Imperial College
London

Department of Electrical and Electronic Engineering

Undergraduate Syllabuses_2005–06

This publication refers to the session 2005–06. The information given, including that relating to the availability of courses, is that current at the time of going to press, October 2005, and is subject to alteration.

For details of **postgraduate** opportunities go to www.imperial.ac.uk/pgprospectus.

Electrical and Electronic Engineering

Imperial College provides undergraduate courses leading to the BEng degree after three years of study, the MEng degree after four years of study, and postgraduate courses leading to the Diploma of the Imperial College (DIC) and the MSc degree. Graduates are also accepted for research leading to the higher degrees MPhil and PhD. Some 160 students are admitted annually onto the undergraduate courses in the Department. There are also 160 or so postgraduate students, 60 of whom are studying on one-year courses leading to the MSc and DIC, whilst 100 are registered as research students working towards MPhil or PhD degrees.

There are a wide range of research activities in Electrical and Electronic Engineering at Imperial, many in collaboration with high technology industries, mainly in the following fields: communications and signal processing; intelligent and interactive systems; optics, semiconductors and micromechanical systems; digital and analogue circuits and systems; control engineering, electrical machines and power systems. The range of expertise is utilised extensively in the planning and presentation of the undergraduate and postgraduate courses, especially in the third and fourth years of the undergraduate courses and project work.

Details of postgraduate opportunities can be found in the online *Postgraduate Prospectus* at www.imperial.ac.uk/pgprospectus.

Undergraduate courses

The Department runs three and four-year courses leading to a BEng or an MEng degree. All courses give a firm foundation in the first two years combined with an unrivalled degree of specialisation in the third and fourth years. There are seven degree courses to choose from but the initial choice is between Electrical and Electronic Engineering (EEE) and Information Systems Engineering (ISE).

Electrical and Electronic Engineering

A unified undergraduate course offers the choice of (i) a three-year course of study leading to the BEng degree, (ii) a four-year course, leading to the MEng degree, in which attention during years three and four is focused on technological subjects (T stream), (iii) a four-year course, leading to the MEng degree in Electrical and Electronic Engineering with Management (EM), in which attention during years three and four is focused on industrial and business studies, alongside technical studies, and (iv) a four-year course, leading to the MEng degree, in which the final year will be spent at a university-level institute in Europe (EY).

The first two years of the course are common to all students and binding decisions about later patterns of study are not made until the end of year two. Advice on choice is given at the end of year two. Entry to year three of any four-year stream is restricted to students with good academic records.

Information Systems Engineering

This course offers the choice of (i) a three-year course of study leading to the BEng degree, (ii) a four-year course, leading to the MEng degree, or (iii) a four-year course leading to the MEng degree, in which the final year will be spent at a university-level institute abroad.

The ISE course is for those who want a balance of electronics and computing. This combination has become of greater significance as computers have become components of many fields in the electrical and computing industries requiring engineers to be able to cope with both software and hardware design. It combines the more practical half of the computing course as taught in the Department of Computing with electronics and communications drawn from the Electrical and Electronic Engineering course.

The first two years of the course are common to all students on the ISE stream and binding decisions about later patterns of study are not made until the end of year two. Advice on choice is given at the end of year two. Entry to year three of any four-year stream is restricted to students with good academic records.

All Electrical and Electronic Engineering courses are accredited by the Institution of Electrical Engineers and the Institute of Measurement and Control; the ISE courses are also accredited by the British Computer Society.

Students entering the first year must normally have satisfied the general University entrance requirements and the course requirements, normally through passes in a recognised GCE examination. For the last two years, the average attainment of entrants has been midway between three As and two As and a B at A level. Three A grades are expected in Mathematics and Physics, and a third scientific subject which is left to the candidate to choose. Further Mathematics is particularly recommended. Applicants also require a qualification in English, i.e. C grade in GCSE or its equivalent.

The course consists of lectures with supporting study groups, practical work involving set laboratory exercises and project tasks. A personal tutorial scheme is organised. Students are encouraged and assisted to obtain industrial experience during the vacations.

Details of the individual courses in the Electrical and Electronic Engineering programme are given below and the examinations are listed on page 145-6.

Syllabuses

Electrical and Electronic Engineering

FIRST YEAR ***(all streams)***
Electrical engineering
Computing
Mathematics
Business studies
Practical work

E.1.1 Analysis of circuits

DR D. HAIGH
Circuit variables: voltage, current, charge and power. Circuit elements. Kirchoff's current and voltage laws. Nodal analysis for resistor circuits. Transient analysis of first order RC and RL circuits. Superposition. Thevenin and Norton theorems. Controlled sources. Phasors and phasor analysis. Transfer functions and filters. Operational amplifier and transistor circuits. Stability. General systematic nodal analysis. Two-port parameters. Feedback. Time domain analysis of larger circuits. Power.

E.1.2 Digital electronics I

PROFESSOR P. CHEUNG
Basic logic theory; Boolean algebra; simple combinatorial circuits; logic minimisation; data representation and number systems; binary addition and adders, simple multiplies; digital building blocks as functional blocks, sequential circuits; flip-flops; finite-state machines, state diagrams; machine identification and control; counters and shift registers.

E.1.3 Devices and fields (EEE stream)

DR K. FOBELETS, DR E. YEATMAN
Semiconductor devices
Electrons and holes used for conduction in semiconductors. MOS capacitor, a capacitor for integrated circuits. Metal-oxide-semiconductor field effect transistor for digital applications. pn-diodes: minority carriers are important. Bipolar junction transistors: towards high gain amplifiers.
Fields
Fields: importance and classification. Steady electric fields (electrostatics): electric charge, Gauss's law, electric potential, equipotentials and field lines, capacitors and capacitance, conductors. Steady magnetic fields (magnetostatics): magnetic force, magnetic flux density, magnetic field intensity, Biot-Savart law, Ampere's law, magnetic materials, inductor and inductance, magnetic analysis. Electromagnetic induction: Faraday's law, mutual inductance, force calculations; basics of transformers.

E.1.4 Analogue electronics I

DR A.S. HOLMES
The bipolar junction transistor (BJT): physical structure and modes of operation; common-emitter amplifier; bias stabilisation; use as a switch.
Small-signal analysis: basic principles; small signal models for two-terminal devices; BJT small-signal

model and Early effect; macromodels; frequency response of AC-coupled circuits.
The MOSFET: physical structure and modes of operation; small-signal models; common-source amplifier; active loads; the body effect.
Analogue building blocks: current mirror; differential amplifier; emitter follower.
Transients: transient behaviour of LR, LC and LRC networks; transients in switched transistor circuits.

E.1.5 Engineering materials (EEE stream)

DR T. PIKE
Introduction to the quantum mechanics of the electron, illustration through example of particle in box and the hydrogen atom. Case study: quantum-well infrared photodetector. Monocyrstalline, polycrystalline and amorphous materials; materials compatibility—thermal expansion coefficient, thermal conductivity, stress and strain. Young's modulus; fabrication of mechanical devices by planar technology; vibration of beams; piezoelectric and piezoresistive effects. Case study—flat screen TV. Polycrystalline semiconductor properties; transparent semiconductors; frequency dependence of dielectric constant, refractive index; optical activity in liquid crystals, dichroism; rotational dielectric forces and energy storage in liquid crystals, optical reflectance and absorpance. Case study—data storage system. Magnetic moment, intensity of magnetisation, relation to B and H; non-linear B–H relations, coercivity, remanence, energy storage, magnetic anisotropy in particulate materials; high permeability materials.

E.1.6 Communications I

DR P. DRAGOTTI
Introduction to signals, energy and power definitions. Signals and vectors. Trigonometric and exponential Fourier series for periodic waveforms. Fourier transform, some properties of Fourier transforms. Power spectral density and power. Analysis and transmission of signals: Fourier transforms, linear time invariant systems, convolution. Distortionless transmission. Amplitude modulation systems. Frequency modulation systems. Digital transmission systems. Transmission lines.

E1.7 Introduction to computing

DR J.V. PITT
Procedural computing: variables, constants and types, conditionals and loops, data structures, procedures and functions, file I/O.
Software design: algorithm design (pseudo code), dataflow, data design, testing, specification.
Modular programming: units, abstract data types, objects (an overview).

E1.8 Algorithms and data structures (ISE stream)

DR M. SHANAHAN
A review of Pascal.
Software engineering principles; data structures; lists; ordered lists; trees; ordered trees.
Hash tables; parsing.

E1.9 Principles of computers and software engineering

DR Y. DEMIRIS, DR T. CLARKE
Architecture
The kernel of computer architecture: the instruction set architecture. Trends in technology and the basics of a computer system architecture.
Introduction to processor design: the MUO architecture. Pitfalls with MUO, the advantages of different instruction formats, an introduction look at the ARM processor. The basics of assembly language programming. Arithmetic instructions, data transfer instructions, pre-and post-index addressing. Further assembly language programming. Conditional execution and the ARM's S-bit. Shifted operands and shift types, multiply instructions, multiplication through shift-and-add, some simple complete ARM programs. Stacks and subroutines. The concept of a stack and its implementation in the ARM, the use of a link register, nested subroutines. The architecture of the ARM. An introduction to pipelining. Instruction encoding. ARM encoding of data processing and data transfer instructions. Memory hierarchies. The principles of locality, unified versus separate instruction and data caches.

Direct-mapped caches: design issues and architecture, cache write strategies.
System programming: exceptions and interrupts, ARM's shadow registers. An introduction to I/O interfaces. Polling, interrupt-drive I/O and DMA. Cache coherency and DMA.
Operating systems (ISE stream only)
Fundamentals: what is an operating system and what services does it provide to users? Examples of operating systems (including desktop, server and embedded OS). Evolution of operating systems; batch systems, multiprogramming, timesharing. Multiprocessor and distributed system, real time OS. Criteria for OS design.
Operating system structures: operating system services and components; system calls; hardware support for OS (memory protection, timers, privileged and user modes of operation); organisation of OS: monolithic and layered systems; virtual machines; client-server models and microkernels.
Process management
Fundamentals: processes, process states, process control blocks, process tables; two-, five- and seven-state models of process management; scheduling queues and queuing diagrams; process creation, termination and switch; introduction to threads: advantages, user and kernel level threads.
Process scheduling: schedulers and interrupts, preemptive and non-preemptive scheduling; priority and non-priority based schedulers; short-term scheduling criteria; scheduling algorithm: first-come-first-served, shortest remaining job first, round robin, priority scheduling, multilevel queue scheduling with/without feedback.
Interprocess communication and synchronisation
Fundamentals: independent and cooperating processes; shared memory and message passing, race conditions, critical regions, mutual exclusion; locks, turn variables, Peterson's solution to mutual exclusion; hardware assisted mutual exclusion; semaphores: basics, associated data structures, implementation; use of semaphores for process coordination and mutual exclusion.
Synchronisation and deadlocks: semaphore solutions to classic synchronisation problems: producer-consumer, readers-writers, dining-philosophers. Deadlocks: definition, examples. Necessary conditions for deadlocks. Deadlock modelling, OS strategies for dealing with deadlocks; deadlock detection and recovery, deadlock avoidance, deadlock prevention.
Memory management
From program to running process: tools and address binding; compilers, assemblers, linkers and loaders. Logical vs physical address space. Memory protection, base/relocation and limit registers; memory allocation: fixed versus dynamic partitioning, memory allocation algorithms. Internal and external fragmentation, compaction, paging, segmentation and virtual memory.

E.1.10 Mathematics (EEE stream)

DR. F. BERKSHIRE, PROFESSOR J.N. ELGIN
Revision: limits, differentiation, integration, Taylor series, complex numbers, Gaussian elimination.
Complex numbers and functions: polar form, de Moivre's theorem, roots of polynomial equations, definition of basic complex functions, roots of transcendental equation, branch cuts.
Ordinary differential equations: first order, separable equations, equations reducible to separable form, integrating factors. Second order, constant coefficients—complementary and particular solutions, numerical integration.
Linear algebra: vectors, equations of lines and planes, Gaussian elimination, matrices—inverse and transpose, LU factorisation, determinants, eigenvalues and eigenvectors, diagonalisation.
Functions of several variables: partial differentiation; contours; total differentials; change of variables; PDEs.
Convergence of infinite series; geometric progression; ratio and comparison tests; alternating series; radius of convergence.
Fourier series: full range Fourier series; exponential form of Fourier series, half range sine and cosine series; convergence; differentiation and integration of Fourier series; Parseval's identity; applications.
Laplace transforms: basic definition, inverse form tables, shift theorem; application to differential equations.

E1.11 Mathematics (ISE stream)

DR M. HOWARD, DR G. JAMES
Analysis: functions of one variable: odd, even, inverse functions. Limits: continuous and discontinuous functions. Differentiation: continuity and differentiability; implicit and logarithmic differentiation; Leibniz's formula; stationary points and points of inflection; polar coordinates. Rolle's and mean value theorems; Taylor's and Maclaurin's series; l'Hôpital's rule. Convergence of power series; ratio and comparison test; alternating series; radius of convergence. Complex numbers and functions: the complex plane; polar representation; de Moivre's theorem; ln z and exp (z). Integration: definite and indefinite integrals; the fundamental theorem; improper integrals; integration by substitution and by parts; partial fractions. Functions of more than one variable: partial differentiation; total differentials; change of variable; Taylor's theorem for a function of two variables; stationary values; contours. PDEs.
Linear algebra: vector algebra: basic rules; cartesian coordinates; scalar and vector products; applications to geometry; equations of lines and planes; triple products; linear dependence. Matrix algebra: double suffix notation; basic rules; transpose, symmetric, diagonal, unit, triangular, inverse and orthogonal matrices. Determinants: basic properties; Cramer's rule. Linear algebraic equations: consistency; elementary row operations; linear dependence; Gauss-Jordan method; Gaussian elimination; LU factorisation. Eigenvalues and eigenvectors; diagonalisation.
Ordinary differential equations: first order equations: separable, homogeneous, exact, linear. Second order linear equations with constant coefficients. Laplace transforms; basic definition; inversion from table; shift theorem; application to ODEs.
Fourier series: standard formulae; even and odd functions; half-range sine and cosine series; complex form; convergence, differentiation and integration of Fourier series; Parseval's identity; applications.

E1.15 Communication skills

PROFESSOR S. GOODLAD, MS S. BAINS
Improvement of written, spoken and general language skills. Giving technical presentations to different types of audience (technical specialists, managers, funding agencies) with force, clarity and confidence. Report writing: different types of technical report; laboratory report, project report, group report. Appropriate abstracts, body and appendices. Writing a CV and covering letter. Interview techniques.

E1.16 Introduction to Management and organizations

DR J. SHELDRAKE
Aims are to provide students with an outline of the economic and social environment of work organizations; an awareness of the economic and social environment of work organizations; an awareness of the range of key managerial and behavioural science theories; an awareness of the processes of management and how to work effectively with others.
More specifically: the importance of strategy, structure and design to business organizations; effective work design; theories of motivation and leadership; the impact of culture on organizational performance; the role of managerial values and their impact on such matters as health and safety and the morale of workers; the development of organizational systems, staff and skills; key issues in organisational change.

Practical work (all streams)

Electrical laboratory

About 120 hours.
A course complementary to all lecture courses.

Computing laboratory

DR J.V. PITT, MR L. MADDEN
About 40 hours.
Weekly laboratory exercises with continual assessment, introducing practical problem solving using computer programs written using the Delphi visual program development environment.

SECOND YEAR

EEE stream
Electrical engineering
Mathematics
Humanities course
Practical work

ISE stream
Electrical engineering
Computing
Mathematics
Humanities course
Practical work

E.2.1 Digital electronics II

MR D.M. BROOKES
IEC617 dependency notation. Interfacing techniques for digital systems: synchronous and asynchronous bit-serial transmission; timing constraints arising from setup and hold times; static RAM memories, microprocessor-to-memory interfacing. Sequencing circuitry using shift registers and counters; analysis and design of synchronous state machines; timing constraints and glitches. Data conversion: D/A converters for signed and unsigned numbers, current switched R-2R ladder, output deglitching. Flash, integrating and successive approximation A/D converters. Sample/hold circuits. Performance criteria for data conversion circuits. Complexity versus delay tradeoffs for adder circuits: performance of alternating bit-inversion, carry-lookahead and carry-skip circuits. Carry-save adder circuit.

E.2.2 Analogue electronics II (EEE stream)

DR C. PAPAVASSILIOU
The main content of the course is: analogue circuit techniques: cascoding, bootstrapping, high frequency BJT and FET amplifier techniques, Miller's theorem; building blocks: single-stage BJT and FET amplifiers, current mirrors, differential pairs, power outage stages, PTAT current sources, operational amplifier.

E.2.3 Power, fields and devices (EEE stream)

DR T. GREEN, PROFESSOR R.R.A. SYMS, DR K. LEAVER
Electrical power engineering
Distribution systems. Analysis of power systems: sinusoidal steady-state, power: real and otherwise, conservation of energy and power. Voltage conversion: linear regulators, step-down DC/DC converters, design of an SMPS, step-up DC/DC converter. Electrical machines: conductors in magnetic fields, elementary machine for generating, a three-winding or three-phase machine, choice of number of phases. Three-phase power systems: star connection, delta connection, power calculation and measurement. Induction machines: general features, principle of operation, equivalent circuit, power flow diagram, torque characteristic, direct-on-line starting, inverter operation.

Electromagnetic fields
Vector treatment of electrostatics and magnetostatics leading to Maxwell's equations in integral and differential form. Practical consequences of Maxwell's equations: boundary conditions; plane wave propagation in dielectrics; propagation in metals, skin effect; transmission lines; Poynting's theorem for power flow.

Micro-electro-mechanical devices
Introduction to MEMS: scaling; materials; processes; applications. Size scaling: microstructure size domain; scaling of physical laws. Silicon MEMS processes: silicon micromaching; CMOS integration. Microelasticity: plane statics; beam bending; buckling. Inertial sensors: mass-spring-damper systems; accelerometers; gyroscopes. Microactuators: electrostatic and electrothermal actuators; other actuation mechanisms. Microsensors: signals and measurands; transduction mechanisms; physical sensors. Electrical MEMS: switches and relays; passive components. Optical MEMS: Gaussian beams and lenses; optical fibres and coupling; waveguide devices; moving mirror devices.

E.2.4 Communications II

LECTURER TO BE ANNOUNCED

Models for noise. Representation of band-limited noise and the effect of noise in an analog baseband system. Effect of noise in AM systems. Effect of noise in FM systems. Introduction to digital communications systems. Performance of digital systems in the presence of noise. Introduction to information theory. Source coding. What does information theory have to say about the performance of analog communication systems? Introduction to communication networks.

E.2.5 Signals and linear systems

DR R. NABAR

We draw a distinction between the fundamentals of signal modelling in the time and frequency domains, and indicate the significance of alternative descriptions. The basic concepts of Fourier series, Fourier transforms, Laplace transforms and related areas are developed. The idea of convolution for linear time variant systems is introduced and expanded on from a range of perspectives. The transfer function for continuous and discrete time systems is used in this context. Stability is discussed with respect to the pole locations. Some elements of statistical signal description are introduced as signal comparison methods. The discrete Fourier transform is discussed as a z-transform evaluation and its consequences examined. Some basic filtering operations for both continuous and discrete signals are developed. Where appropriate use of MATLAB is made for demonstration purposes.

E.2.6 Control engineering

DR I. JAIMOUKHA

An introduction to feedback controller design compromises. Mathematical modelling; transfer function and state-space models. Properties of second-order systems. Definitions of open- and closed-loop stability. Stability tests based on the Routh array. Root-locus analysis and design. Frequency response methods. Nyquist analysis and design, robust stability. Various compensator structures including phase led and phase lag, proportional, integral and derivative action. PID regulators and Ziegler-Nichols, brief treatment of non-linear systems and the effect of feedback.

E.2.8 Mathematics (EEE stream)

PROFESSOR J.D. GIBBON, DR M. CROWDER

Basic probability; conditional probability and independence; random variables and distributions; some standard distributions, discrete and continuous; bivariate distributions; estimation and testing; sampling distributions; random processes.

E2.11 Mathematics (ISE stream)

PROFESSOR J.R. CASH, DR M. DE IORIO

Fourier transforms: basic definitions and properties; the complex integral method; the convolution theorem, Parseval's theorem; the delta function; the uncertainty principle. Laplace transforms: revision of definition and shift theorems; the inverse transform; transforms of derivatives and integrals; the convolution theorem. Line integrals; parametric representation of curves in a plane. Path independence in simply connected domains; finding a potential. Double in integrals: double and iterated integrals in simple and general domains; applications to computing volumes in three dimensions. Green's theorem in simply-connected domains; applications to computing line and double integrals. Functions of a complex variable; revision of complex numbers; analytic functions; Cauchy's theorem; residue theorem. Probability and statistics: random experiments; sample spaces; events; relative frequency; axioms of probability; elementary probability results; conditional probability; the law of total probability; Baye's theorem; independence. Discrete random variables; binominal and Poisson distributions; Poisson process. Continuous random variables; distribution functions: exponential, normal and uniform distributions. Expectation; variances; standard deviation; examples. Reliability, hazard rates.

E2.12 Software engineering II—object-orientated software engineering and real time and internet programming (ISE stream)

MR L. MADDEN

Software engineering. Abstraction. OO concepts. OO concepts expressed in C++ and UML. Process model, RUP/CRC methodology. Testing (validation and verification).

E2.13 Computer architecture (ISE stream)

DR W. LUK (COMPUTING)
Introduction: overview; performance. Instructions: formats; representations, interface with software. Arithmetic: number representation; hardware for arithmetic operations; arithmetic logic unit. Datapath and control unit: single-clock and multiple clock implementations; microprogramming; exception handling. Memory hierarchy: caches, virtual memory. Pipelining: pipelined datapaths, data and branch hazards, exceptions. Advanced topics: hardware compitation, parallel architectures, special-purpose processors.

E2.15 Language processors (ISE stream)

DR Y. DEMIRIS
Fundamentals: introduction to language processors; types of language processing; assemblers, compilers, preprocessors, interpreters and disassemblers; T-diagram representations of compilers; examples of language processors (GCC, Tex/Latex, Matlab, SysTran, Postscript, XML): compiling and running a compiler, cross-compilation and bootstrapping; semantics, conceptual structure of language processors; front and back-ends; passes; compiler width; criteria for design and evaluation of language processors; history and evolution of language processors; a complete example of a language processor (an infix to postfix expression converter) in full detail; syntax-directed translation; attributes and annotated parse trees; tree-traversal methods.
Theoretical underpinnings of language processors: introduction to grammars; basics; production rules and derivation of strings; formal definitions; Chomsky's hierarchy; context-sensitive and context-free grammars; Turing machines; linearly-bound automata; push-down automata; regular grammars; finite state automata; BNF/EBNF syntax; regular expressions and their limitations.
Lexical analysis: introduction to lexical analysis; tokens and attributes; deterministic and non-deterministic finite state automata; epsilon-transition; equivalency of NFA and DFA; elimination of e-transitions and non-deterministic transitions; epsilon-closures; subset construction; Thompson's algorithm for converting a regular expression to NFA; automatic construction of DFAs; DFA minimisation; automatic generation of lexical analysers using Lex/Flex.
Parsing: introduction to parsing; leftmost and rightmost derivations; parsing ambiguities; top-down vs bottom-up parsing; L{L/R} {k} notation, recursive-descent parsing; lookaheads and predictive-parsing; FIRST and FOLLOW sets and their computation; left-recursion and its elimination; left-factoring; transition diagrams and tables and their construction; bottom-up parsing; shift-reduction parsing; stack implementation; LR(k) parsing; LR/SLR/Canonical LR/LALR; construction of parsing tables; automatic construction of parsers using YACC/Bison.
Context-handling: introduction to context-handling; attributes and attribute grammars; dependency graphs; S- and L-attributed grammars; S-attributes and bottom-up parsing; inherited attributes; type-checking; symbol tables.
Code generation and optimisation: introduction to code generation; intermediate code generation; types of intermediate code (Pascal P-code, Java byte-code; 3-address code); translation of intermediate code to target code; instruction selection issues; storage management; memory, heap, garbage collection; register allocation; flow graphs and basic blocks; converting 3-address statement sequences into basic blocks; local and global transformations; dead-code elimination; common-subexpression elimination; algebraic transformations; computation of next-use information; register and address descriptors; register allocation in detail; interference graphs; register allocation through graph colouring; optimisation: peep-hole optimisation; flow of control optimisations; removal of redundancy; loads and stores; removal of unreachable code; copy propagation; code motion; constant folding; data-flow analysis; code profiling.
Case studies: GCC and internals; front and back ends; register-transfer language; construction of a PASCAL to ARM assembly language processor (assessed laboratory coursework).

E2.17 Discrete mathematics and computational complexity (ISE stream)

DR G.A. CONSTANTINIDIES
Functions, relations and sets. Logic: forms of logic, logical connectives, normal forms, universal and existential quantification. Recurrence relations: definitions, the master theorem. Algorithmic analysis: upper and average case complexity, big O, little o, omega notation, recurrence relations for recrusive algorithms. Computability: tractability, intertractability and uncomputability.

E2.18 Algorithms and data structures (EEE stream)

DR M SHANAHAN
A review of Pascal.
Software engineering principles; data structures; lists; ordered lists; trees; ordered trees.
Hash tables; parsing.

E2.19 Introduction to Computer architecture (EEE stream)

DR T CLARKE
The kernel of computer architecture: the instruction set architecture. Trends in technology and the basics of a computer system architecture.
Introduction to processor design: the MUO architecture. Pitfalls with MUO, the advantages of different instruction formats, an introduction look at the ARM processor. The basics of assembly language programming. Arithmetic instructions, data transfer instructions, pre-and post-index addressing. Further assembly language programming. Conditional execution and the ARM's S-bit. Shifted operands and shift types, multiply instructions, multiplication through shift-and-add, some simple complete ARM programs. Stacks and subroutines. The concept of a stack and its implementation in the ARM, the use of a link register, nested subroutines. The architecture of the ARM. An introduction to pipelining. Instruction encoding. ARM encoding of data processing and data transfer instructions. Memory hierarchies. The principles of locality, unified versus separate instruction and data caches.
Direct-mapped caches: design issues and architecture, cache write strategies.
System programming: exceptions and interrupts, ARM's shadow registers. An introduction to I/O interfaces. Polling, interrupt-drive I/O and DMA. Cache coherency and DMA.

Humanities

Students take one of the following courses, the syllabuses of which are shown in the Humanities section: French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Russian, Spanish, Philosophy, Controversies and ethical dilemmas in science and technology, European history: 1870–1989, Politics, Science and technology in western civilisation, Global history of twentieth-century things, History of medicine, Modern literature and drama, Art of the twentieth century, Music and western civilisation, The Roman empire, Communicating science: the public and the media, Creative writing, Science, communication and society, Music technology, Saying true things: how science invents and persuades.

Optional courses (EEE stream)

An additional Humantities course, selected from the list above, may be taken by students of sufficient academic standing.

Practical work

Electrical laboratory

About 100 hours.
Students perform a course of experiments and projects complementary to all lecture courses.

Computing laboratory

30 hours computing laboratory.

Other activities

Students participate in group projects in which they investigate technological, economic and social aspects of a complex engineering problem, reporting by means of an oral presentation, a written report, and a web page.

THIRD YEAR *(EEE stream)*

Lecture courses

Students are offered a range of lecture courses—technical, humanities, business studies—from which to select their third year lecture programme. Guidance will be given on the composition of appropriate programmes. The requirements are:
MEng(T) course: six technical and one non-technical course *must* be taken. Up to two additional courses may be taken.
MEng (EY) course: as T.
MEng (EM) course: at least three business studies core courses, three technical courses and one other course (which may be technical or non-technical) *must* be taken. Up to two additional courses may be taken.
BEng course: five technical and one non-technical course *must* be taken. Up to three additional courses may be taken.

Technical courses (each of 20 lectures—E.3.01–E.3.20)

Syllabus follows.

Business studies courses for 3EM stream (see Tanaka Business School syllabus)

Core courses
- BS0801 Accounting
- BS0821Project Management
- BS0815 Managerial Economics
- BS0809 Finance and Financial Management
- BS0806 Entreprerneurship
- BS0826 Innovation Management

Optional courses
- BS0612 Organisational Behaviour and Human Resource Management
- BS0817 Marketing
- BS0803 Business Strategy
- BS0826 International Business

Business studies options (see Tanaka Business School syllabus)

For BEng, 3T and 3EY streams:
- BS0801 Accounting
- BS0821 Project Management
- BS0815 Managerial Economics
- BS0808 Finance and Financial Management
- BS0806 Entrepreneurship
- BS0820 Innovation Management

Other non-technical courses (see Humanities Programme syllabus)

French, German, Japanese, Italian, Mandarin (with option for Cantonese speakers), Russian, Spanish, Philosophy, Controversies and ethical dilemmas in science and technology, European history: 1870–1989, Politics, Science and technology in western civilisation, Global history of twentieth century things, History of medicine, Modern literature and drama, Art in the twentieth century, Music and western civilisation, The Roman empire, Communicating science: the public and the media, Creative writing, Music technology, Saying true things: how science invents and persuades, Humanities essay .

Coursework

Students spend approximately 20 hours on coursework associated with each of their chosen options. MEng students undertake a group or study project in the summer term. BEng students undertake an individual project from November through to the end of the summer term.

FOURTH YEAR *(EEE stream)*

Lecture courses

Students are offered a range of lecture courses, technical (E.4.01–E.4.46), business studies and humanities, from which to select their fourth year lecture programme. Guidance will be given on the composition of appropriate programmes. The requirements are:
MEng (T) course: six technical and one non-technical course *must* be taken. Up to two additional courses may be taken.
MEng (EY) course: full year in a continental educational institution. Studies include an individual project, dissertation and technical courses.
MEng (EM) course: at least three core business studies courses, three technical courses and one other course (which may be technical or non-technical) *must* be taken. Up to two additional courses may be taken.

Technical courses (each of 20 lectures—see E.4.01–E.4.46)

Business studies courses for 4EM stream (see Tanaka Business School syllabus)

Core courses

- BS0801 Accounting
- BS0821 Project Management
- BS0612 Organisational Behaviour and Human Resource Management
- BS0809 Finance and Financial Management
- BS0806 Entrepreneurship
- BS0820 Innovation Management

Optional courses

- BS0817 Marketing
- BS0803 Business Strategy
- BS0826 nternational Business

Business studies courses for 4T stream (see Tanaka Business School syllabus)

- BS0801 Accounting
- BS0821 Project Management
- BS0808 Finance and Financial Management
- BS0806 Entrepreneurship
- BS0820 Innovation Management

Other non-technical courses (see Humanities syllabus)

French, German, Japanese, Italian, Mandarin (including option for Cantonese speakers), Russian, Spanish, Philosophy, Controversies and ethical dilemmas in science and technology, European history: 1870–1989, Politics, Science and technology in western civilisation, Global history of twentieth-century things, History of medicine, Modern literature and drama, Art of the twentieth century, Music and western civilisation, The Roman empire, Communicating science: the public and the media, Creative writing, Music technology, Saying true things: how science invents and persuades, Humanities essay.

Practical work

4EM and 4T students spend about 10 hours per week in the autumn and spring terms and work full-time (after final examinations) on individual projects in the summer term.

Other activities

Each student gives an oral presentation on his/her individual project during the summer term.

Technical course syllabuses

20 lectures each.

THIRD YEAR

E.3.01 Analogue integrated circuits and systems

PROFESSOR C. TOUMAZOU
Design techniques. Modelling and simulation (SPICE) of MOSFETS. Modelling and simulation (SPICE) of BJTs. Noise sources in op-amps and integrated circuits and low noise design. Refresher of CMOS building locks, current-mirrors, amplifiers, differential pairs. Design case study of typical CMOS IC op-amp. Introduction to integrated switched capacitor filters and continuous-time filters.

E.3.02 Instrumentation

DR C. PAPAVASSILIOU
Definitions and examples of measurements and their limitations: resolution, accuracy, sensitivity. Noise in electronic systems. Analogue, digital and sampling oscilloscopes. DC and AC bridges. Amplifiers: sampling and analogue to digital conversion. Oversampling. Oscillators and synthesisers. Phase noise. Frequency measurements. Coherent measurements and interferometry. Correlation techniques. Network and spectrum analysis at radio frequencies. Time domain reflectometry.

E.3.03 Communication systems

DR A. MANIKAS
Communication sources and channels: modelling of communication sources and communication channels, measures of information, Gaussian sources and channels, etc.
Performance criteria and limits of communication systems: introductory concepts, energy utilisation efficiency (EUE), bandwidth utilisation efficiency (BUE), bandwidth expansion factor, signal-to-noise power ratio (SNR), probability of error. Shannon's threshold capacity curve, theoretical limits on performance of digital communication systems and the concept of an ideal communication system. The (Pe/SNR, EUE, BUE) parameter planes. Representation of the major communication systems on the parameter planes. Comments, comparisons and discussions.
Digital transmission of analogue signals: a brief review of sampling theory and quantisation (uniform, ideal and natural sampling, practical problems, uniform quantisers), maximum-SNR-non-uniform quantisers, A-law and μ-law compaders, differential quantisers, basic concepts of differential PCM.
Principles of source and channel coding: source encoder-decoder (the prefix of a binary sequence, prefix code, Kraft inequality, defining an optimum code, Shannon's first coding theorem, etc.). Channel capacity. Error control coding (Shannon's second coding theorem, linear block codes, convolutional codes). Interleaving-deinterleaving. Line codes and digital modems.
Principles of multiplexing and public switched telephone networks: using concepts and analytical tools presented in the previous topics, the examination of multiplexing and PSTN will be presented, based on the CCITT recommendations for PCM and the associated digital hierarchy.
Principles of ADSL/VDSL.
Mobile communication systems: a compact review of a mobile radio network and a detailed description/analysis of the Pan-European cellular communication system. The analysis will be based on European telecommunication standards.

E.3.05 Digital system design

PROFESSOR P.Y.K. CHEUNG
Case study: definition of the digital system to be used as demonstrator; linked finite state machines; FSM implementation issues; race, hazards and metastability; dynamic memory interface; special memory devices; multiplier circuits; bit-serial arithmetic circuits; data coding circuits; design for testability; programmable logic, FPGAs and CPLDs; system level interfacing.

E.3.06 VHDL and logic synthesis

DR T.J.W. CLARKE

VHDL—Modelling of hardware: model of behaviour, time and structure. Major VHDL constructs: entity declarations; architecture bodies; subprograms; packages and 'use' clauses. Basic VHDL data types: literals; scalars; vectors. Behavioural description: processes; activation and suspension of processes; sequential assignments; signal assignments; variable assignments; sequential control; procedure and function calls; concurrent statements. Structural description: parts; component instantiation; configuration specifications; busses. Access types: files, file I/O.

Testing and verification—VHDL testbenches. Procedural abstraction. Exhaustive, random, *ad hoc* testing methods. Test coverage metrics.

Synthesis—multi-level logic minimisation techniques; boolean optimisation. Critical path optimisation. High level synthesis: state minimisation in FSM. Technology mapping: gate arrays, FPGA, PLDs.

E.3.07 Digital signal processing

DR P.A. NAYLOR

Sampling theory, z-transforms, system functions. Digital filter structures, signal flow graphs, elementary FIR/IIR filter design techniques, windows, bilinear and band transformations. Discrete Fourier transform, relationship between DFT and DTFT, simple and short-time spectral estimation, fast computation of DFT as decimation-in-time. Linear convolution, cyclic convolution, sectioned convolution (overlap-add and overlap-save), application to fast filtering algorithms, windowing. Basic multi-rate elements and identities, design of sample rate changing systems, polyphase representation of filters, maximally decimated filter banks, polyphase representation of maximally decimated filter banks, typical applications. Overview of microprocessor architectures for DSP, implementational aspects of simple DSP algorithms.

E.3.08 Advanced signal processing

DR P.D. MANDIC

Discrete random signals; statistical stationarity, strict sense and wide sense. Averages; mean, correlations and covariances. Bias-variance dilemma. Curse of dimensionality. Linear stochastic models. ARMA modelling. Stability of linear stochastic models. Introduction to statistical estimation theory. Properties of estimators; bias and variance. Role of the Cramer-Rao lower bound. Minimum variance unbiased estimator. Best linear unbiased estimator (BLUE) and maximum likelihood estimation. Maximum likelihood estimator. Bayesian estimation. Least square estimation: orthogonality principle, block and sequential forms. Wiener filtering, adaptive filtering and signal modelling. Simple non-linear adaptive filtering. Concept of an artificial neuron. Applications: acoustic echo cancellation and signal enhancement, inverse system modelling and denoising.

E.3.09 Control engineering

PROFESSOR R.B. VINTER

Nyquist plots and robust stability, classical frequency domain approaches to controller design; state space modelling; pole placement via state feedback and dynamic output feedback; observer design; controllability and observability; linear quadratic optimal control; non-linear systems analysis (describing function); discretisation and computer control.

E.3.10 Mathematics for signals and systems

DR G. WEISS

Vector spaces, independence, dimension, sequence spaces, analytic functions, normed spaces, inner products, Hilbert and Banach spaces, Weierstrass theorem, completion, L^p spaces, essential supremum, H^p spaces on various domains, boundary traces of H^p functions, span, orthogonal complement, closure, orthonormal basis, Fourier series, bounded linear operators, their norm, orthogonal projectors, isometric and unitary operators, Z- and Laplace transforms, convolution, Paley-Wiener theorem (discrete-time and continuous-time versions), shift operators, time-invariant operators, Foures-Segal theorem (discrete-time and continuous-time versions), linear systems, transfer functions, band-limited functions, sampling theorem.

E3.11 Advanced electronic devices

DR K. FOBELETS

Energy band diagrams as a route to semiconductor devices. Processing: how is it done? Discussion and comparison of different field effect transistors: JFET, GaAs MESFET, Si:SiGe MODFET and GaAs/InGaAs

HEMT. Strain as an extra parameter to engineer devices. Optimising the 'classical BJT' using a combination of materials: HBT. Quantum mechanics how it is used in semiconductor devices. An example:the resonant tunneling diode. SOI, SGOI, sSOI nove substrates for better device performance. Carbon nanotubes, devices for the future.

E.3.12 Optoelectronics

PROFESSOR R.R.A. SYMS

Maxwell's equations; the wave equation for electromagnetic waves; evanescent waves; power flow. Waveguide structures: boundary matching, slab dielectric waveguide; guided and radiation modes; cut-off conditions; free carrier contribution to the dielectric constant; waveguides in semiconductors—homostructure and heterostructure guides; epitaxy and lattice matching; channel waveguides. Channel waveguide devices: power splitters, filters. Diode-based waveguide structures: homojunctions and heterojunctions; carrier injection phase modulators; electro-optic phase modulators; switches and intensity modulators. Photodetectors: absorption of light by semiconductors; quantum efficiency; photoconductive detectors; p-i-n photodiodes; heterojunction photodiodes. LEDs: spontaneous and stimulated emission; electroluminescence in p-n junctions; simple LED structures; emission spectrum of LED; DC efficiency and frequency response of LED; ELEDs.

Semiconductor lasers: conditions for laser oscillation; inversion and optical gain; emission spectrum of laser; the double heterostructure; threshold condition and power-current characteristics.

E.3.13 Electrical energy systems

DR B. PAL, DR C A HERNANDEZ-ARAMBURO

Overview of power systems: topological characteristics, challenges and future trends. Basic theory of three phase systems. Theory of operation and models for synchronous machines. Theory of operation and models for transformers and their variants. Use of a per-unit system in power networks. Transmission line models. Review of solution methods for non-linear equations. Statement and solution strategies of the power flow problem. Voltage, frequency, active and reactive power control, optimal operation of power systems, fault analyses.

E.3.14 Power electronics and machines

DR T.C. GREEN

Comparison of power semiconductors with signal transistors; improvements to basic switch-mode power supply circuits to provide isolation and high efficiency; inversion of DC to AC and rectification with sinusoidal current; classification of machine types; comparison of permanent magnet and field winding excitation; development of brushless pm machines; control of induction machines with an inverter.

E.3.15 Human-computer interaction

DR J.V. PITT

HCI: motivation, requirements, Norman's stages of action. Evaluation: criteria, products, processes. Physical interactions: input/output devices, environment, workspace/workplace design. Dialogues: menus, icons, windows, forms, command language, natural language, direct manipulation, user agents. Design: user-centred and participatory design, design rationale and prototyping, design methodology (task, dialogue and screen design), design standards and guidelines. Information: visualisation, presentation and representation. Advanced topics: extreme interface, affective computing.

E.3.16 Artificial intelligence

DR J.V. PITT

Search: search space, problem formulation, generic graph search algorithm; graph theory; uninformed search strategies—depth first, breadth first, uniform cost, iterative deepening; informed search strategies—best first, A*, iterative deepening A*; analysis of algorithms—completeness, complexity, optimality; minimax, alpha-beta search; reinforcement learning and potential fields for path planning. Knowledge representation and reasoning: knowledge acquisition, knowledge engineering; propositional logic—semantic proof, syntactic proof, soundness and completeness of proof systems; automated reasoning with KE; predicate calculus and expert systems; modal logic and practical reasoning. Distributed AI: agents, agency and multi-agent systems; BDI agents.

E3.17 Communication networks

DR J.A. BARRIA
Introduction to layered approach to the analysis of communication networks. Study and analysis of different communication networks, their architectures and associated protocols: local area network (LAN), metropolitan area network (MAN), wide area networks (WAN) and internet. Design of data and packet switched networks, topological issues, routing strategies and congestion control, TCP/IP internet protocols. B-ISDN protocol reference model, multimedia traffic characterisation and performance analysis. Optimal routing problem.

E3.18 Microwave technology

DR S. LUCYSZYN
Review of the electromagnetic spectrum. Review of Maxwell's equations. Electromagnetic numerical modelling techniques. Transmission line theory: general and rectangular waveguides. Antenna theory. Microwave materials: reciprocal and non-reciprocal. Passive components: reciprocal and non-reciprocal. Thermionic devices. Solid state active devices; two-terminal and three-terminal. Integrated circuit technologies. HMICS and MMICS. S-parameters: general and signal flow graph techniques. Measurement techniques: general and laboratory sessions. Applications of microwave technology.

E.3.19 Real-time digital signal processing

TO BE ANNOUNCED
C6x architecture; data conversion; software tools; I/O and interrupts; fixed point vs floating point; FIR filters; IIR filters; frame processing; speech enhancement project.
Laboratory work: getting started with C6x; data conversion; learning C and Sinewave generation; Interrupt I/O free; FIR filter implementation; IIR filter implementation; real-time spectral analysis. Project.

E3.20 Discrete Mathematics and Computational Complexity

Dr G. A CONSTANTINIDIES
Functions, relations and sets. Logic: forms of logic, logical connectives, normal forms, universal and existential quantification. Recurrence relations: definitions, the master theorem. Algorithmic analysis: upper and average case complexity, big O, little o, omega notation, recurrence relations for recrusive algorithms. Computability: tractability, intertractability and uncomputability.

FOURTH YEAR

E.4.01 Advanced communication theory

DR A. MANIKAS
Introductory concepts: modelling of information sources, communication channels and sinks. Definitions of priori and posterior probabilities in relation to the model of a communication channel. MAP criterion, likelihood functions and likelihood ratio. An initial study on the performance of a digital communication system and expansion to a spread spectrum system.
Optimum detection theory: detection criteria. Receiver operating characteristics (ROC). Detection of known signals in the presence of white noise and the concept of an optimum receiver. Matched filter receivers and their mathematical analysis. Extension to non-white noise. Orthogonal signals and the 'approximation theorem'. M-ary signals and signal constellation. Basic concepts and analysis of orthogonal and biorthogonal M-ary communication systems. 64-ary Walsh-Hadamard signal set.
PN-sequences: Galois field GF(2) basic theory, shift registers, basic properties of m-sequences, statistical properties of m-sequences, Gold sequences.
PN-signals: modelling, cross/auto correlation functions and power spectral density, partial correlation properties.
Spread spectrum systems (SSS): basic concepts and parameters. Classification and modelling of jammers. Modelling of BPSK and QPSK direct sequence SSS in a jamming environment, estimation of SNIR and bit-error-probability. Direct sequence SSS on the (SNR/pe, EUE, BUE) parameter plane. Frequency hopping SSS.
Principles of CDMA system: investigation of important system components with special attention given to

RAKE receiver. Modelling and analysis with emphasis given on capacity issues. An overview of the TIA/ISA IS-95 CDMA standards. Wideband CDMA (3G).
Space-time communications: definitions, notation, spaces and projection operators. Modelling an array received signal-vector and the concept of the array manifold. Multidimensional correlators. Estimation of signal parameters including directions of arrival, powers, cross-correlations, etc. Array pattern and beamformers. Vector-channel effects (including multipaths, angular spread, Doppler spread and fading). Outage probability. Integrated array CDMA systems. Single-user and multi-user array CDMA receivers.

E.4.03 Mobile radio communication

DR M.K. GURCAN
Transmission path: VHF and UHF propagation; propagation losses; inverse fourth power propagation; Rayleigh fading, shadowing losses. Coverage probability; outage and coverage probabilities, error performance analysis for transmission systems; quality factor and re-use distance calculations. Transmission schemes: wideband channels and wideband transmission; equalisation and multiplexing; multiple access schemes. Area coverage, analogue and digital transmission systems.

E.4.04 Advanced data communication

DR M.K. GURCAN
Data transmission systems; elements of the system, the source, shaping filters and modulation systems and techniques. Equalisation. Convolution codes, Maximum likelihood detection and MAP algorithm and coded modulation schemes. Tubo codes and ADSL systems.

E.4.05 Traffic theory and queueing systems

DR J.A. BARRIA
Introduction to teletraffic analysis. Mathematical basis of traffic theory: Markov processes. Loss-system analysis: route congestion in circuit-switched systems; models for overflow traffic; restricted availability; congestion in circuit switches. Delay-system analysis: introduction to queueing theory; congestion in message-switched systems and packet-switched systems; queueing network models. Analysis of random-access protocols; traffic characterisation of broadband services; admission and access control in broadband networks; routing in ATM networks. Performance/reliability (performability) models.

E.4.06 Optical communication

DR E.M. YEATMAN
Fundamentals of communicating with light. Guided electromagnetic waves: the slab waveguide, modes, dispersion. Modes and attenuation in fibres. Properties of LEDs and lasers as communication sources. Photodiodes and receiver circuits, sensitivity, noise and bandwidth. Modulation techniques, coherent communication. Time-division and wavelength division multiplexing. Optical amplifiers, non-linear effects. System architectures and applications. Free space systems. Signal processing, routing and timing.

E.4.07 Coding theory

DR A.A. IVANOV (DEPARTMENT OF MATHEMATICS)
Elementary ideas of redundancy. Fundamental problems in coding theory and practice. Distance measures. Bounds to the performance of codes. Important linear codes. Construction and properties of finite fields. Cyclic codes, BCH and Reed Solomon codes. Error correction for BCH and RS codes.

E.4.08 Digital image processing

DR P.T. STATHAKI
Image transforms: definition and properties of one-dimensional and two-dimensional unitary transforms. Fourier transform. Discrete cosine transform. Walsh transform. Hadamard transform. Karhunen-Loeve transform. Image enhancement: enhancement by point processing. Spatial filtering. Enhancement in the frequency domain. Image restoration: description of the degradation model. Deterministic techniques for Image restoration (direct-inverse filtering, constrained least squares (CLS), iterative, recursive), stochastic techniques for image restoration (direct-Wiener filtering, iterative-iterative Wiener filtering). Image coding: scalar quantisation. Vector quantisation. Codebook design. Codeword assignment. Transform image coding. Image model coding. Fractal coding. Coding standards (MPEG, JPEG).

E.4.10 Probability and stochastic processes

PROFESSOR K K LEUNG
Axiomatic basis of probability theory. Conditional probability, independence. Random variables and probability distributions. Expectation, moments, characteristic functions, conditional exceptions. Vector random variables. Least squares estimation. Sequences of random variables. Modes of convergence. Stochastic processes. Markov processes. Gaussian process. Stationary processes: auto-correlation and cross-correlation; spectral density functions; white noise. The Kalman filter.

E.4.12 Digital signal processing and digital filters

DR P. T STATHAKI
Finite and infinite impulse response digital filter design techniques, interpolation and decimation, half-band filters and spectral analysis, spectral transformations, circular convolutions, Discrete Fourier transforms and computational complexity, the fast Fourier transform and prime radix algorithms, Number theoretic transforms, sectioned convolution applications to speech signal analysis, image processing, television signal processing, limit-cycle performance, reduced sensitivity structures including wave digital filters and linear transformation techniques, lattice structures and half-band filter realisations.

E4.13 Spectral estimation and advanced signal processing

DR D. MANDIC
Aspects of estimation theory: bias, variance, maximum likelihood and efficiency. Resolution and stability; time-bandwidth product. Classical spectral estimation: periodogram, averaging and Blackman-Tukey method. Parametric models: linear, rational transfer function, and non-linear models. Order selection. Block and sequential parameter estimation techniques. Levison, lattice, Cholesky factorisation, steepest descent, least mean square and recursive least squares adaptive algorithm families. Kalman filtering/ Blind equalisation and source separation. Nonlinear adaptive filters and temporal neural networks. Time-frequency and time-scale methods. Spectral redundancy and cyclostationarity. Case studies.

E.4.14 Speech processing

DR P. NAYLOR
The human vocal and auditory systems. Characteristics of speech signals: phonemes, prosody, IPA notation. Lossless tube model of speech production. Time and frequency domain representations of speech; window characteristics and time/frequency resolution tradeoffs. Properties of digital filters: mean log response, resonance gain and bandwidth relations, bandwidth expansion transformation, all-pass filter characteristics. Autocorrelation and covariance linear prediction of speech; optimality criteria in time and frequency domains; alternate LPC parametrisation. Speech coding: PCM, ADPCM, CELP. Speech synthesis: language processing, prosody, diphone and formant synthesis; time domain pitch and speech modification. Speech recognition: hidden Markov models and associated recognition and training algorithms. Dynamic programming. Language modelling. Large vocabulary recognition. Acoustic preprocessing for speech recognition.

E.4.16 Current-mode analogue signal processing

DR M. DRAKAKIS, DR C PAPAVASSILIOU
Current-mode vs voltage mode processing; supply-current sensing, current conveyors, current-mode instrumentation amplifiers. Adjoint networks. Translinear circuits. High-performance amplifier architectures, current-feedback op-amps. Current-mode filters; switched current processing, translinear/log domain filters. Current-mode instrumentation amplifiers and precision rectifiers; switched current techniques; problems with traditional current output circuits; basic current-conveyor applications.

E4.17 High performance analogue electronics

DR E. RODRIGUEZ-VILLEGAS
System-level design: introduction to wireless receiver architectures, system-level specifications.
Design techniques: noise analysis and low noise design; high-frequency transistor performance, impedence matching, CMOS and BJT linearisation. Building blocks: integrated continuous-time filters, analogue mixers and multipliers, integrated oscillators. System-level case studies: video/TV receivers; paging receivers.

E.4.18 Radio frequency electronics

DR S. LUCYSZYN

Topics in radio frequency and microwave circuit design and testing. Power and noise link budget. Narrowband matching. Transmission line circuits, the Smith chart and its uses. Lumped and distributed filters, impedence transformations. S-parameters. Transistor amplifier design. Stability at high frequencies, oscillators. Power amplifier design. RFIC and Monolithic microwave integrated circuits.

E.4.20 Introduction to digital integrated circuit design

PROFESSOR P.Y.K. CHEUNG

This course in integrated circuit design covers the complete range of digital integrated circuit design from concept to implementation on silicon. A significant part of the course is taken up by a group design project in which students design an integrated circuit on advanced graphics workstations. The course provides a good grounding for any student wishing to work in the IC design industry. The main topics covered include: design methodology; behavioural, logic and circuit simulation; floorplanning; geometric layout; circuit structures and techniques; testing and design for test, etc.

E.4.22 Linear optimal control

DR A. ASTOLFI

State-space models for linear control systems. Stability, controllability and observability, stabilisability and detectability. Pole assignment, full and reduced-order observers. Formulation of optimal control problems. Principle of optimality. The linear quadratic regulator problem, properties of the algebraic Riccati equation (ARE), return difference inequality, robustness properties of the optimal state feedback. The minimum principle and time optimal control problems.

E.4.23 Stability and control of non-linear systems

DR J.C. ALLWRIGHT

For non-linear systems, methods for determining stability and for designing stabilising controllers are studied using state-space (Lyapunov theory, variable structure analysis), function space (small gain theorem, passivity) and frequency-domain (Popov and circle criteria, describing function) methods. Model reference adaptive control is treated using the passivity concept.

E.4.24 Discrete-time systems and computer control

DR J.C. ALLWRIGHT

Aspects of digital signal processing relevant to modelling and the implementation of digital controllers are studied using the Z, Delta, W and discrete time Fourier transforms. Discrete time control systems are analysed and synthesised using root-locus, Nyquist and state-space techniques, bearing in mind the necessity for bounded-input bounded-output stability, small tracking error and robustness.

E.4.25 Design of linear multivariable control systems

DR I. JAIMOUKHA

Analysis: system representations, return difference matrix, stability theory, multivariable poles and zeros. Design: design criteria, dominance-based approaches, LQG design methods, norm-based methods, robust stability and performance, $H\infty$ design techniques. Model reduction. Design examples: use of CAD techniques in the design of controllers for industrial processes.

E.4.27 System identification

DR G. WEISS

Dynamical systems and their mathematical models, random variables and signals, spectral and correlation analysis. Guiding principles behind least-squares parameter estimation, statistical properties of estimates. Identification of the transfer function of linear systems in continuous time. Models for discrete time linear systems: these include FIR, AR, ARX, ARMA and state-space models. Various methods for recursive estimation. Experiments for data acquisition and their design. The course will have a theoretical flavour and will contain a number of case studies.

E.4.29 Optimisation

DR A. ASTOLFI
Topics covered include unconstrained optimisation and the associated algorithms of steepest descent and conjugate gradient, Newton methods, rates of convergence, constrained optimisation and the method of Lagrange multipliers, quadratic programming, penalty methods.

E.4.31 Advanced computer architecture

PROFESSOR P. KELLY, DR J. BRADLEY (DEPARTMENT OF COMPUTING)
Performance: measuring and reporting computer systems performance. Amdahl's law.
Pipelined CPU architecture: instruction set design and pipeline structure.
Dynamic scheduling using scoreboarding and Tomasulo's algorithm. Software instruction scheduling and software piping. Superscalar and long-instruction-word architectures. Branch prediction and speculative execution.
Caches: associativity, allocation and replacement policies, sub-block placement. Multi-level caches, multi-level inclusion. Cache performance issues.
Uniprocessor cache coherency issues: self-modifying code, peripherals, address translation.
Vectorising compilers and their capabilities; applications to parallelisation and memory hierarchy optimisation.
Interconnection networks: topology, routing, flow control, deadlock avoidance. The k-ary n-cube family of topologies. Virtual channels, wormhole routing and virtual cut-through.
Implications of shared memory: the cache coherency problem. Update vs invalidation. The bus-based 'snooping' protocol design space. Scalable shared memory using directory-based cache coherency. Alternative approaches.

E.4.32 Graphics

DR D. GILLIES, DR D. RUECKERT (DEPARTMENT OF COMPUTING)
Device independent graphics: raster and vector devices, normalised device coordinates, world coordinates,the normalisation transformation, output primitives input primitives. Raster graphics algorithms: line drawing; differential algorithms filling; seed filling dithering. Planar polyhedra: three-dimensional database representation, projection to viewing surface. Transformation of graphical scenes; homogenous coordinates, affine transformations, scaling, rotation, translation. Affine transformations and homogenous coordinates using projection. Clipping and containment in three-dimensional convex objects, splitting concave objects. Texture mapping and anti-aliasing. Shading planar polygons; Gouraud shading, Phong shading. Using colours: tri-stimulus model, RGB model, YCM model, perceptual colour spaces. Polygon rendering and Open GL. Ray tracing: ray/object intersection calculations; secondary rays, shadows, reflection and refraction, computational efficiency, object space coherence, ray space coherence. Ray tracing and computational space geometry. Radiosity: modelling ambient light; form factors; specular effects; shooting patches; computational efficiency. Geometric warping. Morphing objects. Special visual effects: motion, blur, lens models, caustics, fog, particle systems, fire, smoke and water.

E.4.38 Modelling and control in power systems

DR T. GREEN, DR B. PAL
Development of the two-axis, rotating reference frame (dqO method) of machine analysis; application of dqO to general three-phase systems, field orientation control of induction machines (via direct and indirect flux vector angle estimation). Examination of flexible AC transmission systems (FACTS) based on power electronic converters and control methods applicable to individual power converters and whole systems.

E.4.39 Environmental and economic issues in power systems

DR B. PAL, DR C.A. HERNANDEZ-ARAMBURO
The world of energy and the panorama for the UK. Generation of electricity at large scale by 'conventional' power plants: hydro-electrics, fossil-fuel fired power plants, gas turbines and combined-cycle gas turbines, nuclear power plants. Generation of electricity using new and renewable technologies: wind generators, non-conventional hydro (tidal, wave and ocean current power) systems, solar panels, biomass based plants. Combined heat and power: available technologies (combined cycle paths, internal combustion engines, fuel cells and Stirling engines), plant selection and optimal

operation. Benefits, drawbacks and current challenges in distributed generation schemes. Electricity market structures and rules around the world. Particular emphasis on the UK market is paid; but the Nordic Pool, California's market and the European super-grid are also covered. Electric power transfer capability: purpose, calculation and enhancement. Optimal power flow: introduction, solution to optimal power flow problems, linear sensitivity analysis, security constraint optimal power flow, bus incremental cost. Flexible AC Transmissions Systems (FACTS); introduction, loop flows in interconnections and power flow through FACTS controllers. FACTS devices (series and shunt); thyristor control series capacitor (TCSC), thyristor switched capacitor (TST), thyristor control phase shifter (TCPS), static var compensator (SVC), static compensator (STATCOM),static synchronous series compensator (SSSC) and unified power flow controller (UPFC).

E4.40 Information theory

MR M. BROOKES

The statistical nature of communication. Elements of information theory of discrete systems; information measures, memoryless and memory sources, the noiseless coding theorem. Methods of source coding. Information theory of continuous systems. Shannon's capacity theorem and its interpretation. Comparison of communication systems with the ideal. Applications of information theory in communications and signal processing.

E4.41 Intelligent data and probabilistic inference

DR D.F. GILLIES (DEPARTMENT OF COMPUTING)

Foundation of intelligent data analysis: data mining and Bayesian method; classification, cluster and causality analysis. Statistic methods—sampling, statistical inference. Induction methods and classification, overfiting and model evaluation. Tree/rule induction. Bayesian networks: Bayesian inference—prior and likelihood information, subjective and objective probabilities, Bayes theorem, the naïve Bayes classifer; simple Bayesian networks—deriving networks from expert knowledge; determining prior and conditional probabilities; propagation of probabilities in trees (lambda messages); reasoning with networks—simple classifiers, training internal nodes, virtual evidence, joint probability of a tree, multi-trees. Probability propagation in directed acyclic graphs—pi-messages, singly connected graphs, multiple parents, multiply connected graphs, conditioning. Probability propagation in trees of cliques. Moralisation, identification of cliques, propagation of probability among cliques. Building networks from data: maximum weighted spanning tree method. Minimum description length method. Monte Carlo-Markov chain methods for building networks; stochastic simulator models. Networks, causal structures and conditional independence. Consequences of the conditional independence assumption, problems in large networks. Hidden nodes: locating the positions of hidden nodes, determining the hidden node parameters. Incomplete data: estimating missing variables, effect on missing data on network structure and propagation. Clustering and applications: distance-based clustering and density-based clustering; EM method and applications; Bayesian clustering, autoclass; Bayesian learning applications, analysing classification algorithms; Bayesian inference application, medical, *et al*.

E4.43 Synthesis of digital architectures

DR G.A. CONSTANTINIDIES

Introduction to the fundamental architectural synthesis problems: scheduling, allocation, binding, estimation and control unit synthesis. Introduction to graph theory and combinatorial optimisation. Scheduling algorithms: as-soon-as-possible and as-late-as-possible, list scheduling, integer linear programming. Resource sharing algorithms: interval graphs, graph colouring, integer linear program models; register sharing.

E4.44 Network security

DR P. BEEVOR

Requirements for network security: examples of types of network attach; passive and active, communication channel and network management, traffic related. Protection by encryption and authentication. Digital signatures. Management controls. Importance of trusted parties in system management. Overhead, cost and other management aspects.

Algorithms and standards: private key systems and DES. Public key systems and PSA. Analysis of strength of protection. Weak keys. Attack by exhaustive search. Calculation of required key length. Types of analytic attack. Relationship with information and coding theory.
Key management: Diffie-Hellman key exchange. RSA key management. Public key certificates. Overall system management and management controls.
Systems for network security: VPN security. Wireless (including wireless LANs) security. LAN security. Internet security and the IPSEc protocol.

E4.45 Wavelets and applications

DR P.L. DRAGOTTI
Introduction and background: motivation: why wavelets, subband coding and mult-iresolution analysis? Mathematical background. Hilbert spaces. Unitary operators. Review of Fourier theory. Continuous and discrete-time signal processing. Time-frequency analysis. Multi-rate signal processing. Projections and approximations.
Discrete-time bases and filter banks: elementary filter banks. Analysis and design of filter banks. Spectral factorisation. Daubechies filters. Orthogonal and biorthogonal filter banks. Tree structured filter banks. Discrete wavelet transform. Multi-dimensional filter banks.
Continuous-time bases and wavelets: interated filter banks. The Haar and Sinc cases. The limit of iterated filter banks. Wavelets from filters. Construction of compactly supported wavelet bases. Regularity. Approximation of properties. Localisation. The idea of multi-resolution. Multi-resolution analysis. Haar as basis for L2(R). The continuous wavelet and short-time Fourier transform.
Applications: fundamentals of compression. Analysis and design of transform coding systems. Image compression, the new compression standard (JPEG 2000) and the old standard. Why is the wavelet transform better than the discrete cosine transform? Video compression and the three-dimensional wavelet transform. Advanced topics: beyond JPEG 2000, non-linear approximation and compression, separable and non-separable bases.

E4.46 Distributed computation and networks: a performance prespective

PROFESSOR E. GELENBE
Description of distributed system architectures and their components; digital sensors and actuators, processing units, local area networks, packet networks and the IP protocol, wireless ad-hoc networks. The role of protocols.
The concept of quality of service (QoS). Performance metrics related to system load, response time and timelines of data, data loss, system availability and reliability. Overall system modelling in terms of service requests and service units. Relation to a practical system architecture. System analysis in terms via experiments, probability models using analytical techniques, and simulation. Performance identification and their deterministic counterparts. Solution techniques for very large models. Separable solutions and product form networks. Solution techniques for systems with dynamic controls. G-networks. System adaptation to changing workloads and operating conditions. The practical use of learning and derivation from analytical models. Gradient techniques, reinforcement learning and learning by imitation. Analysis of a large experimental system via theoretical models and experiments.

Examinations

FIRST YEAR	*Date*
EEE stream	
Mathematics (two papers)	June
Analysis of circuits	June
Digital electronics I	June
Devices and fields	June
Analogue electronics I	June
Engineering materials	June
Communications I	June
Management and organisations	April/May

ISE stream	*Date*
Analysis of circuits	June
Digital electronics I	June
Analogue electronics I	June
Communications I	June
Software engineering I	June
Computer systems	June
Mathematics	June
Management and organisations	April/May

SECOND YEAR

EEE stream	
Mathematics (two papers)	June
Digital electronics II	June
Analogue electronics II	June
Power, fields and devices	June
Communications II	June
Signals and linear systems	June
Control engineering	June
Algorithms and data structures	June
Introduction to computer architecture	June
Non-technical option(s)	March/April

ISE stream	
Digital electronics	June
Communication II	June
Signals and systems	June
Control engineering	June
Software engineering II	June
Computer architecture	April/May
Language processors	June
Discrete mathematics and computational complexity	June
Mathematics	June
Non-technical option	April/May

THIRD YEAR

Three-year stream

Students are required to register for and be examined in *at least five* technical courses and *at least one* non-technical course.

T stream

Students are required to register for and be examined in *at least six* technical courses and *at least one* non-technical course.

EY stream

As T, but students may be required to study a language as one of their non-technical options.

EM stream

At least three core business studies courses, at least three technical courses and at least one other course, which may be technical or non-technical.

FOURTH YEAR

T stream

Students are required to register for and be examined in at least six technical courses and at least one non-technical course.

EY stream
Students will be examined in an agreed number of technical courses in the continental institute.
EM stream
Students are required to register for and be examined in at least three core business studies courses, at least three technical courses and at least one other course which may be technical or non-technical.

THIRD YEAR *(ISE stream)*

Lecture courses

Students are offered a range of lecture courses (technical, humanities, business studies) from which to select their third year lecture programme. The requirements are:
MEng: ISE3.2 Databases is compulsory for students on the MEng course:
Students also choose seven technical courses and one management, humanities or language course (a total of eight optional courses). At least one technical course must be taken from each department.
BEng: ISE3.2 Databases is compulsory for students on the BEng course:
Students also choose five or six technical courses and one or two management, humanities or language courses (a total of seven optional courses). At least one technical course must be taken from each department.

Technical courses (each of 20 lectures, ISE3.1 – ISE3.38)

Non-technical courses

Business studies courses (see Tanaka Business School syllabus)

Accounting, Project management, Entrepreneurship. Finance and financial management, Innovation management, Managerial economics.

Humanities courses (see Humanities syllabuses)

French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Spanish, Russian, Philosophy, Controversies and ethical dilemmas in science and technology, European history: 1870–1989, Politics, Science and technology in western civilisation, Global history of twentieth-century things, History of medicine, Modern literature and drama, Art of the twentieth century, Music and western civilisation, Communicating science: the public and the media, The Roman empire, Creative writing, Music technology, Saying true things: how science invents and persuades.

Coursework

Students spend approximately 20 hours on coursework associated with each of their compulsory and chosen subjects. MEng students undertake a group project in the summer term; alternatively they may take a five-month industrial elective. BEng students undertake an individual project from November through to the end of the summer term.

FOURTH YEAR *(ISE stream)*

Lecture courses

Students are offered a range of lecture courses, technical (ISE4.2–ISE4.54), business studies and humanities, from which to select their fourth year lecture programme. The requirements are:
six or seven technical courses and one or two management, humanities or language courses (a total of eight courses). At least one technical course must be taken from each Department.

MEng (Y) course

Full year in a European educational institution. Studies include an individual project, dissertation and technical courses.

Technical courses (each of 20 lectures, see ISE4.2 – ISE4.54)

Other non-technical courses (see Humanities syllabuses)

Business studies courses (see Tanaka Business School syllabuses)

Accounting, Entrepreneurship, Finance and financial management, Innovation management, Project management.

Humanities courses (see Humanities Programme syllabuses)

French, German, Italian, Japanese, Mandarin (with option for Cantonese speakers), Spanish, Russian, Philosophy, Ethics in science and technology, European history 1870–1989, Politics, Science and technology in western civilisation, Global history of twentieth-century things, History of medicine, Modern literature and drama, Art of the twentieth century, Music and western civilisation, Communicating science: the public and the media, The Roman empire, Creative writing, Music technology, Saying true things: how science invents and persuades, Humanities essay.

Coursework

A number of the courses have coursework associated with them. Students also undertake an individual project from November through to the end of the summer term.

ISE3.1 Human-computer interaction

DR J.V. PITT
HCI: motivation, requirements, Norman's stages of action. Evaluation: criteria, products, processes. Physical interactions: input/output devices, environment, workspace/workplace design. Dialogues: dialogue styles, menus, icons, windows, forms, command language, natural language, direct manipulation, user agents. Design: user-centred and participatory design, design rationale and prototyping, design methodology (task, dialogue and screen design), design standards and guidelines. Information: visualization presentation and representation, extreme interfaces affective computing.

ISE3.2 Databases

DR F. SADRI, DR K. AMIRI
Introduction to databases, including data modelling, database management, data dictionary, query formulation and evaluation.
Relational databases: design, functional dependencies, normalisation up to and including the fourth normal form, losslessness, dependency preservation.
Relational database languages, including relational algebra and relational tuple calculus. Views and database integrity.
Transaction management and recovery: transaction atomicity, database log, commit and rollback, recovery from system and media failure, deferred and immediate database modifications, checkpoints.
Concurrency: including conflict serialisability, conflict equivalence, precedence graphs, serialisability, locking, two phase locking protocol, deadlock.
Entity-relationship modelling and translation to the relational model.
The course will be supported by laboratory sessions using the relational database system, Ingres, and the language SQL.

ISE3.3 Communication systems

DR A. MANIKAS
Communication sources and channels: modelling of communication sources and communication channels, measures of information, Gaussian sources and channels, etc.
Performance criteria and limits of communication systems: introductory concepts, energy utilisation efficiency (EUE), bandwidth utilisation efficiency (BUE), bandwidth expansion factor, signal-to-noise power ratio (SNR), probability of error. Shannon's threshold capacity curve, theoretical limits on performance of digital communication systems and the concept of an ideal communication system. The (Pe/SNR, EUE, BUE) parameter planes. Representations of the major communication systems on the parameter planes. Comments, comparisons and discussions.
Digital transmission of analogue signals: a brief review of sampling theory and quantisation (uniform, ideal and natural sampling, practical problems, uniform quantisers), maximum-SNR-non-uniform quantisers. A-law and μ-law compaders, differential quantisers, basic concepts of differential PCM.
Principles of source and channel coding: source encoder-decoder (the prefix of a binary sequence, prefix

code, kraft inequality, defining an optimum code, Shannon's first coding theorem, etc.) Channel capacity. Error control coding (Shannon's second coding theorem, linear block codes, convolutional codes). Interleaving-deinterleaving. Line codes and digital modems.
Principles of multiplexing and public switched telephone networks: using concepts and analytical tools presented in the previous topics, the examination of multiplexing and PSTN will be presented, based on the CCITT recommendations for PCM and the associated digital hierarchy.
Principles of ADSL/VDSL.
Mobile communication systems: a compact review of a mobile radio network and a detailed description/analysis of the Pan-European cellular communication system. The analysis will be based on European telecommunication standards.

ISE3.4 Custom computing

MR W. LUK, DR O. MENCER
Overview: motivations; features and examples of custom computers, summary of development methods and tools. Design: parameterised description of leaf components and composite structures; resource and performance characterisation; high-level design tools. Optimisation: techniques for improving design efficiency such as pipelining, serialisation, transposition and their combinations. Realisation: bit-level designs, data refinement, FPGA-based implementations. System-on-chip architectures, technology trade offs, design and optimization methods. Examples will be selected from a number of application areas including digital signal processing, computer architecture and non-numerical operations.

ISE3.5 VHDL and logic synthesis

DR T.J.W. CLARKE
VHDL—modelling of hardware: model of behaviour, time and structure. Major VHDL constructs: entity declarations, architecture bodies, subprograms, packages and 'use' clauses. Basic VHDL data types: literals, scalars, vectors. Behavioural description: processes, activation and suspension of processes, sequential assignments, signal assignments, variable assignments, sequential control, procedure and function calls, concurrent statements. Structural description: parts, component instantiation, configuration specifications, busses. Access types: files, file I/O.
Testing and verification—VHDL testbenches. Procedural abstraction. Exhaustive, random, *ad-hoc* testing methods. Test coverage metrics.
Synthesis—Multi-level logic minimisation techniques: boolean optimisation. Critical path optimisation. High level synthesis: state minimisation in FSM. Technology mapping: gate arrays, FPGA, PLDs.

ISE3.7 Mathematics for signals and systems

DR G. WEISS
Vector spaces, independence, dimension, sequence spaces, analytic functions, normed spaces, inner products, Hilbert and Banach spaces, Weierstrass theorem, completion, L^p spaces, essential supremum, H^p spaces on various domains, boundary traces of H^p functions, span, orthogonal complement, closure, orthonormal basis, Fourier series, bounded linear operators, their norm, orthogonal projectors, isometric and unitary operators, Z- and Laplace transforms, convolution, Paley-Wiener theorem (discrete-time and continuous-time versions), shift operators, time-invariant operators, Foures-Segal theorem (discrete-time and continuous-time versions), linear systems, transfer functions, band-limited functions, sampling theorem.

ISE3.8 Software engineering methods

DR M. HUTH
The course features state-of-the-art methods in software engineering practices from a managerial, technical and ethical perspective. First we present prominent and well proven agile and iterative development techniques, focusing on management and some programming aspects: we discuss the methods Scrum, Extreme Programming, the Unified Process, and Evolutionary Project Management and explore the history and utility of these methods.
On the more technical side as explore what solutions are currently available that aid implementors in achieving quality assurance of their code. We mostly study an approach of annotating source code with

integrity constraints (object invariance, pre- and post-conditions etc) and survey some of the freeware tool support that is available at present. If time permits, we will give a brief introduction to the CASE tool Rational Rose.
On the purely professional side, we identify some professional issues that may not have managerial or technical solutions. Notably we ask which problems have an ethical dimension and try to identify what an 'ethical dimension' is. We offer some exploration tools that help in recognizing and assessing ethical dilemmas and we apply these tools to some case studies.

ISE3.9 Control engineering

PROFESSOR R.B. VINTER
Nyquist plots and robust stability, classical frequency domain approaches to controller design; state space modelling; pole placement via state feedback and dynamic output feedback; observer design: controllability and observability; linear quadratic optimal control; non-linear systems analysis (describing function); and discretisation computer control.

ISE3.11 Digital signal processing

DR P.A. NAYLOR
Sampling theory, z-transforms, system functions. Digital filter structures, signal flow graphs, elementary FIR/IIR filter design techniques, windows, bilinear and band transformations. Discrete Fourier transform, relationship between DFT and DTFT, simple and short-time spectral estimation, fast computation of DFT as decimation-in-time. Linear convolution, cyclic convolution, sectioned convolution (overlap-add and overlap-save), application to fast filtering algorithms, windowing. Basic multirate elements and identities, design of sample rate changing systems, polyphase representation of filters, maximally decimated filter banks, polyphase representation of maximally decimated filter banks, typical applications. Overview of microprocessor architectures for DSP, implementational aspects of simple DSP algorithms.

ISE3.12 Multimedia systems

DR O. MENCER, DR S.M. RUEGER
Design of multimedia systems: software architecture, hardware architecture, managing multimedia projects The underlying technologies: the physics of images and sounds, their capture into the computer system. Music notation and representation in the computer. Compression of images and sounds—Fourier frequency band quantisation, discrete cosine transform. Fractal image compression, JPEG and MPEG-2 standards. The bandwidth of communication systems and associated processing power required to handle multimedia data.
Standards underlying multimedia processing: CD-i, CD-ROM, photo-CD, MIDI standards. H.261 standard for video telephony. Multimedia data transmission over ISDN links. Asymmetric home-video distribution over ADSL links.
Advanced multimedia applications and underlying technology: virtual reality, distributed interactive navigation systems; speech, image and gesture recognition algorithms; principles of video databases. Wireless technology. Development of media, impact on society.
Preparation of multimedia material. Transmission of multimedia material over advanced networks.

ISE3.14 Distributed systems

PROFESSOR M.S. SLOMAN
Overview of distributed system architecture: motivation, system structures, architecture, ODP. Reference model and distribution transparencies, design issues.
Interaction primitives: message passing, remote procedure call, remote object invocation.
Software structures and components: composite components, Darwin architecture description language, first and third party binding.
Interaction implementation: message passing, RPC, concurrency and threads, heterogeneity of systems and languages.
Security: threat analysis, security policies—military (Bell Lapadula) versus commercial models; access control concepts—identification, authentication, authorisation and delegation; authorisation policy: access matrix, access rules and domains; firewalls; access control lists, capabilities, secret and public

key encryption, digital signatures, authentication, Kerberos, security management.
Distributed systems management: SNMP and OSI management models, monitoring and event generation, domains and policy.

ISE3.16 Graphics

DR D. GILLIES, DR D. RUECKERT
Device independent graphics: raster and vector devices, normalised device coordinates, world coordinates, the normalisation transformation, output primitives input primitives. Raster graphics algorithms: line drawing; differential algorithms filling; seed filling dithering. Planar polyhedra: three-dimensional database representation, projection to viewing surface. Transformation of graphical scenes; homogenous coordinates, affine transformations, scaling, rotation, translation. Affine transformations and homogenous coordinates using projection. Clipping and containment in three-dimensional convex objects, splitting concave objects. Texture mapping and anti-aliasing. Shading planar polygons; Gouraud shading, Phong shading. Using colours: tri-stimulus model, RGB model, YCM model, perceptual colour spaces. Polygon rendering and open GL. Ray tracing: ray/object intersection calculations; secondary rays, shadows, reflection and refraction, computational efficiency, object space coherence, ray space coherence. Ray tracing and computational space geometry. Radiosity: modelling ambient light; form factors; specular effects; shooting patches; computational efficiency. Geometric warping. Morphing objects. Special visual effects: motion, blur, lens models, caustics, fog, particle systems, fire, smoke and water.

ISE3.17 Advanced signal processing

DR D.P. MANDIC
Discrete random signals; statistical stationarity, strict sense and wide sense. Averages; mean, correlations and covariances. Bias. variance dilemma. Curse of dimensionality. Linear stochastic models. ARMA modelling. Stability of linear stochastic models. Introduction to statistical estimation theory. Properties of estimators; bias and variance. Role of Cramer-Rao lower bound. Minimum variance unbiased estimator. Best linear unbiased estimator (BLUE) and maximum likelihood estimation. Maximum likelihood estimator. Bayesian estimator. Least square estimation: orthogonality principle, block and sequential forms. Wiener filtering, adaptive filtering and signal modelling. Simple non-linear adaptive filtering. Concept of an artificial neuron. Applications: acoustic echo cancellation and signal enhancement, inverse system modelling and denoising.

ISE3.18 Simulation and modelling

DR A.J. FIELD
Introduction and basic simulation procedures.
Model classification (with worked examples for each): Monte Carlo simulation, discrete-event simulation, continuous system simulation, mixed continuous/discrete-event simulation.
Queueing networks: analytical and simulation modelling of queueing systems.
Input and output analysis: random numbers, generating and analysing random numbers, sample generation, trace- and execution-driven simulation, point and interval estimation.
Process-oriented and parallel simulation.

ISE3.19 Digital system design

PROFESSOR P.Y.K. CHEUNG
Case study: definition of the digital system to be used as demonstrator; linked finite state machines; FSM implementation issues; race, hazards and metastability; dynamic memory interface; special memory devices; multiplier circuits; bit-serial arithmetic circuits; data coding circuits; design for testability; programmable logic, FPGAs and CPLDs; system level interfacing.

ISE3.22 Operations research

PROFESSOR B. RUSTEM, DR P. PARPAS
To introduce optimal decision-making processes in design and management. To give the necessary mathematical background and its application to solving a selection of constrained optimisation problems with special reference to computation.

Preview: optimal policy in design and management: mathematical models.
Linear programming: the Simplex method, two-phase Simplex method, duality, shadow prices.
Linear integer programming: Gomory's cutting plane methods for pure and mixed linear integer programming.
Search methods; branch and bound algorithms.
Game theory; two-person non-cooperative games. Saddle points. Matrix games.

ISE3.23 Artificial intelligence

DR J.V. PITT
Search: search space, problem formulation, generic graph search algorithm; graph theory; uninformed search strategies—depth first, breadth first, uniform cost, iterative deepening; informed search strategies—best first, A*, interative deepening A*; analysis of algorithms—completeness, complexity, optimality, minimax, alpha-beta search; reinforcement learning and potential fields for path planning. Knowledge representation and reasoning: knowledge acquisition, knowledge engineering; propositional logic—semantic proof, syntactic proof, soundness and completeness of proof systems; automated reasoning with KE; predictate calculus and expert systems; modal logic and practical reasoning. Distributed AI: agents, agency and multi-agent systems; BDI agents.

ISE3.26 Advanced computer architecture

DR P.H.J. KELLY
Performance: measuring and reporting computer systems performance. Amdahl's Law.
Pipelined CPU architecture. Instruction set design and pipeline structure.
Dynamic scheduling using scoreboarding and Tomasulo's algorithm. Software instruction scheduling and software piping. Superscalar and long-instruction-word architectures. Branch prediction and speculative execution.
Caches: associativity, allocation and replacement policies, sub-block placement. Multilevel caches, multilevel inclusion. Cache performance issues. Uniprocessor cache coherency issues: self-modifying code, peripherals, address translation.
Vectorising compliers and their capabilities; applications to parallelisation and memory hierarchy optimisation.
Interconnection networks: topology, routing, flow control, deadlock avoidance. The k-ary n-cube family of topologies. Virtual channels, wormhole routing and virtual cut-through.
Implementations of shared memory: the cache coherency problem. Update vs invalidation. The bus-based 'snooping' protocol design space. Scalable shared memory using directory-based cache coherency. Alternative approaches.

ISE3.27 Concurrent and distributed programming

PROFESSOR J. KRAMER
To study the concepts, formal models and implementation techniques appropriate for design, analysis and construction of concurrent and, to a lesser extent, distributed programmes.
Students will perform a laboratory exercise involving concurrent programming using Java.
Key ideas: interleaved actions, synchronisation, interference, deadlock, starvation, fairness, safety and liveness.
Monitors: entry queues, condition variables, wait and notify, reasoning about monitors.
Models: introduction to fomalisms for the specification and verification of concurrent systems; labelled transition system, process calculus, model checking.
Model based design: structuring applications into concurrent, distributable software components; component types and instances; nesting and component composition; component interfaces.
Message passing: processes, synchronous and asynchronous communication, ports, send and receive, request-reply communication.

ISE3.30 Computational finance

DR N. GULPINDAR
The course will discuss computational aspects of financial engineering. This includes computational models, algorithms and software design.
Option pricing: binomial tree and lattice models. Stock price process. Ito's lemma and the Black-Scholes differential equation. Risk neutral valuation. Recursion and dynamic programming. Finite difference method. Monte Carlo simulation. Interest rate derivatives.
Portfolio optimisation: mean-variance optimisation. Multi-stage stochastic programming. Network models. Hedhing options via stochastic optimisation.
Software tools and developments in finance: deriving symbolic computation for options modelling. Symbolic computing for stochastic partial differential equations in finance. Deriving parallel code from symbolic models

ISE3.31 Communication networks

DR J.A. BARRIA
Introduction to layered approach to the analysis of communication networks. Study and analysis of different communication networks, their architectures and associated protocols: local area network (LAN), metropolitan area network (MAN), wide area networks (WAN) and internet. Design of data and packet switched networks, topological issues, routing strategies and congestion control. TCP/IP internet protocols. B-ISDN protocol reference model, multimedia traffic characterisation and performance analysis. Optimal routing problem.

ISE3.33 Real-time digital signal processing

DR D. WARD
C6x architecture; data conversion; software tools; I/O and interrupts; fixed point vs floating point; FIR filters; IIR filters; frame processing; speech enhancement project.
Laboratory work: getting started with C6x; data conversion; learning C and Sinewave generation; Interrupt I/O free; FIR filter implementation; IIR filter implementation; real-time spectral analysis. Project.

ISE3.36 Introduction to bioinformatics

DR S. COLTON, DR M GHANEM
Motivation from biology; scale of information being gathered; human genome project; drug design; potential of bioinformatics. Biological background: DNA; genes; protein structure, classification and prediction; expression concepts, drug design. Protein sequences: online databases, dot-plots; scoring schemes; BLAST algorithm; dynamic programming algorithm; structural inferences; profiles; PSI-BLAST; HMMS. Machine learning approaches: methodology; applications. Inductive logic programming: neural networks; HMMs. Drug design: data mining; HT methods; analysis of gene, protein and metabolyte expressions.

ISE3.38 Decision analysis

DR F. KRIWACZEK
Decision analysis: main elements involved in decision-making, decision-making under certainty, risk and uncertainty, decision trees and influence diagrams, value of information, venture analysis, expected monetary value criterion, Bayes' theorem. Utility: utility functions, risk aversion, standard lotteries, constructing an individual's utility function, utility axioms, risk tolerance, utility functions for non-monetary attributes. Decisions involving multiple criteria: SMART technique, value trees, direct rating and value functions, swing weights, mutual preference, independence, efficient frontier, sensitivity analysis. Risk and multi-attribute utilities: mutually utility independence, multi-attribute utility functions, performing consistency checks and sensitivity analysis. Dynamic programming: characteristics of dynamic programming problems; policy decisions, stages, principle of optimality, uncertain payoffs, uncertain states stochastic dynamic programs. Markov decision processes: Markov processes, transition probabilities, Markov chains, finite-stage Markov decision problems, infinite-stage Markov decision problems.

ISE4.2 Computer vision

DR G.Z. YANG
To introduce the concepts behind computer-based recognition and extraction of features from raster images. To illustrate some successful applications of vision systems and their limitations
Overview of early, intermediate and high level vision: first and second moments of illumination for recognition and classification of machine shop components in silhouette.
Segmentation: region splitting and merging; quadtree structures for segmentation; mean and variance pyramids; computing the first and second derivatives of images using the isotropic, Sobel and Laplacian operators; grouping edge points into straight lines by means of the Hough transform; limitations of the Hough transform; parameterisation of conic sections.
Perceptual grouping: failure of the Hough transform; perceptual criteria; improved Hough transform with perceptual features; grouping line segments into curves.
Overview of mammalian vision: experimental results of Hubel and Weisel; analogy to edge point detection and Hough transform; neural networks based on the mammalian vision system.
Relaxation labelling of images: detection of image features; simulated annealing.
Grouping of contours and straight lines into higher order features such as vertices and facets.
Depth measurement in images; triangulation; projected grid methods; shape from shading based on multi-source illumination.
Matching of images: the correspondence problem for stereo vision; two-camera and multiple-camera systems; shape from motion as a further stage of stereo vision; optical flow between adjacent video frames.
Expert system modelling in computer vision: model based vision using inference engines and rules.

ISE4.3 Mobile radio communication

DR M.K. GURCAN
Transmission path: VHF and UHF propagation; propagation losses; inverse fourth power propagation; Rayleigh fading, shadowing losses. Coverage probability; outage and coverage probabilities, error performance analysis for transmission systems; quality factor and re-use distance calculations.
Transmission schemes: wideband channels and wideband transmission; equalisation and multiplexing; multiple access scheme. Area coverage, analogue and digital transmission systems.

ISE4.4 Advanced databases

DR K. AMIRI, DR P MCBRIEN
Database management system architecture: main components of a DBMS, buffers, caches, and optimisation high level query languages and low level primitive operations.
Concurrency control and recovery: ACID properties of transactions, recoverability, serialisability. Transaction histories as a method for analyzing database execution. Two-phase locking (2PL) ANSI SQL concurrency control levels.
Query optimisation.
Distributed databases(DDB): a general distributed database architecture. Fragmentation: horizontal, vertical, hybrid. Replication. Top-up design of DDB: the allocation problem. Bottom-down design of DDB: the schema integration problem. Tasks in schema integration and strategies to follow. Reverse engineering relational database schemas. Schema integration transformations. Concurrency control in DDB. Replication of locks. Distributed deadlock detection. Atomic commitment of transactions.
Building advanced (distributed) database applications. Distributed query processing and optimisation. Programmer's interface. Data migration: data warehousing. OLAP XML and relational databases. Alternatives to the relational database model. Object-oriented databases. Object-relational databases.

ISE4.7 Digital signal processing and digital filters

DR P.T. STATHAKI
Finite and infinite impulse response digital filter design techniques, interpolation and decimation, halfband filters and spectral analysis, spectral transformations, circular convolutions, discrete Fourier transforms and computational complexity, the fast Fourier transform and prime radix algorithms, number theoretic transforms, sectioned convolution applications to speech signal analysis, image processing , television signal processing, limit-cycle performance, reduced sensitivity structures including wave digital filters and linear transformation techniques, lattice structures and half-band filter realisation

ISE4.8 Multi-agent systems

PROFESSOR K.L. CLARK

General introduction to the concept of a software agent and a computation embedded in an environment, achieving one or more goals, taking into account changes in the environment. Introduction to a multi-threaded logic programming language to be used on the course (Qu-Prolog or Go!). Distributed problem solving and the contract net protocol. Implementation of the contract net. Agents with mental state: agent0 and BDI agents; implementing and generalising agent0. Agent communication languages: KQML and FIPA ACL and matchmakers. Issues concerning the semantics of ACLs. Implementing a matchmaker agent. Mobile agents: agent stations as places for agents to visit and security issues. Implementation of a mobile agent. Infrastructure and a mobile information gathering agent.

ISE4.9 Advanced data communications

DR M. GURCAN

Data transmission systems; elements of the system, the source, shaping filters and modulation systems and techniques. Equalisation, convolution codes, maximum likelihood detection and MAP algorithm and coded modulation schemes. Turn codes and ADSL systems.

ISE4.10 Parallel algorithms

PROFESSOR P.G. HARRISON, DR W. KNOTTENBETT

Introduction and motivation: key concepts, performance metrics, scalability and overheads.
Classification of algorithms, architectures and applications: searching, divide and conquer, data parallel. Static and dynamic, message passing and shared memory, systolic.
Sorting and searching algorithms: mergesort, quicksort and bitonic sort, implementation on different architectures. Parallel depth-first and breadth-first search techniques.
Matrix algorithms: striping and partitioning, matrix multiplication, linear equations, eigenvalues, dense and sparse techniques, finite element and conjugate gradient methods.
Optimisation: graph problems, shortest path and spanning trees. Dynamic programming, knapsack problems, scheduling. Element methods.
Synthesis of parallel algorithms: algebraic methods, pipelines, honomorphisms.

ISE4.11 Advanced communication theory

DR A. MANIKAS

Introductory concepts: modelling of information sources, communication channels and sinks.
Definitions of priori and posterior probabilities in relation to the model of a communication channel. MAP criterion, likelihood functions and likelihood ratio. An initial study on the performance of a digital communication system and expansion to a spread spectrum system. Optimum detection theory: detection criteria. Receiver operating characteristics (ROC). Detection of known signals in the presence of white noise and the concept of an optimum receiver. Matched filter receivers and their mathematical analysis. Extension to non-white noise. Orthogonal signals and the 'approximation theorem'. M-ary signals and signal constellation. Basic concepts and analysis of orthogonal and biorthogonal M-ary communication systems. 64-ary Walsh-Hadamard signal set. PN-sequences: Galois field GF(2) basic theory, shift registers, basic properties of m sequences, statistical properties of m-sequences, Gold sequences. PN-signals: Modelling, cross/auto correlation functions and power spectral density, partial correlation properties. Spread spectrum systems (SSS): basic concepts and parameters. Classification and modelling of jammers. Modelling of BPSK and QPSK Direct Sequence SSS in a jamming environment, estimation of SNIR and bit-error-probability. Direct sequence SSS on the (SNR/pe, EUE, BUE) parameter plane. Frequency hopping SSS. Principles of CDMA system: investigation of important system components with special attention given to RAKE receiver. Modelling and analysis with emphasis given on capacity issues. An overview of the TIA/ISA IS-95 CDMA standards. Wideband CDMA (3G). Space-time communications: definitions, notation, spaces and projection operators. Modelling an array received signal-vector and the concept of the array manifold. Multi-dimensinal correlators. Estimation of signal parameters including directions of arrival powers, cross-correlations, etc. Array pattern and beamformers. Vector-channel effects (including multipaths, angular spread, Doppler spread and fading). Outage probability. Integrated array CDMA systems. Single user and multi-user array CDMA receivers.

ISE4.15 Coding theory

DR A.A. IVANOV (DEPARTMENT OF MATHEMATICS)
Elementary ideas of redundancy. Fundamental problems in coding theory and practice. Distance measures. Bounds to the performance of codes. Important linear codes. Construction and properties of finite fields. Cyclic codes, BCH and Reed Solomon codes. Error correction for BCH and RS codes.

ISE4.16 Software engineering environments

MS S. EISENBACH, DR M. HUTH
Software Process Development Techniques: We present current methods for developing systems such as Aspect Oriented Programming, Extreme Programming, use of Open Source Software, and Agile Programming methodologies. The emphasis is on developing the ability to choose the most suitable methodology for each task and to be able to evaluate new methodologies as they become popular.
Maintenance: Software maintenance is the modification of a software product after delivery to correct faults, to improve performance or other attributes, or to adapt the product to a changed environment. We look at a collection of software maintenance problems associated with old and new code (Fortran and Java) and at reverse engineering techniques for code improvement.
Quality Assurance: What solutions are currently available that aid implementors in achieving quality assurance of their code.? We mostly study an approach of annotating source code with integrity constraints (object invariance, pre- and post-conditions etc) and survey some of the freeware tool support that is available at present. If time permits, we will give a brief introduction to the CASE tool Rational Rose.

ISE4.17 Speech processing

DR P.A. NAYLOR
The human vocal and auditory systems. Characteristics of speech signals: phonemes, prosody, IPA notation. Lossless tube model of speech production. Time and frequency domain representations of speech; window characteristics and time/frequency resolution tradeoffs. Properties of digital filters: mean log response, resonance gain and bandwidth relations, bandwidth expansion transformation, allpass filter characteristics. Autocorrelation and covariance linear prediction of speech; optimality criteria in time and frequency domains; alternate LPC parameterisation. Speech coding: PCM, ADPCM, CELP. Speech synthesis: language processing, prosody, diphone and formant synthesis; time domain pitch and speech modification. Speech recognition: hidden Markov models and associated recognition and training algorithms. Dynamic programming. Language modelling. Large vocabulary recognition. Acoustic preprocessing for speech recognition.

ISE4.19 Introduction to digital integrated circuit design

PROFESSOR P.Y.K. CHEUNG
This course in integrated circuit design covers the complete range of digital integrated circuit design from concept to implementation on silicon. A significant part of the course is taken up by a group design project in which students design an integrated circuit on advanced graphics workstations. This course provides good grounding for any students wishing to work in the IC design industry. The main topics covered include: design methodology; behavioural, logic and circuit simulation; floorplanning; geometric layout; circuit structures and techniques; testing and design for test, etc.

ISE4.20 Computing for optimal decisions

PROFESSOR B. RUSTEM
To provide mathematical concepts and advanced computational methods for quantitative problems in management decision making. To introduce unconstrained and constrained optimal decision formulations and associated optimality conditions. To discuss quadratic and general non-linear programming formulations and algorithms.
Introduction to optimisation and optimal decisions. Unconstrained optimisation. Constrained optimisation. Management decision formulations. Optimality conditions for constrained problems. Necessary conditions, sufficient conditions. Quadratic programming: problem formalisation; portfolio selection.

Optimality conditions. Algorithms for quadratic programming. Non-linear programming: example formulations; capacity expansion, inventory control. Problem formulation. Algorithms for non-linear programming.

ISE4.21 Discrete-time systems and computer control

DR J.C. ALLWRIGHT
Aspects of digital signal processing relevant to modelling and the implementation of digital controllers are studied using the Z, Delta, W and discrete-time Fourier transforms. Discrete-time control systems are analysed and synthesised using root-locus, Nyquist and state-space techniques, bearing in mind the necessity for bounded-input bounded-output stability, small tracking error and robustness.

ISE4.23 Design of linear multivariable control systems

DR I.M. JAIMOUKHA
Analysis: system representations, return difference matrix, stability theory, multivariable poles and zeros. Design: design criteria, dominance based approaches, LQG design methods, norm-based methods, robust stability and performance. H-infinity design techniques. Model reduction. Design examples: use of CAD techniques in the design of controllers for industrial processes.

ISE4.27 Stability and control of non-linear systems

DR J.C. ALLWRIGHT
For non-linear systems, methods for determining stability and for designing stabilising controllers are studied using state-space (Lyapunov theory, variable structure analysis), function space (small gain theorem, passivity) and frequency-domain (Popov and circle criteria, describing function) methods. Model reference adaptive control is treated using the passivity concept.

ISE4.31 Spectral estimation and adaptive signal processing

DR D. MANDIC
Aspects of estimation theory: bias, variance, maximum likelihood and efficiency. Resolution and stability; time-bandwidth product. Classical spectral estimation: periodogram, averaging and Blackman-Tukey method. Parametric models: linear, rational transfer function, and non-linear models. Order selection. Block and sequential parameter estimation techniques. Levison, lattice, Cholesky factorisation, steepest descent, least mean square and recursive least squares adaptive algorithm families. Kalman filters. Blind equalisation and source separation. Non linear adaptive filters and temporal neural networks. Time-frequency and time-scale methods. Spectral redundancy and cyclostationarity. Case studies.

ISE4.33 Digital image processing

DR P.T. STATHAKI
Image transforms: definition and properties of one-dimensional and two-dimensional unitary transforms. Fourier transform. Discrete cosine transform. Walsh transform. Hadamard transform. Karhunen-Loeve transform. Image enhancement: enhancement by point processing. Spatial filtering. Enhancement in the frequency domain. Image restoration: description of the degradation model. Deterministic techniques for image restoration (direct-inverse filtering, constrained least squares (CLS), iterative, recursive), stochastic techniques for image restoration (direct-Wiener filtering, iterative-iterative Wiener filtering). Image coding: scalar quantisation. Vector quantisation. Codebook design. Codeword assignment. Transform image coding. Image model coding. Fractal coding. Coding standards (MPEG, JPEG).

ISE 4.36 Optical communications

DR E. YEATMAN
Fundamentals of communicating with light. Guided electro-magnetic waves: the slab waveguide, modes, dispersion. Modes and attenuation in fibres. Properties of LEDs and lasers as communication sources. Photodiodes and receiver circuits, sensitivity, noise and bandwidth. Modulation techniques, coherent communication. Time-division and wavelength division multiplexing. Optical amplifiers, non-linear effects. System architectures and applications. Free space systems. Signal processing, routing and timing.

ISE4.37 Advanced operations research

DR I. MAROS
(i) Characteristics of large scale real-life decision problems. Typical models of industry, trade and finance. The need for optimisation.
(ii) Advanced linear programming (LP): need for linear model. The sparse simplex method; primal and dual algorithms; computational implications. Interior point algorithms. State-of-the-art in solving LP problems.
(iii) Integer programming (IP): situations requiring integer valued models. IP problem formulation. Logic constraints and IP. Constraint classification. Connection to planning and scheduling. Solution methods; implicit enumeration, branch and bound (B&B) method. State-of-the-art in solving IP problems.
(iv) Network optimisation. Minimal cost network flows, capacitated transportation. Network problem assignment, maximum flow and shortest path problems.
(v) Modelling: basics of modelling. Modelling methodology. Model generation and management. Modelling languages, modelling systems.

ISE4.40 Advances in artificial intelligence

DR F. TONI
Planning: partial order planning; STRIPS, situation calculus and event calculus. Practical planning; hierachical decomposition, regression planners. Graphplan. Planning in dynamic enviornments: incomplete information, conditional planning, replanning, integrating planning and execution.
Neural networks: perceptrons, multi-layer networks, back propagation, recurrent networks, learning and generalisation, hybrid systems.
Learning: learning functions: decision trees, reinforcement learning, learning sets of rules; explanation based learning, inductive logic programming.
Assumption-based reasoning: Theorist. Assumption-based truth maintenance systems. Abductive logic programming.
Agents: general introduction to the concept of an agent interacting and embedded in an environment which it senses using a set of fixed percepts and tries to modify using a repertoire of fixed actions. Types of agents—tropistic, hysterectic, goal orientated, plan generating. Example tropistic agents, example hysterectic agents with finite internal state. Rule-based and finite state automata agent programs.

ISE4.41 System identification

DR G. WEISS
Dynamical systems and their mathematical models, random variables and signals, spectral and correlation analysis. Guiding principles behind least-squares parameter estimation, statistical properties of estimates. Identification of the transfer function of linear systems in continuous time. Models for discrete-time linear systems: these include FIR, AR, ARX, ARMA and state-space models. Various methods for recursive estimation. Experiments for data acquisition and their design. The course will have a theoretical flavour and will contain a number of case studies.

ISE4.43 Synthesis of digital architectures

DR G.A. CONSTANTINIDIES
Introduction to the fundamental architectural synthesis problems: scheduling, allocation, binding, and control synthesis. Introduction to graph theory and combinatorial optimisation. Scheduling algorithms: as-soon-as-possible and as-late-as-possible, list scheduling, integer linear programming. Resource sharing algorithms: interval graphs, graph colouring, integer linear program models; register sharing.

ISE4.45 Network security

DR P. BEEVOR
Requirements for network security: examples of types of network attach; passive and active, communication channel and network management, traffic related. Protection by encryption and

authentication. Digital signatures. Management controls. Importance of trusted parties in system management. Overhead, cost and other management aspects.
Algorithms and standards: private key systems and DES. Public key systems and PSA. Analysis of strength of protection. Weak keys. Attack by exhaustive search. Calculation of required key length. Types of analytic attack. Relationship with information and coding theory.
Key management: Diffie-Hellman key exchange. RSA key management. Public key certificates. Overall system management and management controls.
Systems for network security: VPN security. Wireless (including wireless LANs) security. LAN security. Internet security and the IPSEc protocol.

ISE4.46 Advanced graphics and visualisation

DR E. EDWARDS, DR D. RUECKERT
Principles of visualisation: fundamentals and concepts, scalar, vector and tensor data. Principles of visualisation: scalar, vector and tensor data, applications such as flow visualisation. Volume rendering: image-order rendering; object-order rendering; scalar and ray transfer functions; isosurface generation; marching cubles algorithm. Surface reconstruction: surface decimation; surface smoothing; surface normal generation; surface triangulation; Voronoi diagrams; Delaunay triangulation. Spline curves: parametric and non-parametric splines; cubic spline patches; Bezier curves; B-spline formulation. Surface modelling: coons patches; bi-cubic surfaces; B spline surfaces; NURBS; rendering spline surfaces. Implicit surface models, soft objects. Image-based rendering and lightfields. Virtual reality: stereo perception; stereo display; head-mounted displays; autostereoscoptic displays; holographic displays; haptic and tactile force feedback; virtual worlds; collision detection for VR. Augmented reality: definitions and examples, augmented real calibration and tracking. Simulation training in medicine. Prerequisite: ISE3.16

ISE4.47 Wavelets and applications

DR P.L. DRAGOTTI
Introduction and background: motivation: why wavelets, sub-band coding and multi-resolution analysis? Mathematical background. Hilbert spaces. Unitary operators. Review of Fourier theory. Continuous and discrete time signal processing. Time-frequency analysis. Multi-rate signal processing. Projections and approximations.
Discrete-time bases and filter banks: elementary filter banks. Analysis and design of filter banks. Spectral factorisation. Daubechies filters. Orthogonal and biorthogonal filter banks. Tree-structured filter banks. Discrete wavelet transform. Multi-dimensional filter banks.
Continuous-time bases and wavelets: interated filter banks. The Haar and Sinc cases. The limit of iterated filter banks. Wavelets from filters. Construction of compactly supported wavelet bases. Regularity. Approximation of properties. Localisation. The ideal of multi-resolution. Multiresolution analysis. Haar as basis for L2(R). The continuous wavelet and short-time Fourier transform.
Applications: fundamentals of compression. Analysis and design of transform coding systems. Image compression, the new compression standard (JPEG 2000) and the old standard. Why is the wavelet transform better than the discrete cosine transform? Video compression and the three-dimensional wavelet transform.

ISE4.48 Intelligent data and probabilistic inference

DR D.F. GILLIES
The course is concerned with probabilistic methods for modelling data and making inferences from it. The first part of the course introduces Bayesian Inference and Networks and includes probability propagation and inference in singly connected networks, generating networks from data, and calculating the network accuracy. The course then goes on to consider highly dependent data and special techniques for exact and approximate inference in these networks. The next topic to be covered is data modelling using distributions and mixture models. The topic of sampling and re-sampling is covered along with data reduction by principal component analysis and special problems that occur with small sample sizes. The last part of the course is concerned with classification using Linear Discriminant analysis and Support Vectors.

The emphasis of the course is algorithmic rather than mathematical, and the coursework is a practical programming exercise in analysing data from a study into the prognosis of Hepatitis C.
Note that the course does not include non-probabilistic methods of data analysis such as Neural Networks, Fuzzy Logic or expert systems.

ISE4.49 Distributed computation and networks: a performance perspective

PROFESSOR E. GELENBE
Description of distributed system architectures and their components; digital sensors and actuators, processing units, local area networks, packet networks and the IP protocol, wireless ad-hoc networks. The role of protocols.
The concept of quality of service (QoS). Performance metrics related to system load, response time and timelines of data, data loss system availability and reliability. Overall system modelling in terms of service requests and service units. Relation to a practical system architecture. System analysis in terms via experiments, probability models using analytical techniques, and simulation. Performance identities and their deterministic counterparts. Solution techniques for very large models. Separable solutions and product form networks. Solution techniques for systems with dynamic controls. G-networks. System adaptation to changing workloads and operating conditions. The practical use of learning and its derivation from analytical models. Gradient techniques, reinforcement learning and learning by imitation. Analysis of a large experimental system via theoretical models and experiments.

ISE4.50 Performance analysis

PROFESSOR P.G. HARRISON, DR S. NEWHOUSE
Motivation and survey; the need for performance prediction in optimisation and system design.
Basic probability theory: renewal processes; Markov processes; birth and death processes; the single server queue; Little's law; embedded Markov chain; M/G/1 queue; queues with priorities; queueing networks—open, closed, multi-class; equilibrium state space probabilities, proof for single class; normalising constants; computation of performance measures; convolution algorithm; mean value analysis; application to multi-access systems with thrashing.
Decomposition and aggregation: Norton's theorem; M/M/n queue; multiple independent parallel servers.

ISE4.51 Information theory

MR M. BROOKES
The statistical nature of communication. Elements of information theory of discrete systems; information measures, memoryless and memory sources, the noiseless coding theorem. Methods of source coding. Information theory of continuous systems. Shannon's capacity theorem and its interpretation. Comparison of communication systems with the ideal. Applications of information in communications and signal processing.

ISE4.52 Grid computing

PROFESSOR J. DARLINGTON
Grid computing (or the 'grid') refers to the high-level use of the emerging network of high-performance and distributed computing resources that are becoming available to today's applied science community. These computing, storage, software and networking resources are typically owned by different organisations who are willing, sometimes under stringent conditions, to share these resources with a community or virtual organisation. The federation of these resources to meet the needs of a particular community takes place through a multi-layered middleware, which may include cluster resource managers, resource schedulers and graphical problem solving environments. The goal of the middleware is to deliver a simple and usable environment to the e-scientist which allows them to transparently exploit the distributed resources that constitute the Grid for their own specific requirements.
This course introduces the architectural challenges within the grid, demonstrating how these have been solved by the current and emerging grid middleware standards.

It illustrates how the application requirements of the e-scientist are motivating the middleware development.
Practical tutorials demonstrate the benefits and limitations of current grid middleware and their services.

ISE4.53 Linear optimal control

DR A. ASTOLFI
State space models for linear control systems. Stability, controllability and observability, stabilisability and detectability. Pole assignment, full and reduced-order observers. Formulation of optimal control problems. Principle of optimality. The linear quadratic regulator problem, properties of the algebraic Riccati equation (ARE), return difference inequality, robustness properties of the optimal state feedback. The minimum principle and time optimal control problems.

ISE4.54 Complexity

DR I. PHILLIPS
The complexity classes associated with computational problems. To develop the ability to fit a particular problem into a class of related problems and so to appreciate the efficiency attainable by algorithms to solve a particular problem. Turning machines, decidability, machine independence. Time complexity: the classes P and NP, NP-completeness, example problems from logic and graphs. Space complexity classes. The parallel computation thesis: PRAMs, the class NC. Probabilistic algorithms. Connections with logic. Cryptography.
Protocols, zero-knowledge proofs.

ISE4.55 Optimisation

DR A. ASTOLFI
Topics covered include unconstrained optimisation and the associated algorithms of steepest descent and conjugate gradient, Newton methods, rates of convergence, constrained optimisation and the method of Lagrange multipliers, quadratic programming, penalty methods.

Information Systems Engineering examinations

THIRD YEAR BEng
Databases—one paper
Seven additional papers, one for each chosen option

THIRD YEAR MEng
Databases—one paper
Eight additional papers, one for each chosen option

FOURTH YEAR MEng
Eight papers, one for each chosen option