202 Information Architecture and Design
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Information architecture as an approach for information systems design. Issues related to user interface design, users, usability and evaluation. Collection, organization, presentation and navigation of information. Information organisation: metadata, controlled vocabularies, classification schemes, taxonomies and ontologies. Application of information architecture and design techniques to the Web.

CI6203 Software Engineering
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Overview of the software development life cycle; Software process models; Traditional software engineering methods. Requirements analysis and systems specification; Fundamentals of object-oriented programming: encapsulation, inheritance, polymorphism. Object-oriented analysis and design concepts and techniques including use of the Unified Modeling Language (UML); Design patterns and object-oriented frameworks; Software testing.

CI6204 Software Project Management
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Introduction to software project management; Project management concepts; Project integration management; Core project management areas: scope, time, cost, quality; Project team: roles, responsibility and authority; Project communication and documentation; Risk Management; Best Practices; Case studies in project management.

CI6205 Database Systems
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Overview of database models: relational database models; Relational database design: data modelling using the Entity-Relationship diagram and normalisation of relational tables; Relational database definition and manipulation: SQL; Semi-structured data representation with XML; Querying XML data with XQuery and

XPath; Managing database environments: database administration, transaction processing, concurrency control, client-server processing, and security.

CI6206 Internet Programming
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Basic networking concepts; Internet communication protocols such as TCP/IP, HTTP, FTP, RTP; Socket programming; Advanced Web page development with JavaScript, CSS and AJAX; Server-side development technologies such as JSP and Java servlets; Web development framework such as Struts and JSF; Security issues including threat identification, security strategies, encryption and authentication.

CI6207 Human Computer Interaction - Users, Tasks and Designs
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Introduction to general design and usability issues; Psychology of design of everyday things; Key cognitive and physical human capabilities and their relations to design of usable and useful systems; Users: personas, human factors and human diversity; Tasks: goals, scenarios; Design: general established design heuristics and guidelines; International design heuristics and guidelines from three perspectives: cultural, ethical and legal; Relate design and usability methods to the wider systems development process.

Elective courses

CI6220 Usability Engineering
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Introduction to a range of user-centred tools, methods and techniques for building usable and useful interactive systems complementing other software development approaches; Creative design aids: requirements analysis, scenario-based design, claims analysis, statecharts; Usability evaluation aids: usability inspection methods - heuristic evaluation, cognitive walkthrough; analytic evaluation methods - GOMS and keystroke level analysis; experimental evaluation methods: qualitative and quantitative methods.

CI6221 Information Visualisation
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Study of concepts, models and examples for improved information visualisation; Rearrangement and interaction: affordances, table lens, mosaic displays, network data, algorithms; Representation and interpretation data: quantitative, ordinal and categorical data; Dynamic exploration: dynamic queries, attribute explorer, neighbourhood explorer, model maker; Connectivity: graph theory, general networks, tree structures; Document visualisation: TileBars, galaxies, themescapes, galaxy of news, Kohonen maps.

CI6222 Mobile and Ubiquitous Applications
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Data communications and networking concept; Wireless networking: wireless cellular networks, mobile IP, IEEE 802.11 Wireless LAN and Bluetooth; Mobile device applications development: J2ME, mobile information device profile (MIDP) and connected limited device configuration (CLDC); Wireless network programming and messaging; WAP, WML and WMLScript; Location-based wireless applications: GPS and network-based positioning techniques.

CI6223 Interactive Media Development
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Multimedia, hypertext, hypermedia and their applications; Multimedia basics: text, graphics, animation, audio, video and file formats; Compression techniques in images, audio and video content; Multimedia standards; Multimedia development tools, technologies and languages; Development for standalone and

Web-based multimedia information systems; Media rights management; Distributed multimedia; Technologies and techniques for multimedia content management.

CI6224 Software Testing and Performance Analysis
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Software test process and principles: planning, specification, execution, checking, recording and completion; Test techniques: functional, structural and non-functional testing techniques, static and dynamic analysis, non-systematic testing techniques, user-acceptance test; Software Reviews; Computer-aided software testing tools; Test management; Risk management; Disaster recovery; Best practices; Case studies in software performance analysis and evaluation.

CI6225 Enterprise Applications Development
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Design and implementation of enterprise application systems; XML processing with XSL, Document Object Model, related APIs and technologies; Enterprise component technologies such as EJB, CORBA and Microsoft .NET; Web services: architecture, protocols, tools and languages; Web server administration: installation, maintenance, performance tuning, and log analysis; Examples of enterprise application systems: information and knowledge portals and digital libraries.

CI6226 Information Retrieval and Analysis
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Representation, storage, and access to very large digital document collections: issues, data structures and algorithms. Information retrieval models including Boolean, vector space and probabilistic models. Indexing and retrieval techniques. Evaluation of information retrieval systems. Text and Web mining: content, structure and usage mining. Web search: search engines, spiders, link analysis, agents. Recommender systems and intelligent information retrieval. Information extraction and integration.

CI6227 Data Mining
AUs: 3
Prerequisites: NIL
Semester 1 and / or 2
The knowledge discovery process. Data preparation including data cleaning, outlier analysis and transformation. Statistical techniques: regression modeling, multivariate statistics, statistical inference. Supervised and unsupervised learning techniques including decision tree induction, nearest neighbour categorisation, cluster analysis, association analysis, support vector machines, Bayesian learning and neural networks. Data mining software and tools. Applications of data mining to complex data types.

CI6228 Managing Information Systems
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Fundamental IS concepts from an organizational and managerial perspective; Organizational impacts of IS; Business value of different types of IS; Technological component of IS; Building and managing IS; Management of Global IS; Integrating emerging information technologies; IS investments; Ethics and Social Issues; Best practices and case studies in management of IS.

CI6229 Management of Information Systems Outsourcing
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Overview of management of IS outsourcing: planning and management of IS outsourcing, sourcing strategies, sourcing models, supplier selection, legal issues related to IS sourcing, relationship management in IS outsourcing and managing global IS outsourcing; Risk mitigation practices: cultural, legal, political, infrastructure, logistical and human resources issues; Best practices and case studies of IS outsourcing.

CI6230 Information Systems Security
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Basic security concepts: confidentiality, integrity, and availability; Protection methods: access control, flow control, and usage control; Algorithms and protocols: encryption, decryption, digital signatures, authentication technologies, security protocols; Network security: TCP/IP, firewalls, intrusion detection system; Secure operating systems and applications; Anti-hacking security tools.

CI6231 Security Policy and Strategy
AUs:3
Prerequisites: NIL
Semester 1and/ or 2
Contrast survivability and information security; Challenge of survivability; Strategies for analyzing and managing risk; Critical assets and their corresponding risks; Best practices for enhancing organizational survivability; Methods of security information assets; Failures and availability management solutions; Policy formulation and implementation; Best practices of configuration management and control; Responsibilities of IT managers and technical people.

CI6232 Intrusion Detection
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Methods of attacking and defending a network. Design of secure information infrastructure: servers, networks, firewalls, workstations, and intrusion detection systems. Intrusion detection and network monitoring techniques. Worms, viruses and other malware: operation, detection and response. Principles of penetration testing for assessment of system security. Hacker exploits, tools and countermeasures. Cybercrime: concepts and principles. Investigative techniques. Ethical, legal and privacy issues.

CI6291-4 Special Topic 1-4
AUs: 3
Prerequisites: NIL
Semester 1 and/ or 2
Courses in special areas of the Information Systems field not covered in the above list may be offered occasionally according to the special interests of staff members and visiting staff.

CI6299 Critical Inquiry in Information Systems
AUs: 3
Prerequisites: NIL
Semester 1 and 2
Overview of how to design and conduct research projects in the area of information systems. Research study design, preparation of proposals and manuscripts, intellectual property and ethics. Introduction to the main types of research methods, with a more in-depth examination of a few useful methods, to address information systems problems.

Dissertation
AUs: 6
Prerequisites: NIL
Semester 1 and/ or 2
Harnessing the knowledge, skills and attitudes acquired in the programme and applying them to solve information systems-related research problems, create new knowledge or develop new information system products or services is an essential part of the programme. In this respect, each student is mentored by a staff member in an in information systems research project leading to a dissertation of up to 15,000 words. The project can be in any information systems area.