# Program overview

**22-Sep-2011 9:38**

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| **Year** | **2011/2012** |
| **Organization** | **Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen** |
| **Education** | **Master Mechanical Engineering** |

| Code | Omschrijving | ECTS | p1 \| p2 \| p3 \| p4 \| p5 |
|---|---|---|---|
| **ME Track Control Engineering (ME-CE)** | | | |
| **Obligatory Courses ME-CE** | | | |
| ME1200 | Robust and Multivariable Control Design | 6 | |
| SC4010 | Introduction Project SC | 3 | |
| SC4025 | Control Theory | 6 | |
| SC4050 | Integration Project SC | 5 | |
| SC4092 | Modeling and Nonlinear Systems Theory | 4 | |
| SC4110 | System Identification | 5 | |
| WB2305 | Digital Control | 3 | |
| **Elective Courses Mechanical Systems ME-CE** | | | |
| WB1406-07 | Experimental Dynamics | 3 | |
| WB1413-04 | Multibody Dynamics B | 4 | |
| WB1418-07 | Engineering Dynamics | 4 | |
| WB1440 | Eng. Optimization: Concept & Applications | 3 | |
| WB2303-10 | Measurement in Engineering | 3 | |
| WB2414-09 | Mechatronic System Design | 4 | |
| WB2428-03 | Mechanical Design in Mechatronics | 5 | |
| WB3404A | Vehicle Dynamics A | 3 | |
| **Elective Courses Processes ME-CE** | | | |
| SC4060 | Model Predictive Control | 4 | |
| WB1427-03 | Advanced Fluid Dynamics A | 5 | |
| WB3421-04 | Automation and Control of Transport and Production Systems | 6 | |
| WB4302 | Thermodynamic Aspects of Energy Conversion | 4 | |
| WB4422-11 | Thermal Power Plants | 6 | |
| WB4432-05 | Process Dynamics and Control | 3 | |
| **Elective Courses Automotive ME-CE** | | | |
| ME1100 | Automotive Crash Safety; Active & Passive Safety Systems | 3 | |
| SC4040 | Filtering & Identification | 6 | |
| SC4210 | Vehicle Mechatronics | 4 | |
| SC4230TU | Vehicle Dynamics B - Antilock Braking Systems | 3 | |
| WB1406-07 | Experimental Dynamics | 3 | |
| WB1413-04 | Multibody Dynamics B | 4 | |
| WB2404 | Man-machine systems | 4 | |
| WB3404A | Vehicle Dynamics A | 3 | |
| **Elective Courses Fundamentals ME-CE** | | | |
| SC4040 | Filtering & Identification | 6 | |
| SC4060 | Model Predictive Control | 4 | |
| SC4081-10 | Knowledge Based Control Systems | 4 | |
| *SC4081-10 D1* | *Knowledge Based Control Systems, Exam* | *3* | |
| *SC4081-10 D2* | *Knowledge Based Control Systems, Literature* | *0,5* | |
| *SC4081-10 D3* | *Knowledge Based Control Systems, Matlab* | *0,5* | |
| SC4091 | Optimization in Systems and Control | 4 | |
| SC4120 | Special Topics in Signals, Systems & Control | 3 | |
| SC4150 | Fuzzy Logic and Engineering Applications | 3 | |
| SC4160 | Modeling and Control of Hybrid Systems | 3 | |
| SC4240TU | Control Methods for Robotics | 3 | |
| SC4250 | Probabilistic Models in the Life Sciences | 2 | |
| WI4218 | Convex Optimization and Systems Theory | 6 | |
| WI4221 | Control of Discrete-Time Stochastic Systems | 6 | |
| **Master year 2** | | | |
| ME2200-15 | Traineeship (optional) | 15 | |
| ME2210-15 | Literature Assignment | 15 | |
| ME2290-45 | MSc Thesis Project | 45 | |

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| **Education** | **Master Mechanical Engineering** |

## ME Track Control Engineering (ME-CE)

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| **Program Coordinator** | Dr. P.S.C. Heuberger |
| **Program Title** | MSc track Control Engineering |
| **Introduction 1** | Control Engineering is about the analysis and design of reliable high-performance measurement and control strategies for a wide variety of dynamic technological processes. It focuses on the fundamental aspects of modelling dynamic systems and on developing algorithms for controller design. This track places particular emphasis on two fields of industrial application: advanced process control, motion control for electromechanical and servohydraulic systems.<br>The curriculum embraces fundamental techniques for the physical and experimental modelling of dynamic systems as well as modern approaches to optimisation-based controller synthesis for multivariable systems. This is supplemented by courses on the hardware and software aspects of the technical implementation of control systems, including practical training in laboratory-based experimental projects. Students can choose between three focal areas: Mechanical Systems, Processes and Automotive Research. These interdisciplinary courses cover advanced control techniques for high-performance mechatronic or hydraulic systems (such as a wafer stage or a flight simulator), as well as complex chemical or industrial processes (such as crystallisers or transportation systems) and Automotive applications (such as Global Chassis Control (GCC), drive-by-wire technology and the use of force sensing bearings for new ABS).<br>In consultation with the MSc supervisor, the student chooses a graduation project related either to fundamental aspects of systems and control or to one of the areas of application in mechanical systems (mechatronics, microsystems, MEMS, robotics), process control (biotechnological, chemical, petrochemical and production processes) or automotive research (vehicle mechatronics and dynamics). Most MSc theses fall within the scope of an ongoing research project at the Delft Center for Systems and Control (DCSC) and are supervised by a member of its academic staff under the auspices of a DCSC professor. Alternatively, theses can be prepared in collaboration with the Mechatronic System Design (PME-MSD) group, with one of the professors of MSD acting as supervisor. |
| **Introduction 2** | MSc Systems and Control versus MSc Mechanical Engineering, Control Engineering track<br><br>A student's perspective.<br>If you have a BSc in Mechanical Engineering and wish to pursue a Master's study in the field of systems and control engineering, there are two options to choose from.<br>1. MSc Systems and Control.<br>2. MSc Mechanical Engineering, selecting the Control Engineering track.<br><br>Below we explain the main differences between these two options, with the arguments for choosing one or other of them.<br>First the main differences.<br><br>The MSc Systems and Control takes the technological aspects of systems and control engineering as its starting point. The subject is approached from its generic themes (system theory, control theory, signal analysis), with its highly multidisciplinary nature revealed through different fields of application in which systems and control engineering plays its part: high-precision motion control systems (mechatronics, robotics, microsystems), industrial process systems, traffic and transportation systems and physical imaging systems. Students take a limited number of compulsory courses (24 EC) directed towards the generic components of the field: physical and experimental modelling, control theory, signal analysis and laboratory projects. They complete their programme with elective courses chosen from an extensive list. The MSc project is prepared under the supervision of a professor from DCSC or one of the affiliated groups: Mechatronic System Design, Man-Machine Systems & Medical Instruments, Control and Simulation (Faculty of Aerospace Engineering), Mathematical System Theory (Faculty of Electrical Engineering, Mathematics and Computer Science), Bioprocess Technology (Faculty of Applied Sciences) or Dynamic Traffic Management (Faculty of Civil Engineering and Geosciences). Upon successful completion of the programme, students are the awarded the degree MSc Systems and Control. |
| **Introduction 3** | The Control Engineering track of the MSc Mechanical Engineering takes mechanical engineering as its starting point. It studies the development and application of system and control engineering concepts in the context of mechanical engineering problems, such as high-precision motion control systems (mechatronics, robotics, microsystems), industrial process systems and automotive applications. Students take more compulsory courses, with an emphasis on mechanical engineering subjects, as well as systems and control courses which partly overlap with those in the dedicated MSc programme. The MSc project is prepared under the supervision of a professor from DCSC or Mechatronics System Design. Upon successful completion of the programme, students are awarded the degree MSc Mechanical Engineering, with a note that the addition Control Engineering track was taken.<br>Both options open up excellent career prospects after graduation. When choosing between them, it is advisable to consider how you eventually wish to profile yourself professionally.<br>To be recognised as a dedicated systems and control engineer, then a BSc Mechanical/Electrical Engineering followed by a MSc Systems and Control is the best choice for you. The combination of these two degrees indicates that you have a solid mechanical/electrical engineering background but that you have transcended the traditional boundaries of that discipline at MSc level to master the more abstract field of systems and control engineering, thus bringing a strong multidisciplinary component to your university education.<br>If you feel strongly committed to mechanical engineering and wish to be recognised professionally as a mechanical engineer, then the best option for you is a BSc Mechanical Engineering followed by the MSc Mechanical Engineering. |
| **Program Structure 1** | * Control Engineering<br>Compulsory Courses: 32<br>10 EC Mechanical Systems or 10 EC Processes or 10 EC Automotive: 10<br>Fundamentals: 10<br>Free elective courses: 8<br>Industrial traineeship: (15, optional)<br>Literature study: 15<br>MSc thesis: 45 (30, in combination with a traineeship) |

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| **Education** | **Master Mechanical Engineering** |

| **Obligatory Courses ME-CE** | |
|---|---|
| **Program Coordinator** | Dr. P.S.C. Heuberger |

| ME1200 | Robust and Multivariable Control Design | 6 |
|---|---|---|
| **Responsible Instructor** | Prof.ir. O.H. Bosgra | |
| **Responsible Instructor** | Dr. P.S.C. Heuberger | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Expected prior knowledge** | Requires solid background on state-space descriptions of multivariable linear systems.<br>sc4022/sc4025 | |
| **Course Contents** | This course replaces the former courses on Multivariable Control Systems (wb2421) and Robust Control (wb2415).<br><br>Contents:<br><br>· Recap on background in linear systems theory and classical feedback control<br>· Multivariable system control: Nyquist, interaction, decoupling<br>· Directionality in multiloop control, gain and interaction measure<br>· Stabilizing controllers and the concept of the generalized plant<br>· Parametric uncertainty descriptions, approximations<br>· The general framework of robust control<br>· Robust stability analysis<br>· Nominal and robust performance analysis<br>· Excursion: The algebraic Riccati equation<br>· The H-infinity control problem and its solution in terms of Riccati equations<br>· The structured singular value: Definition of mu, properties, computation, bounds<br>· Mu synthesis, DK-iteration, role of uncertainty structure.<br>· Design of robust controllers, choice of performance criterion and weights | |
| **Study Goals** | The student is able to reproduce theory and apply computational tools for robust controller analysis and synthesis.<br><br>More specifically, the student must be able to:<br>1. substantiate relation between frequency-domain and state-space description of dynamical systems<br>2. define stability and performance for multivariable linear time-invariant systems<br>3. construct generalized plant for complex system interconnections<br>4. describe parametric and dynamic uncertainties<br>5. translate concrete controller synthesis problem into abstract framework of robust control<br>6. reproduce definition, properties and computation of the structured singular value<br>7. master application of structure singular value for robust stability and performance analysis<br>8. sketch derivation and precisely formulate the solution of the H-infinity control problem<br>9. specify the role of Riccati equation within H-infinity control<br>10. design robust controllers on the basis of the H-infinity control algorithm<br>11. apply controller-scalings iteration for robust controller synthesis | |
| **Education Method** | Lectures (4 hours per week) | |
| **Computer Use** | Computer exercises with Matlab's Robust Control Toolbox. | |
| **Literature and Study Materials** | Course material:<br>S. Skogestad, I. Postlethwaite, Multivariable Feedback Control, 2nd Edition. John Wiley & Sons, 2005.<br><br>References from literature:<br>K. Zhou, J.C. Doyle, K. Glover, Robust and optimal control, Prentice Hall, 1996<br>D.-W. Gu, P.Hr. Petkov, M.M. Konstantinov, Robust Control Design with Matlab. Springer Verlag, London, UK, 2005 | |
| **Assessment** | Written exercise and oral examination | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4010 | Introduction Project SC | 3 |
|---|---|---|
| **Responsible Instructor** | Dr. P.S.C. Heuberger | |
| **Contact Hours / Week x/x/x/x** | 6/0/0/0 | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | To achieve good controller designs it is necessary to connect theory with problems of practical interest. In this project the concepts and theory of the basic program concerning Control Systems and Signal Analysis will be reviewed. Implementation issues of e.g. PID controllers via continuous-time techniques on real experimental servo-systems are treated. The laboratory sessions use a digital signal processing controller. These controllers are programmed via the Simulink block diagram language which is part of the Matlab control system design software. | |
| **Study Goals** | The goal of this project is to refresh and apply theoretical knowledge gained in previous classical control courses and to get the ability to tune mechanical servo systems. The concepts and tools to be used include modelling mechanical systems, measurement of the frequency responses and controller design in the time and frequency domain.<br>The designed controllers have to be implemented on a real experimental servo-system and their performances have to be analysed. | |
| **Education Method** | Project combined with theoretical lectures to support the students during the exercises. Part of the lectures, including a computer session, will be taught during the Introduction Week for new MSc students (5-9 September 2011). Presence of all students during this week is mandatory to be able to follow this project. | |
| **Literature and Study Materials** | Lecture slides,<br>G.F.Franklin, J.D. Powell, A.Emami-Naeini 'Feedback Control of Dynamic Systems" Addison-Wesley, or another relevant book on classical feedback control. | |
| **Prerequisites** | Undergraduate curriculum, classical feedback control, signal analysys. experience with MATLAB could be useful but is not required. | |
| **Assessment** | The results of the exercises and experiments must be summarized in a short report, and will be discussed and examined during an oral examination.<br>A written test may be part of the assessment.<br>The deadline for handing in the report is November 21, 2011. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4025 | Control Theory | 6 |
|---|---|---|
| **Responsible Instructor** | T. Keviczky | |
| **Contact Hours / Week x/x/x/x** | 6/0/0/0 | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | 1<br>2 | |
| **Course Language** | English | |
| **Course Contents** | - State-space description of multivariable linear dynamic systems, interconnections, block diagrams<br>- Linearization, equilibria, stability, Lyapunov functions and the Lyapunov equation<br>- Dynamic response, relation to modes, the matrix exponential and the variation-of-constants formula<br>- Realization of transfer matrix models by state space descriptions, coordinate changes, normal forms<br>- Controllability, stabilizability, uncontrollable modes and pole-placement by state-feedback<br>- LQ regulator, robustness properties, algebraic Riccati equations<br>- Observability, detectability, unobservable modes, state-estimation observer design<br>- Output feedback synthesis (one- and two-degrees of freedom) and separation principle<br>- Disturbance and reference signal modeling, the internal model principle | |
| **Study Goals** | The student is able to apply the developed tools both to theoretical questions and to simulation-based controller design projects. More specifically, the student must be able to:<br><br>- Translate differential equation models into state-space and transfer matrix descriptions<br>- Linearize a system, determine equilibrium points and analyze local stability<br>- Describe the effect of pole locations to the dynamic system response in time- and frequency-domain<br>- Verify controllability, stabilizability, observability, detectability, minimality of realizations<br>- Sketch the relevance of normal forms and their role for controller design and model reduction<br>- Describe the procedure and purpose of pole-placement by state-feedback and apply it<br>- Apply LQ optimal state-feedback control and analyze the controlled system<br>- Reproduce how to solve Riccati equations and describe the solution properties<br>- Explain the relevance of state estimation and build converging observers<br>- Apply the separation principle for systematic 1dof and 2dof output-feedback controller design<br>- Build disturbance and reference models and apply the internal model principle | |
| **Education Method** | Lectures and Exercise Sessions | |
| **Computer Use** | The exercises will be partially based on Matlab in order to train the use of modern computational tools for model-based control system design. | |
| **Literature and Study Materials** | B. Friedland, Control System Design: An Introduction to State-space Methods. Dover Publications, 2005<br><br>K.J. Astrom, R.M. Murray, Feedback Systems: An Introduction for Scientists and Engineers, Princeton University Press, Princeton and Oxford, 2009<br>http://www.cds.caltech.edu/~murray/amwiki/index.php?title=Main_Page | |
| **Assessment** | Written mid-term examination (15%) and written final examination (85%). For the resit examination (January 2012) there will be a written examination (100%) for which the mid-term result will not count. | |
| **Design Content** | Simulation-based state-space approach to model-based control system design | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4050 | Integration Project SC | 5 |
|---|---|---|
| **Responsible Instructor** | Prof.dr. R. Babuska | |
| **Instructor** | Dr. G.A. Delgado Lopes | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/4 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | The course is based on practical laboratory sessions, in which students gain hands-on experience with the application of control theory to real-world systems. Matlab and Simulink are used as the primary software environment for the design, analysis and real -time implementation of the algorithms. Students work in groups of two in the lab, with a setup of their choice: inverted pendulum (two variants), 'helicopter' model, inverted wedge, rotational double pendulum, crane and a distillation column. | |
| **Study Goals** | The goal of this course is to integrate and apply the theoretical knowledge gained in the courses `Control Theory' (SC4020), `Modeling and System Analysis' (SC4030) and `Filtering and Identification' (SC4040), which are compulsory within the M.Sc. program 'Systems and Control.' The concepts and tools to be used include mechanistic modeling (based on principles like mass balances, Lagrange equations, etc.), filtering and estimation (e.g., Kalman filtering), linear control design and performance analysis, system identification in open and closed loop. It is assumed that students already know these concepts or are able to look them up in the literature. No theoretical lectures are given in this course. | |
| **Education Method** | Project | |
| **Literature and Study Materials** | See Blackboard | |
| **Prerequisites** | Control Theory (SC4025)<br>Physical Modeling for System and Control (SC4032)<br>Filtering and Identification (SC4040)<br><br>Students who have not followed these courses should contact the lecturer in order to find out whether their control background is at a sufficient level and what literature they should consult. | |
| **Assessment** | There is no written exam. The final grade is determined on the basis of a written report, the discussion of the results with the lecturer and the performance in the lab sessions. | |
| **Special Information** | The laboratory sessions are compulsory in the time slots scheduled for this course - usually on Monday morning (8:45-10:30) and Wednesday morning (8:45-10:30). Besides these slots, other dates and times will be scheduled by the students. Location: DCSC laboratories on the fourth floor and ground floor of block 5A, Mekelweg 2. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4092 | Modeling and Nonlinear Systems Theory | 4 |
|---|---|---|
| **Responsible Instructor** | Dr.ing. D. Jeltsema | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | 2<br>3 | |
| **Course Language** | English | |
| **Expected prior knowledge** | Linear algebra, calculus, linear systems and control theory. Basic knowledge of electrical and mechanical is helpful. | |
| **Course Contents** | Based on the analogies between the physical laws and energy flows of electrical, mechanical, hydraulical, and thermal components, a systematic modelings approach is developed to describe the dynamic behavior of a large class of physical systems. The resulting nonlinear differential equations are represented as nonlinear state space models and are used to study various qualitative aspects.<br><br>The first fundamental topic to be treated is concerned with the study of the system's internal behavior via Lyapunov stability theory. The extension of Lyapunov stability theory to systems with inputs and outputs will be accomplished by the introduction of the concept of dissipative systems. The two main examples of dissipative systems are passive systems and nonlinear control systems having finite input-output L2-induced norm. Important results, such as the small-gain theorem, are highlighted and implications towards the stability analysis of large-scale physical systems, as well as to the robustness of stability with respect to unmodeled dynamics are discussed.<br><br>Another main topic concerns the extension of the controllability and observability concepts to nonlinear control systems. The key ingredients to analyze controllability of a nonlinear system are the so-called Lie brackets of the associated system vector fields. Observability can be analyzed by considering the (repeated) Lie derivatives of the output mapping with respect to the system vector fields. The necessary mathematical preliminaries are introduced during the lectures.<br><br>In the last part of the course, the problem of transforming a nonlinear control system by feedback transformations and the choice of state space coordinates into a linear control system is discussed. It turns out that for controllable systems an elegant if and only if condition can be given, stated in terms of the involutivity of certain Lie bracket expressions of the system vector fields. Applications with respect to control problems such as tracking of desired output trajectories will be provided.<br><br>All topics will be illustrated by examples from various application domains, in particular actuated mechanical systems (robotics), electrical circuits (power converters), mechatronics (electric and magnetic transducers), hydraulic systems (interconnected tanks) and process (heat exchanger) systems. | |
| **Study Goals** | The purpose of the course is to introduce the students to basic concepts and results in physical modeling and the theory of nonlinear control systems.<br><br>After successful completion of the course, the student is able to<br><br>- construct models of systems from the knowledge of physics, with an emphasize on the internal energy of the system.<br>- write models of systems described by differential and algebraic equations in a control systems form.<br>- distinguish between linear and nonlinear systems properties.<br>- decide when to apply the linear and when to apply the nonlinear theory.<br>- determine several stability properties for nonlinear systems.<br>- apply dissipativity and passivity concepts for stabilization and to analyze input-output stability.<br>- determine controllability and observability properties for nonlinear systems.<br>- design linearizing feedback transformations. | |
| **Education Method** | Lectures, instructions, self study assignments, discussion forum. | |
| **Literature and Study Materials** | Reader + hand outs | |
| **Assessment** | Case studies + written exam | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4110 | System Identification | 5 |
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| **Responsible Instructor** | Dr.ir. X.J.A. Bombois | |
| **Instructor** | Prof.dr.ir. P.M.J. Van den Hof | |
| **Contact Hours / Week x/x/x/x** | 0/0/6/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | Experimental modelling of dynamic systems; methodology.<br>Discrete-time signal- and system-analysis. Identification of transferfunctions.<br>Representations of linear models; black-box models.<br>Identification of prediction-error-methods; least squares-method.<br>Approximation modelling; algorithms. Experiment design and<br>data-analysis. Identification in time- and frequency-domain;<br>closed-loop identification; model validation; Matlab toolbox;<br>laboratory assignment. | |
| **Study Goals** | General learning objectives<br><br>System identification deduces and subsequently validates mathematical models of real-life dynamical systems (industrial processes, mechanical servo-systems, ) based on experimental data collected from those systems. This course can be considered as a follow up of the course Sc4010 Filtering and Identification where different solutions to identify a model are presented (note nevertheless that Sc4010 is in no way a prerequisite for this course). The course Sc4110 selects two widely-used linear identification methodologies: Empirical Transfer Function Estimate (ETFE) and Prediction Error Identification (PEI) and provides the students with engineering and theoretical skills to perform the identification in a suitable way. In particular, after this course, the students are able to set up an experiment, identify a nominal model, assess the accuracy/precision of this model, and make appropriate design choices to arrive at a validated model.<br><br>Detailed learning objectives:<br><br>1) Based on time-domain input-output data collected on the true system in open loop, the student is able to deduce a frequency-domain model of a system using the ETFE identification method<br>2) The student is able to specify the bias and variance properties of models identified by the ETFE identification method.<br>3) For the ETFE identification method, the student is able to interpret the bias and variance properties of identified models, and knows how these properties can be influenced by input signal design and by applying windowing techniques.<br>4) The student is able to specify different linear model structures, and to characterize their computational and statistical properties in prediction error identification.<br>5) The student masters the statistical properties (bias, variance, consistency) of prediction error estimators both for the situation of exact plant and noise model sets, and for the situation of exact plant model sets only.<br>6) The student can interpret estimated models as approximations of an underlying physical systems, through the specification of well-defined approximation criteria in the frequency domain, and is able to select design variables so as to arrive at identified models that have prechosen approximative properties.<br>7) The student is able to specify how experiment design and signal to noise ratio affect estimated models. This includes mastering the concept of sufficiently exciting input signals, and the design of appropriate input signals.<br>8) The student is able to apply and interpret correlation-based model structure validation tests, and to draw conclusions on the (in)validity of model structures, distinguishing between plant models and noise models.<br>9) For both ETFE and PE identification methods, the student is able to appropriately acquire digital data from a real-life system (choice of sampling frequency, data processing).<br><br>Required level for the assignment<br><br>1) the student is able to explain in details the presented theory, to demonstrate important properties and to make links and comparisons between the different parts of the course<br>2) the student is able to use the presented tools in practice on a laboratory setup and to interpret his/her result with a critical attitude | |
| **Education Method** | Lectures and project 0/0/6/0<br>Assignment form: final project on a laboratory setup followed by an oral examination | |
| **Literature and Study Materials** | lecture notes and slides | |
| **Prerequisites** | Basics in linear algebra and signal theory | |
| **Assessment** | Oral and project<br>Assignment form: final project on a laboratory setup followed by an oral examination | |
| **Remarks** | Course load: 14 theory courses, 3 exercise sessions and 2 computer sessions | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| WB2305 | Digital Control | 3 |
|---|---|---|
| **Responsible Instructor** | T. Keviczky | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | 2<br>3 | |
| **Course Language** | English | |
| **Expected prior knowledge** | wb2207 and wb2420 or sc4025<br>Knowledge of classic control techniques as well as the state space theory is required. | |
| **Course Contents** | Computer control. Sampling of continuous-time signals. The sampling theorem. Aliasing. Discrete-time systems. State-space systems in discrete-time. The z-transform. Selection of sampling-rate. Analysis of discrete-time systems. Stability. Controllability, reachability and observability. Disturbance models. Reduction of effects of disturbances. Stochastic models. Design methods. Approximations of continuous design. Digital PID-controller. State-space design methods. Observers. Pole-placement. Optimal design methods. Linear Quadratic control. Prediction. LQG-control. Implementational aspects of digital controllers. | |
| **Study Goals** | The student must be able to:<br>1. describe the essential differences between continuous time and discrete-time control<br>2. transform a continuous time description of a system into a discrete-time description<br>3. calculate input-output responses for discrete-time systems<br>4. analyse the system characteristics of discrete-time systems<br>5. employ a pole-placement method on a discrete-time system<br>6. implement an observer to calculate the states of a discrete time system<br>7. apply optimal control on discrete-time systems<br>8. describe the functioning of the Kalman-filter as a dynamic observer | |
| **Education Method** | Lectures and computer exercises | |
| **Computer Use** | Matlab is used to carry out the exercises of this course. | |
| **Literature and Study Materials** | Course material:<br>Lecture notes are made available on Blackboard<br><br>References from literature:<br>K.J. Astrom, B. Wittenmark 'Computer-controlled Systems', Prentice Hall ,1997, 3rd edition<br>B.C. Kuo 'Digital Control Systems', Tokyo, Holt-Saunders, 1980<br>G.F. Franklin, J.D. Powell 'Digital Control of Dynamic Systems', 1989, 2nd edition, Addison-Wesley | |
| **Assessment** | Final quiz in class + project assignment | |
| **Remarks** | The project assignment can be completed only during the quarter when the course is offered (i.e. the project has no resit during other periods). | |
| **Design Content** | The design aspects of digital controllers are discussed. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

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| **Year** | **2011/2012** |
| **Organization** | **Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen** |
| **Education** | **Master Mechanical Engineering** |

| **Elective Courses Mechanical Systems ME-CE** | |
|---|---|
| **Program Coordinator** | Dr. P.S.C. Heuberger |
| **Introduction 1** | Minimal 10 ECTS to select from Mechanical Systems or 10 ECTS from Processes or 10 ECTS from Automotive. |

| WB1406-07 | Experimental Dynamics | 3 |
|---|---|---|
| **Responsible Instructor** | D. de Klerk | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | none | |
| **Course Language** | English | |
| **Parts** | The course consists of two parts:<br>- part A Classes<br>- part B Laboratory experiments (four in total) | |
| **Course Contents** | Part A: Theory<br>- How does a modern measurement system work?? In specific how does it minimize desturbances and does it cope with filter effects?<br>- Pitfalls in Frequency Analysis: Descrete algorithms, Leakage, Aliasing. Know it or you'll mess up your experements.<br>- The power of Transfer and Frequency Response Functions (FRF); why are the so usefull?<br>- Experimental Modal Analysis: Does and don't, pitfalls & challenges in practice.<br>- Harmonic excitation (with frequency stepping), impulsive excitation, stochastic excitation.<br>- Sensors, how do they work, what is important when using them.<br>- Rotoranalysis, operational system analysis.<br>- Latest advances in measurement technology.<br><br>Moto: In theory, theory and practice are the same... In practice they are not.<br>This course concentrates on pointing where those differences orignate from, valuable for any who'll perform measurements, needs to analyse measurements or who tries to match his / her simulation to the experiment.<br><br>Part B: Experimental analysis<br>The second part of the course involves working on assigments meant to illustrate concepts described in Part A and to deepen insight.<br>Teams of three students each, carry out multi´ple experiments. Last year students got to simulate in Matlab a measurement system as a first assignment. Their final project involved analyzing measurement data measured by them selves on my car on the Rotterdamsestraatweg. Can it be more exciting? Yes, maybe you have always wanted to analyze a different product like a boat, train, motorbike, music instrument, etc. maybe we can come up with that exciting experiment in this year's course! | |
| **Study Goals** | In general the student is able to perform dynamic measurements, being aware of possible pitfalls.<br><br>More specifically, the student must be able to:<br>1. describe the effects of Quantization, Leakage, Aliasing in measurements and measurement equipment.<br>2. explain the principle of extracting modal parameters (resonance frequency, spring constant, damping ratio) from system response both in the time domain and in the frequency domain<br>3. explain the principle of extracting modal parameters (modal frequencies, modal gains, modal damping ratios) from system response both in the time domain and in the frequency domain<br>4. discuss relative merits of different excitation techniques (shaker with frequency sweep, impact hammer, shaker with random excitation)<br>5. discuss the prinicples and the elative merits of different sensing techniques (strain gauge, seismic mass, piezo crystal, electromagnetic induction, laser vibrometer)<br>6. carry out dynamic experiments, analyze the data, and report and discuss his findings. | |
| **Education Method** | Classes followed by laboratory projects. | |
| **Computer Use** | Matlab<br>Word<br>LaTeX<br>PowerPoint | |
| **Literature and Study Materials** | Course material:<br>- Part A: Course notes<br>- Part B: Laboratory assignments manual<br><br>References from literature:<br>- see the reference list in the Course notes. | |
| **Assessment** | Written report, and oral discussion of experiment activities and of report. | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB1413-04 | Multibody Dynamics B | 4 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. A.L. Schwab | |
| **Course Coordinator** | Ir. J.J.L. Neve | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | none<br>Different, to be announced | |
| **Course Language** | English | |
| **Expected prior knowledge** | wb1113wb, wb1216 | |
| **Course Contents** | In this course we will cover a systematic approach to the generation and solution of equations of motion for mechanical systems consisting of multiple interconnected rigid bodies, the so-called Multibody Systems. This course differs from 'Advanced Dynamics', which mostly covers theoretical results about classes of idealized systems (e.g. Hamiltonian systems), in that the goal here is to find the motions of relatively realistic models of systems (including, for example, motors, dissipation and contact constraints). Topics covered are:<br>-Newton-Euler equations of motion for a simple planar system, free body diagrams, constraint equations and constraint forces, uniqueness of the solution.<br>-Systematic approach for a system of interconnected rigid bodies, virtual power method and Lagrangian multipliers.<br>-transformation of the equations of motion in terms of generalized<br>independent coordinates, and lagrange equations.<br>-Non-holonomic constraints as in rolling without slipping, degrees of freedom and kinematic coordinates.<br>-Unilateral constraints as in contact problems.<br>-Numerical integration of the equations of motion, stability and accuracy of the applied methods.<br>-Numerical integration of a coupled differential and algebraic system of equations (DAE's), Baumgarte stabilisation, projection method and independent coordinates.<br>-Newton-Euler equations of motion for a rigid three-dimensional body, the need to describe orientation in space, Euler angles, Cardan angles, Euler parameters and Quaternions.<br>-Equations of motion for flexible multibody systems, introduction to Finite Element Method approach, Linearised equations of motion.<br><br>Upon request and if time and ability of the instructor allows, related topics are open for discussion. | |
| **Study Goals** | The student is able to find the motions of linked rigid body systems in two and three dimensions including systems with various kinematic constraints, like there are: sliding, hinges and rolling, and closed kinematic chains.<br><br>More specifically, the student must able to:<br>1. derive the Newton-Euler equations of motion for a simple planar system, draw free body diagrams, set-up constraint equations and introduce constraint forces, and demonstrate the uniqueness of the solution<br>2. derive the equations of motion for a system of interconnected rigid bodies by means of a systematic approach: virtual power method and Lagrangian multipliers<br>3. transform the equations of motion in terms of generalized independent coordinates, and derive and apply the Lagrange equations of motion<br>4. apply the techniques from above to systems having non-holonomic constraints as in rolling without slipping, degrees of freedom and kinematic coordinates<br>5. apply the techniques from above to systems having unilateral constraints as in contact problems<br>6. perform various numerical integration schemes on the equations of motion, and predict the stability and accuracy of the applied methods<br>7. perform numerical integration on a coupled system of differential and algebraic equations (DAE's), apply Baumgarte stabilization, the coordinate projection method and transformation to independent coordinates<br>8. derive the Newton-Euler equations of motion for a general rigid three-dimensional body system connected by constraints, identify the need to describe orientation in space<br>describe the orientation in 3-D space of a rigid body by means of: Euler angles, Cardan angles, Euler parameters and Quaternions, derive the angular velocity and accelerations in terms of these parameters and their time derivatives, and their inverse<br>9. derive the equations of motion for flexible multibody systems by means of a Finite Element Method approach, and extend this to linearised equations of motion | |
| **Education Method** | Lectures (2 hours per week) | |
| **Computer Use** | The course is computer-oriented. In doing the assignments you will be using Matlab, Maple or related computer software. | |
| **Literature and Study Materials** | Course material: Arend L. Schwab, `Applied Multibody Dynamics', Delft, 2003<br><br>References from literature:<br>A.A.Shabana, ' Dynamics of multibody systems', Wiley, New York, 1998.<br>E.J.Haug, ' Computer aided kinematics and dynamics of mechanical systems, Volume I: Basic methods', Allyn and Bacon, Boston, 1989.<br>P.E.Nikravesh, ' Computer-aided analysis of mechanical systems', Prentice-Hall, Englewood Cliffs, 1988.<br>M. Géradin, A. Cardano, ' Flexible multibody dynamics: A finite element approach', J. Wiley, Chichester, New York, 2001. | |
| **Assessment** | Final Project | |
| **Remarks** | There will be weekly assignments and a final project. You have to make a report on the final project. In doing the assignments I strongly encourage you to work together. The final project is individual. Check out the up-to-date web page at http://tam.cornell.edu/~als93/ | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB1418-07 | Engineering Dynamics | 4 |
|---|---|---|
| **Responsible Instructor** | Ir. P. Tiso | |
| **Instructor** | Prof.dr. D.J. Rixen | |
| **Contact Hours / Week x/x/x/x** | 4/0/0/0 | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Required for** | Engineering Dynamics and Mechanicsms (wb1419, extension of wb1418), Multibody Dynamics A (wb1310), Multibody Dynamics B (wb1413), Numerical Methods in Dynamics (wb1416), Non-Linear Vibrations (wb1412). | |
| **Expected prior knowledge** | Statics and Strength of materials (e.g. wb1214), Dynamics (e.g. wb1311), Linear Algebra | |
| **Course Contents** | The dynamic behavior of structures (and systems in general) plays an essential role in engineering mechanics and in particular in the design of controllers. In this master course, we will discuss how the equations describing the dynamical behavior of a structure and of a mechatronical system can be set up. Fundamental concepts in dynamics such as equilibrium, stability, linearization and vibration modes are discussed. If time permits, also an introduction to discretization techniques to approximate continuous systems is proposed.<br><br>The course will discuss the following topics:<br><br>- Review of the virtual work principle and Lagrange equations<br>- linearization around an equilibrium position: vibrations<br>- Free vibration modes and modal superposition<br>- Forced harmonic response of non-damped and damped structures | |
| **Study Goals** | The student is able to select different ways of setting up the dynamic equations of mechanical systems, to perform an analysis of the system in terms of linear stability and vibration modes and to properly use mode superposition techniques for computing transient and harmonic responses.<br><br>More specifically, the student must be able to:<br>1. explain the relations between the principle of virtual work and the Lagrange equations for dynamics to the basic Newton laws<br>2. describe the concept of kinematic constraints (holonomic/non-holonomic, scleronomic/rheonomic) and choose a proper set of degrees of freedom to describe a dynamic system<br>3. write the Lagrange equations for a minimum set of degrees of freedom and extend it to systems with additional constraints (Lagrange multiplier method)<br>4. linearize the dynamic equations by considering the different contributions of the kinetic and potential energies (both for system with and without overall motion imposed by scleronomic constraints)<br>5. analyze the linear stability of dynamic systems (damped and undamped) according to their state space formulation if necessary<br>6. explain and use the concept of free vibration modes and frequencies<br>7. interpret and apply the orthogonality properties of modes to describe the transient and harmonic dynamic response of damped and undamped systems<br>8. evaluate the approximations introduced when using truncated modal series (spatial and spectral)<br>9. explain how mode superposition can be used to identify the eigenparamters of linear dynamic systems | |
| **Education Method** | Lecture | |
| **Computer Use** | The assignement will require using Matlab-like software. | |
| **Literature and Study Materials** | Course material:<br>Lecture notes (available through blackboard)<br><br>References from literature:<br>Mechanical Vibrations, Theory and Application to Structural Dynamics, M. Géradin and D. Rixen, Wiley, 1997.<br>Applied Dynamics, with application to multibody and mechatronic systems, F.C. Moon, Wiley, 1998, isbn 0-471-13828-2.<br>Engineering vibration, D.J. Inman, Prentice Hall, 2001, isbn 0-13-726142-X<br>The Finite Element Method: Linear Static and Dynamic Finite Element Analysis, T.J.R. Hughes Prentice-Hall, 1987.<br>Structural Dynamics in Aeronautical Engineering, M.N. Bismark-Nasr, AIAA education series, 1999, isbn 1-56347-323-2 | |
| **Assessment** | Oral exam + assignment | |
| **Remarks** | An assignment will be given which will make up part of the final mark. SInce the enphasis of the lectures will be on understanding concepts in dynamics more than memorizing formulas, the oral exam will be open book to evaluate your understanding of the concepts. | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB1440 | Eng. Optimization: Concept & Applications | 3 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. M. Langelaar | |
| **Instructor** | Prof.dr.ir. A. van Keulen | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | Different, to be announced | |
| **Course Language** | English | |
| **Required for** | wb1441 | |
| **Expected prior knowledge** | Basic knowledge of mechanical engineering and mathematics. Experience with Matlab is helpful. | |
| **Course Contents** | Formulation of optimization problems<br>Typical characteristics of optimization problems<br>Minimization without constraints<br>Constrained minimization<br>Simple optimization algorithms<br>Discrete design variables<br>Approximation concepts<br>Sensitivity analysis | |
| **Study Goals** | The student is able to formulate a proper optimization problem in order to solve a given design problem, and is able to select a suitable approach for solving this problem numerically. Furthermore, he is able to interpret results of completed optimization procedures.<br><br>More specifically, the student must be able to:<br>1. formulate an optimization model for various design problems<br>2. identify optimization model properties such as monotonicity, (non-)convexity and (non-) linearity<br>3. identify optimization problem properties such as constraint dominance, constraint activity, well boundedness and convexity<br>4. apply Monotonicity Analysis to optimization problems using the First Monotonicity Principle<br>5. perform the conversion of constrained problems into unconstrained problems using penalty or barrier methods<br>6. compute and interpret the Karush-Kuhn-Tucker optimality conditions for constrained optimization problems<br>7. describe the complications associated with the use of computational models in optimization<br>8. illustrate the use of compact modeling and response surface techniques for dealing with computationally expensive and noisy optimization models<br>9. perform design sensitivity analysis using variational, discrete, semi-analytical and finite difference methods<br>10. identify a suitable optimization algorithm given a certain optimization problem<br>11. perform design optimization using the optimization routines implemented in the Matlab Optimization Toolbox<br>12. derive a linearized approximate problem for a given constrained optimization problem, and solve the original problem using a sequence of linear approximations<br>13. describe the basic concepts used in structural topology optimization | |
| **Education Method** | Lectures (2x2 hours per week), exercises | |
| **Computer Use** | MATLAB is used for exercises. | |
| **Literature and Study Materials** | Course material: P.Y. Papalambros et al. Principles of Optimal Design: Modelling and Computation.<br><br>References from literature: R.T. Haftka and Z. Gürdal: Elements of Structural Optimization. | |
| **Assessment** | MATLAB exercises, optimization project. | |
| **Percentage of Design** | 80% | |
| **Design Content** | The course is focusing on design optimization. | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB2303-10 | Measurement in Engineering | 3 |
|---|---|---|
| **Responsible Instructor** | W.M. van Spengen | |
| **Instructor** | Prof.ir. R.H. Munnig Schmidt | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Expected prior knowledge** | Knowledge on mechatronic design principles and physical optics. Either by following WB2414 or by studying chapter 3,4,5 and 6 and 7 of the reader/book on "Mechatronic System Design". | |
| **Course Contents** | The course will focus on measurement techniques that are usually applied in Mechanical Engineering so integrated in larger equipment for feedback or calibration purposes but also in stand alone setups.<br><br>Topics include:<br><br>General performance characteristics of measurement instruments.<br>Elements in measurement systems: Sensors, Signal conditioning and Signal processing.<br>Electronics used in measurement systems and EMC. Signal manipulation and transmission, filtering, noise suppression, amplitude modulation.<br>Measurement uncertainty, error sources, correction methods. Interfering and modifying error sources.<br>Calibration, traceability and standards.<br>Dynamics of measurement systems and measurement of dynamics. Transfer functions in the frequency and time domain.<br>Measuring devices for both linear and angular motion (displacement, velocity, acceleration)<br>Force, torque and pressure sensors.<br>Strain gauge principles<br>Optical measurement systems, encoders and laser interferometry | |
| **Study Goals** | * The student will be capable of understanding the fundamental approach in measuring physical quantities and the influence of the different elements on the performance of the measurement system.<br>* The student will be capable of applying the basic principles of measurement of mechanical magnitudes.<br>* The student will be capable of determining the suitable measurement systems for a given metrology problem.<br>* The student will be able to design a concept measurement system for a given measurement problem by using different physical principles. | |
| **Education Method** | Classroom Lectures. Basic theory and application by the main teacher and max. 2 invited speakers on a certain theme. These can be from industry, another faculty or phd students about their research topic | |
| **Course Relations** | This course is directly related with Mechatronic System Design (WB 2414). In principle the knowledge from WB2414 is necessary to be able to follow this course. | |
| **Books** | "Mechatronic System Design" by R. Munnig Schmidt, J. van Eijk and G. Schitter, is expected to be ready at the start of the lectures. Details will be posted on blackboard. | |
| **Assessment** | Written examination, closed book | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB2414-09 | Mechatronic System Design | 4 |
|---|---|---|
| **Responsible Instructor** | Prof.ir. R.H. Munnig Schmidt | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | 2<br>3 | |
| **Course Language** | English | |
| **Required for** | All PME students | |
| **Expected prior knowledge** | Bsc Mechanical Engineering, Electrical Engineering or Physics.<br>ME1611-10 (Physics for mechanical Engineers) and SC4026 (Control system Design) is needed as preparation | |
| **Course Contents** | Mechatronic system design deals with the design of controlled motion systems by utilizing a multitude of disciplines. It starts with thinking how the required function of a machine can be achieved by utilizing its different subsystems following a systems Engineering approach (V-model).<br><br>Some supporting disciplines are not originally the working area of mechanical engineers like electronics and electromechanics. This course aims to connect these disciplines with motion control principles to realise an optimally designed system.<br><br>The target application of controlled motion systems explicitly includes the controlling of any movement ranging from perfectly standing still, slow motion precision manipulators to high speed applications with extreme precision to sub nm level.<br><br>The course covers four main subjects:<br><br>1: Dynamics of motion systems in the time and frequency domain of actively controlled motion systems. It includes transfer functions represented in Bode plots.<br><br>2: Motion control with PID-feedback,and model based feedforward.<br><br>3: Electromechanical Actuators, both electromagnetic and piezoelectric<br><br>4: Analog electronics, operational amplifiers and power electronics used for driving actuators.<br><br>While these disciplines mostly are dealt with in separate specialized courses, in this course the mutual relationship in the application in controlled motion systems is the central theme.<br><br>The most important aspect that will be assessed is the capability to match theory with practice. Translate a real system into a dynamic model and vice versa. Understand what a position control system really does. Observe a system top-down. Starting with a global overview and use approximating (scalar) calculations by hand to get a sufficient feel of the problem to make concept design decisions. Learn to use detailed calculations only as a last step to determine the details with the help of a (finite element) computer program. | |
| **Study Goals** | The student can analyze active dynamic systems by means of bode diagrams.<br><br>The student can solve new mechatronic problems in a structured way, starting with the required function.<br><br>The student will be able to understand the role of different disciplines that are used in mechatronic systems in their mutual relationship.<br><br>The student will be able to determine the optimal combination of the different disciplines to achieve a specific controlled motion function. | |
| **Education Method** | Lectures around theory and practice of mechatronic systems based on a reader/book that is made available both on blackboard and in printed form as a book (planned not 100% sure if ready in time).<br><br>The lectures will be aiming at introducing the material and make the students learn by intensive studying and practicing in individual exercises. | |
| **Computer Use** | No computers will be used nor will the emphasis lay on exact calculated values. | |
| **Literature and Study Materials** | A reader is in concept published on blackboard.<br>When possible in time it will be made available in printed form as a book.<br><br>The presentations will also be published on blackboard | |
| **Books** | "Mechatronic System Design" by R. Munnig Schmidt a.o. (planned in 2011) | |
| **Assessment** | During the lectures five exercises have to be made as homework, of which at least three need to be passed to be admitted to the written examination(open book). | |
| **Permitted Materials during Tests** | Calculator. | |
| **Percentage of Design** | 50% | |
| **Design Content** | The course gives methods to design complex systems by following the System Engineering guidelines of INCOSE. Clearly distinguishing requirements and specifications.<br><br>Further it is focusing on mechatronic concept design by optimally combining different disciplines and pinpointing (dynamic) interactions between the different elements of a system | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |
| **Judgement** | In the examination the judgment is determined for 60% on the proof of the real understanding of the problem and its solution including knowledge of physical phenomena and basic relations. 40% is determined by crisp formulation and the related calculations. | |

| WB2428-03 | Mechanical Design in Mechatronics | 5 |
|---|---|---|
| **Responsible Instructor** | Ir. P.C.J. van Rens | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | Different, to be announced | |
| **Course Language** | English | |
| **Course Contents** | Mechanical design principles for high precision positioning, controlling degrees of freedom<br>Stress and strain, design for stiffness<br>Design principles to eliminate friction, wear and hysteresis | |
| **Study Goals** | To gain sound understanding of mechanical design principles for high precision applications in mechatronics | |
| **Education Method** | Lectures (4 hours per week) | |
| **Literature and Study Materials** | Will be made available on Blackboard | |
| **Assessment** | Oral exam (semester 2A) and Design Exercise (semester 2B) | |
| **Percentage of Design** | 90% | |
| **Design Content** | Mechanical design principles for high precision applications | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB3404A | Vehicle Dynamics A | 3 |
|---|---|---|
| **Responsible Instructor** | Ir. E.J.H. de Vries | |
| **Course Coordinator** | Ir. J.J.L. Neve | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | Basic elements of the dynamics of road vehicles (car, truck, motorcycle). Ride vibration response to road unevenness. Sine and stochastic roadprofile. Single, two and three mass/spring/damper systems. Linear and non-linear models. Vibrational modes and stability. Discomfort analysis. System identification. Roadholding: vehicle handling and stability. Response to stear input and side wind. Singel two-wheel vehicle model to discuss effects of tyres, inertia and geometry. Influence of several design variables: steering and wheel suspension, kinematics and compliance, toe angle, camber, roll axis, roll stabilizer, load transfer. Motorcycle stability and modal shapes (brief discussion of results) | |
| **Study Goals** | The student is able to apply dynamics methods and knowledge on vehicle specific problems<br><br>More specifically, the student must be able to:<br>1. quantify comfort and road holding: recognise the paradox for optimal suspension design<br>2. realize that linear models are approximations of reality in many aspects<br>3. employ single mass and higher order models for vertical vibration analysis, and justify the choice for single d.o.f., quarter car or half car model<br>4. implement the most common non linear elements in vehicle(models) and discover some analytical solution methods<br>5. solve non-Linear problems with numerical integration routines<br>6. apply Lagrange method to derive equations of motion<br>7. analyze driving stability in the horizontal plane using Hurwitz criterion<br>8. characterize vehicle handling in terms of under- and oversteer, apply critical and characteristic velocity on the vehicle behaviour<br>9. derive the single track model, linear and including elementary non-linear properties | |
| **Education Method** | Lectures (4 hours per week), practical exercises | |
| **Computer Use** | In working out the problems the computer will be helpful, for some problems essential. MatLab will be used for analysis and simulation | |
| **Literature and Study Materials** | Course material:<br>Lecture notes: Vehicle Dynamics A (pdf on blackboard)<br><br>References from literature:<br>Mitschke, Dynamik der Kraftfahrzeuge<br>Gillespie, Fundamentals of vehicle dynamics 1992<br>Genta, Motor Vehicle Dynamics 1997, 2003, 2006<br>Pacejka, Tyre and Vehicle Dynamics 2002, 2006 (2nd) | |
| **Assessment** | Oral exam, by appointment | |
| **Remarks** | Laboratory project(s):<br>About 7 problems (exercises) are requested to prepare at home. | |
| **Design Content** | The effect of design parameters of wheel suspension and stearing system are discussed. | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

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|---|---|
| **Year** | **2011/2012** |
| **Organization** | **Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen** |
| **Education** | **Master Mechanical Engineering** |

| **Elective Courses Processes ME-CE** | |
|---|---|
| **Program Coordinator** | Dr. P.S.C. Heuberger |
| **Introduction 1** | Minimal 10 ECTS to select from Mechanical Systems or 10 ECTS from Processes or 10 ECTS from Automotive. |

| SC4060 | Model Predictive Control | 4 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. A.J.J. van den Boom | |
| **Contact Hours / Week x/x/x/x** | 0/0/3/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Expected prior knowledge** | Undergraduate curriculum | |
| **Course Contents** | The model predictive control (MPC) strategy yields the optimization of a performance index with respect to some future control sequence, using predictions of the output signal based on a process model, coping with amplitude constraints on inputs, outputs and states. The course presents an overview of the most important predictive control strategies, the theoretical aspects as well as the practical implications, that makes model predictive control so successful in many areas of industry, such as petro-chemical industry and chemical process industry. Hands-on experience is obtained by MATLAB exercises with academic examples and a industrial simulation of MPC on a two-product (binary) distillation column. Contents of the course: General introduction. Differences in models and model-structures, advantages and limitations. Prediction models in state-space setting. Standard predictive control scheme. Relation standard form with GPC, LQPC and other predictive control schemes. Finite/Infinite horizon MPC. Solution of the standard predictive control problem. Stability, robustness, initial and advanced tuning. Robust design in predictive control. See also: http://www.dcsc.tudelft.nl/~sc4060 | |
| **Study Goals** | Study Goals:<br>The student should be able to<br>1. Explain how and why MPC has emerged from industry.<br>2. List the five basic items of MPC and discuss their role.<br>3. Identify, recognize and describe different type of models in MPC and explain when a type of model is suited for a specific application.<br>4. Show that all models can be transformed into a state-space model.<br>5. Understand the concept of prediction in MPC.<br>6. Make a prediction in the noiseless and the noisy case.<br>7. Explain why a standard formulation is desirable.<br>8. Transform any MPC problem into the standard MPC problem.<br>9. Derive the steady-state of a system.<br>10. Solve the finite and infinite horizon problem.<br>11. Derive the realization for the LTI-case and for the inequality constrained case.<br>12. Describe two ways to deal with infeasibility.<br>13. Discuss stability for the LTI case and in the inequality constrained case.<br>14. Describe the use of the end-point constraint and the infinite prediction horizon.<br>15. Give the relation of the MPC scheme and the IMC scheme.<br>16. Motivate the rules-of-thumb for initial tuning and use these rules for tuning an MPC controller.<br>17. Describe the concept of robustness in MPC.<br>18. Motivate and use the rules of robust tuning in MPC.<br>19. Derive an MPC controller for various academic and industrial examples using MATLAB. | |
| **Education Method** | Lectures 0/0/3/0 | |
| **Literature and Study Materials** | Course notes "Model Predictive Control" by Ton van den Boom (TU Delft) 2011. | |
| **Assessment** | Written exam and a homework assignment | |
| **Remarks** | Computer use: for the homework assignment, the use of MATLAB on PC is required. The assignment can be done either at home or at the DCSC laboratory. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| WB1427-03 | Advanced Fluid Dynamics A | 5 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. C. Poelma | |
| **Contact Hours / Week x/x/x/x** | 2/2/0/0 | |
| **Education Period** | 1<br>2 | |
| **Start Education** | 1 | |
| **Exam Period** | 2<br>3 | |
| **Course Language** | English | |
| **Required for** | wb1424ATU, 1424BTU | |
| **Expected prior knowledge** | wb1123 , wb1220 , wb1321, wi3105mw | |
| **Course Contents** | In this course the fundamental and mathematical principles of fluid mechanics are treated. Point of departure is the conservation equations for mass and momentum. Based on these equations the equations of motion for a incompressible flow are derived. In order to close the equation of conservation of momentum a relationship must be prescribed between the stress tensor and the deformation-rate tensor leading to the constitutive equation for a Newtonian fluid. The result is known as the Navier-Stokes equations. First these equations are simplified for the case of an inviscid fluid which are known as the Euler equations. The solution of these equations for the case of a irrotational flow leads to a treatment of potential flow theory and the law of Bernoulli. This theory and law are applied to the flow around a sphere and around a cylinder. The flow around a cylinder is two dimensional and it is shown that in this case potential flow theory can be described in terms of complex function theory. This theory is applied to the flow around a cylinder in combination with a line vortex and by means of conformal transformations a relationship is derived with the lift force on a airfoil. In the remaining of the course the full Navier-Stokes equations, i.e. including the viscosity terms, are considered and the Reynolds number is defined. The effect of viscosity is coupled to dissipation of energy and diffusion of vorticity. As example of a very viscous flow, we discuss the Stokes flow in particular the flow around a sphere. For large Reynolds numbers the boundary-layer theory is derived and the Blasius solution for the boundary layer over a flat plate is discussed.<br><br>NOTE:<br>Knowledge of vector analysis is essential for this course. Students not familiar with vector analysis should follow wi3105me in the first quarter. | |
| **Study Goals** | The student is able to describe the basic fundamentals of classical, incompressible fluid mechanics and to apply the fundamental and mathematical principles of fluid mechanics.<br><br>More specifically, the student must be able to:<br>1. formulate the conservation equations for mass and momentum<br>2. derive the equations of motion for an incompressible flow, based on the conservation equations for mass and momentum<br>3. derive the constitutive equation for a Newtonian fluid (the Navier-Stokes equations)<br>4. simplify the Navier-Stokes equations for the case of an in viscid fluid (the Euler equations)<br>5. solve the Euler equations for the case of an irrotational flow, leading to a treatment of potential flow theory and the law of Bernoulli<br>6. apply the potential flow theory and the law of Bernoulli to the flow around a sphere and around a cylinder<br>7. derive that in the case of a flow around a cylinder, the flow is two dimensional, and the potential flow theory can be described in terms of complex function theory<br>8. derive a relation with the lift force on a airfoil by applying the complex function theory to the flow around a cylinder in combination with a line vortex and by means of conformal transformations<br>9. consider the full Navier-Stokes equations, i.e. including the viscosity terms, and to define the Reynolds number<br>10. couple the effect of viscosity to dissipation of energy and diffusion of vorticity<br>11. discuss the Stokes flow, in particular the flow around a sphere, as example of a very viscous flow<br>12. drive the boundary-layer theory for large Reynolds numbers and discuss the Blasius solution for the boundary layer over a flat plate | |
| **Education Method** | Lectures (2 hours per week), computer demonstration | |
| **Computer Use** | Computers are used for demonstrations of the lecture material during the course on the basis of home-made software and on the basis of the symbolic manipulation program Maple. | |
| **Literature and Study Materials** | Course material:<br><br>Book: Fluid Mechanics by Cohen & Kundu, Elsevier Academic Press (4th edition). | |
| **Assessment** | Written exam | |
| **Percentage of Design** | 0% | |
| **Design Content** | This is a fundamental subject which has only indirect relationship with design. | |
| **Department** | 3mE Department Process & Energy | |

| WB3421-04 | Automation and Control of Transport and Production Systems | 6 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. G. Lodewijks | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | Different, to be announced | |
| **Course Language** | English | |
| **Course Contents** | This course focuses on the automation and control of modern transport and production systems. Automation is often necessary to increase the capacity or to reduce operating costs of industrial systems on one hand while maintaining a sufficient level of operational accuracy on the other hand. Automation requires full control of an industrial system and its equipment and a throughout understanding of the transport/manufacturing process and the dynamics of the equipment involved. In this course the automation of a number of typical systems will be studied and the dificulties and opportunities of new technologies. Basis of this course is a study of the dynamics of the operational process and the equipment. In an automated system data communication is important to ensure reliable performance. In this respect equipment and process monitoring is important as well. Therefore data acquisition, mining, analysis and transfer will be discussed in detail. The course is concluded by a practical assignment where the control of equipment used in an automated system will be studied. | |
| **Study Goals** | (1) To categorise industrial systems and identify properties that determine their performance; (2) to describe mathematically the transport process and the behaviour of equipment; (3) to determine the requirements to automate an industrial system in terms of control algorithms and equipment involved; (4) to experience the difference between automation in concept and automation in practice. | |
| **Education Method** | Lectures (2 hours per week), practical assignment | |
| **Computer Use** | Uses of data acquisition equipment and database software | |
| **Literature and Study Materials** | Course material:<br>Lecture book<br><br>References from literature:<br>To be determined | |
| **Assessment** | Assignment | |
| **Remarks** | Access to the oral examination only after completion of the practical assignment. | |
| **Design Content** | Not applicable | |
| **Department** | 3mE Department Maritime & Transport Technology | |

| WB4302 | Thermodynamic Aspects of Energy Conversion | 4 |
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|---|---|
| **Responsible Instructor** | Dr. P.V. Aravind |
| **Instructor** | Ir. T. Woudstra |
| **Contact Hours / Week x/x/x/x** | 4/0/0/0 |
| **Education Period** | 1 |
| **Start Education** | 1 |
| **Exam Period** | 1<br>2 |
| **Course Language** | English |
| **Required for** | st310, wb4422, wb4410, wb4412, wb4419, wb4420 |
| **Expected prior knowledge** | wb4100, wb1224, wb3560 |
| **Course Contents** | · Short recapitulation of the fundamentals of engineering thermodynamics: first law, energy balance of closed and open systems, second law, entropy and irreversibility.<br>· Specific thermodynamic properties of fluids: properties of water and steam, properties of ideal gas.<br>· Extended definition of exergy and environment. Chemical exergy. Exergy of fuels. Exergy efficiencies.<br>· Value diagrams. Application for heat exchanging equipment and combustion processes.<br>· Exergy losses of basic processes: fuel conversion, heat transfer, turbines, compressors.<br>· Exergy analysis and optimisation of conventional power stations (boiler/steam cycle):<br>boiler: air preheating, steam conditions, feedwater temperature;<br>steam cycle: selection of working fluid, friction losses in boilers, losses in condensor and piping, feedwater pump, extraction feed water heating.<br>· Gas turbine processes, losses and optimization:<br>closed cycle GT process: pressure ratio, turbine inlet temperature, cycle configuration (intercooling, recuperation, reheat);<br>open cycle GT process: cycle configuration, value diagram;<br>combined cycle systems: exergy losses HRSG, multiple pressure steam cycles, supplementary firing;<br>· Combined heat and power production (CHP): thermodynamic principle of CHP, evaluation criteria, applications, power to heat matrix.<br>· Fuel cells: calculation of reversible power and reversible cell voltage, effect of irreversibilities on cell performance, Nernst equation and some characteristics of SPFC (PEMFC), MCFC and SOFC, exergy losses in fuel cell systems.<br>· Refrigeration cycles and heat pumps: properties of working fluids, processes with mixtures, refrigeration and heat pump processes.<br>· Introduction to thermodynamics of new and renewable energy systems. Biomass, Solar Thermal, Geo Thermal and CO2 capture systems etc |
| **Course Contents Continuation** | · Short recapitulation of the fundamentals of engineering thermodynamics: first law, energy balance of closed and open systems, second law, entropy and irreversibility.<br>· Specific thermodynamic properties of fluids: properties of water and steam, properties of ideal gas.<br>· Extended definition of exergy and environment. Chemical exergy. Exergy of fuels. Exergy efficiencies.<br>· Value diagrams. Application for heat exchanging equipment and combustion processes.<br>· Exergy losses of basic processes: fuel conversion, heat transfer, turbines, compressors.<br>· Exergy analysis and optimisation of conventional power stations (boiler/steam cycle):<br>boiler: air preheating, steam conditions, feedwater temperature;<br>steam cycle: selection of working fluid, friction losses in boilers, losses in condensor and piping, feedwater pump, extraction feed water heating.<br>· Gas turbine processes, losses and optimization:<br>closed cycle GT process: pressure ratio, turbine inlet temperature, cycle configuration (intercooling, recuperation, reheat);<br>open cycle GT process: cycle configuration, value diagram;<br>combined cycle systems: exergy losses HRSG, multiple pressure steam cycles, supplementary firing;<br>· Combined heat and power production (CHP): thermodynamic principle of CHP, evaluation criteria, applications, power to heat matrix.<br>· Fuel cells: calculation of reversible power and reversible cell voltage, effect of irreversibilities on cell performance, Nernst equation and some characteristics of SPFC (PEMFC), MCFC and SOFC, exergy losses in fuel cell systems.<br>· Refrigeration cycles and heat pumps: properties of working fluids, processes with mixtures, refrigeration and heat pump processes |
| **Study Goals** | The student is able to evaluate the thermodynamic performance of various conversion processes and systems by applying the exergy concept and to identify ways to reduce overall exergy losses of frequently applied processes and systems.<br><br>More specifically, the student must be able to:<br>1. determine the exergy values, including chemical exergy, of fluid mixtures and fuels<br>2. determine exergy losses and exergy efficiencies of basic processes like fuel conversion (combustion, gasification, reforming), heat transfer, expansion turbines and compression and to present exergy losses in property diagrams and value diagrams<br>3. determine fluid properties of pure components as well as binary fluids from property diagrams and to present the processes and cycles in property diagrams of the considered fluids<br>4. identify thermodynamic losses (exergy losses) of processes that take place in the main equipment of conventional power plants, like boiler, piping, steam turbine, condenser, feedwater heaters and pumps and to explain how these losses are affected by the selected steam parameters and alternative system configurations<br>5. identify the thermodynamic losses (exergy losses) of gas turbine cycles (open cycles and closed cycles) and to explain how these losses are affected by the selected design parameters (turbine inlet temperature and pressure ratio) and alternative system configurations (intercooling, recuperation and reheat)<br>6. explain how combined cycle plants can reduce overall exergy losses in comparison with conventional power plants and gas turbine cycles and to show the effects of multiple pressure steam generation and supplementary firing<br>7. explain how and under what circumstances combined heat and power generation (CHP) can reduce overall exergy losses in comparison with separate generation of heat and power by applying value diagrams and power to heat matrices<br>8. describe the processes that occur in various types of fuel cells under development and to determine the power that can be obtained from a reversible fuel cell and indicate the losses that will occur in fuel cell systems<br>9. describe the processes that occur in refrigeration and heat pump systems<br>10. describe the processes that occur in new and renewable energy systems (Biomass, Solar Thermal, Geothermal abd CO2 capture systems) |
| **Education Method** | Lectures (4 hours per week) |
| **Literature and Study Materials** | Course material:<br>· Thermodynamica voor energiesystemen. J.J.C. van Lier, N. Woudstra. (Delft University Press, ISBN 90-407-2037-1)<br>· Fundamentals of Engineering Thermodynamics. Moran, M.J., Shapiro, H.N.. John Wiley & Sons, ISBN 0 471 97960 0<br><br>References from literature:<br>· Thermodynamik. Eine Einführung in die Grundlagen und ihre technische Anwendungen. Baehr, H.D.. ISBN 3-540-08963- |

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| | 2<br>· Thermodynamik. Grundlagen und technische Anwendungen. Einstoffsysteme. Stephan, K., Mayinger, F.. ISBN 3-540-15751-4<br>· Technische Thermodynamik. Mehrstoffsysteme und chemische Reaktionen. Schmidt, E.. ISBN 3-540-07978-5<br>· Chemical Engineering Thermodynamics. Smith, J.M., Van Ness, H.C., Abbott, M.M.. ISBN 0-07-118957-2<br>· Combined-Cycle Gas & Steam Turbine Power Plants. Kehlhofer, R..ISBN 0-88173-076-9<br>· Absorption chillers and heat pumps. K.E. Herold, R. Radermacher, S.A. Klein. (CRC Press, ISBN 0-8493-9427-9) |
| **Assessment** | Written exam |
| **Percentage of Design** | 50% |
| **Design Content** | design and optimization of system components and system lay-out |
| **Department** | 3mE Department Process & Energy |

| WB4422-11 | Thermal Power Plants | 6 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. B.J. Boersma | |
| **Instructor** | Dr.ir. W. de Jong | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/4 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | 4<br>5 | |
| **Course Language** | English | |
| **Course Contents** | The objective of the lecture Thermal Power Engineering is develop a thorough understanding of technical options to produce heat and electricity in centralized and decentralized power plants. Boundary conditions which are taken into account are sustainability, environmental impact and economical competitiveness. Possibilities to contribute to the development of highly efficient, environmentally friendly and integrated processes for the production and utilization of heat, power and secondary fuels like hydrogen will be discussed.<br><br>The lecture comprises:<br>1. Introduction: current developments, requirements, thermodynamics<br>2. Scheme of a steam power plant and a combined cycle<br>3. Combustion: fundamentals, combustion systems, emissions and emission control<br>4. Steam generation: fundamentals, boilers, design of a steam generator<br>5. Steam turbine<br>6. Cooling system and feed water preparation<br>7. Possibilities for efficiency improvement and future developments<br>8. Gas turbines and combined cycles for natural gas<br>9. Combined cycles for solid fuels (Integrated gasification combined cycle, Pressurized fluidized bed combustion, Pressurized pulverized coal combustion, Externally fired combined cycle)<br>10. Alternative concepts: fuel cells, MHD, CO2 sequestration<br>11. Possibilities for Biomass conversion | |
| **Study Goals** | The student is able to understand the technical options to produce heat and electricity in centralized and decentralized power plants. Boundary conditions which have to be taken into account like sustainability, environmental impact and economical competitiveness. Possibilities to contribute to the development of highly efficient, environmentally friendly and integrated processes for the production and utilization of heat, power and secondary fuels like hydrogen.<br><br>More specifically, the student must be able to:<br>1. describe current developments in the energy situation and trends, requirements for energy conversion systems, and the thermodynamic basics<br>2. design a scheme of a steam power plant, a combined cycle power plant and a combined heat and power plant and to calculate efficiency and basic process parameters<br>3. describe the combustion process: its fundamentals, the design characteristics of different combustion systems for different fuels, and to calculate emissions and design systems emission control<br>4. explain the construction of steam generation equipment: fundamentals that determine the design of boilers, and to calculate the main dimensions of a steam generator<br>5. describe the functioning of a steam turbine, and to calculate the power developed from steam properties<br>6. list the different parts of a energy conversion systems, describe their role, construction and operation, and to calculate the main dimensions for cooling system and feed water preparation<br>7. use thermodynamic knowledge to identify possibilities for efficiency improvement and to be aware of future developments and the bottle necks to be overcome<br>8. describe the basic properties of gas turbines and combined cycles for natural gas, and to design these systems<br>9. describe the system for combined cycles using solid fuels (Integrated gasification combined cycle, Pressurized fluidized bed combustion, Pressurized pulverized coal combustion, Externally fired combined cycle), the different components of the systems and their specific properties<br>10. describe the basics of alternative concepts: fuel cells, MHD and their impact on future energy systems<br>11. list the different options for CO2 capture and sequestration | |
| **Education Method** | Lectures, Excursion to Industrial plant with large energy consumption | |
| **Computer Use** | In the Process scheme calculation following on this course, the computer programm Cycle Tempo will be used to make the thermodynamic calculations. | |
| **Literature and Study Materials** | Course material:<br>Copies of the sheets on the internet<br>For some chapters a manuscript is available<br><br>References from literature:<br>· Strauß, K.: Kraftwerkstechnik zur Nutzung fossiler, regenerativer und nuklearer Energiequellen. Springer-Verlag, Berlin, 1998. ISBN 3-540-64750-3<br>· Black&Vatch: Drbal, L-F., Boston, P-G: Power Plant Engineering. New York, Chapman & Hall, 1996. ISBN 0-412-06401-4<br>· Stultz, S.C., Kitto, J.B.: Steam, it´s generation and use.Babcock Wilcox, Barberton, Ohio, USA, 1992. ISBN 0-9634570-0-4<br>· Elliot, T.C., Chen, K., Swanekamp, R.C.: Standard Handbook of powerplant engineering. McGraw-Hill, New York, 1997. ISBN 0-07-019435-1<br>· Dolezal, R. Dampferzeugung, Springer Verlag, ISBN 3-540-13771-8 of ISBN 0-387-13771-8. | |
| **Assessment** | Written test<br>1st hour: closed book on theoretical questions<br>2-3rd hour: open book on problem calculations | |
| **Remarks** | · Linked to (and follow up of) Thermal Power Plants is the calculation of a power plant cycle with the programme CYCLE TEMPO<br>· The participation in the lecture and exercise is strongly recommended for the examination.<br><br>Laboratory project(s):<br>The Process Scheme calculation after the course has to be completed in about 200 hours | |
| **Design Content** | The design of thermal power plants consisting of several kinds of components like: turbines, pumps, condensors, steam boilers, reheaters, preheaters that are connected by pipes and for which thermodynamic optimization is very important. | |
| **Department** | 3mE Department Process & Energy | |

| WB4432-05 | Process Dynamics and Control | 3 |
|---|---|---|
| **Responsible Instructor** | R. Toth | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/4 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | 4<br>5 | |
| **Course Language** | English | |
| **Course Contents** | Introduction<br>Overview of the process and energy industry<br>Design versus operation, batch and continuous operation<br>Objectives of process control<br><br>Modeling<br>System boundary, conservation laws and constitutive equations<br>Degrees of freedom (DOFs)<br>Examples: stirred tank (reactor), furnace, distillation column<br>Differential and algebraic equations (DAEs)<br>Simulation and analysis of DAEs<br>Common causes for nonlinearities and linear model development<br>Model representations: State space and IO forms<br>Laplace transformation and analysis (poles, zeros, stability)<br>Common building blocks of transfer functions<br>Model approximation and reduction<br><br>Control<br>Instrumentation: sensors, actuators, control systems<br>Process and Instrumentation Diagrams (P&IDs)<br>Feedback and feedforward control approaches<br>Control in the Laplace domain<br>- PID control: tuning and practical aspects (scaling, tamed D-action, etc.)<br>- Internal Model Control (IMC) and direct synthesis<br>- Extensions: ratio, feedforward, cascade, override, split-range<br>Interaction: pairing (RGA) and decoupling<br>Plantwide control: production rate control, quality control and recycles<br>Batch control and Sequential Function Charts (SFCs)<br>Optimization: Model Predictive Control (MPC), Real Time Optimization (RTO) and Scheduling and Planning (S&P) | |
| **Study Goals** | The student is capable to apply basic and advanced theoretical concepts of the Systems & Control theory which are relevant for dynamic modeling, simulation and control of chemical and energy conversion processes.<br><br>More specifically, the student must be able to:<br>1. Have a general understanding of process operation.<br>2. Develop models of a process and analyze its dynamic properties.<br>3. Design a control system for a process which is able to achieve a specified performance. | |
| **Education Method** | Lectures | |
| **Computer Use** | During the lectures and the assignment Matlab will be used. | |
| **Literature and Study Materials** | Course material:<br>Slides<br>Standard text book see below (not obligatory)<br><br>References from literature:<br>Process Dynamics and Control, Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp. | |
| **Assessment** | Assignment & oral examination | |
| **Special Information** | - | |
| **Remarks** | The final mark will be based on the assignment and the oral examination. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

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| **Year** | **2011/2012** |
| **Organization** | **Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen** |
| **Education** | **Master Mechanical Engineering** |

| **Elective Courses Automotive ME-CE** | |
|---|---|
| **Program Coordinator** | Dr. P.S.C. Heuberger |
| **Introduction 1** | Minimal 10 ECTS to select from Mechanical Systems or 10 ECTS from Processes or 10 ECTS from Automotive. |

| ME1100 | Automotive Crash Safety; Active & Passive Safety Systems | 3 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. R. Happee | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/4 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | 4<br>5 | |
| **Course Language** | English | |
| **Required for** | Specialisation Automotive in the tracks ME-CE, ME-PME, ME-BMD | |
| **Expected prior knowledge** | WB3404A Vehicle Dynamics A can be followed in parallel (recommended, not essential). | |
| **Summary** | Automotive safety technologies are covered with a focus on:<br>- vehicle dynamics control<br>- human machine interfacing and<br>- injury biomechanics. | |
| **Course Contents** | Active safety (accident prevention)<br>Passive safety (injury reduction) | |
| **Course Contents Continuation** | 1.THE ROAD SAFETY PROBLEM<br>Introduction of the course stating the problem in terms of:<br>o Fatalities, injuries and vehicle damage in a national and international perspective.<br>o Breakdown into injuries of car occupants, pedestrians, cyclists, motorcyclists and others.<br><br>Road Safety Countermeasures<br>Pre-crash, In-crash and Post-crash measures (Haddon Matrix).<br>o Vehicle safety technologies (which are the focus of this course)<br>o Road infrastructure<br>o Enforcement of speed, alcohol and other regulations<br>o Education<br><br>The Young Driver Problem & Driver Education<br>o High accident rates, countermeasures and training.<br><br>2.ACCIDENT CAUSATION<br>The majority of road accidents is caused by one or more human errors.<br>o Perception, decision and execution errors.<br>o Perception of speed, direction and distance, awareness, reaction times & failure to act.<br><br>3.ACTIVE SAFETY 1  DRIVER ASSISTANCE SYSTEMS & OBSTACLE DETECTION<br>o Driver assistance systems such as (adaptive) cruise control, brake assist, steering assist.<br>o Capabilities of radar and wireless communication to detect obstacles & improve traffic flow.<br>o Automation versus support, driver acceptance, trust and overreliance.<br><br>4.ACTIVE SAFETY 2 - VEHICLE DYNAMICS CONTROL<br>The role of tyre, suspension, steering and braking systems.<br>o Non-linear tyre properties in longitudinal and lateral slip (Moores Circle).<br>o Antilock Braking Systems (ABS) Electronic Stability Control (ESC/ESP).<br>o Real World Benefits ABS & ESC.<br><br>5.CRASH DUMMIES & INJURY CRITERIA<br>Crash dummies for the various crash test scenarios.<br>o Biofidelity: the biomechanical basis of crash test dummies.<br>o Injury severity scales (AIS, MAIS, ), injury criteria and tolerances and their derivation from biomechanical testing and real accidents.<br>o Computer simulation<br>o Detailed biomechanical models representing the real human body.<br><br>6.PASSIVE SAFETY 1  FRONTAL IMPACT<br>Frontal car impact will be used to explain how occupant safety is enhanced by the deformable vehicle front structure, the protective vehicle compartment, belt system, airbag and seat. The mechanical interaction will be illustrated quantitatively including calculation assignments.<br>o Injuries to car occupants in Frontal Impact.<br>o Vehicle structural crash; optimal energy dissipation, compartment integrity.<br>o Triggering of belt pretensioner and airbag(s).<br>o Adaptation of belt and airbag operation towards crash conditions and occupant size and position.<br>o Test procedures and design methods.<br><br>7.PASSIVE SAFETY 2  OTHER IMPACT MODES<br>SIDE IMPACT: Injuries. Test procedures & dummies. Protection offered by the protective vehicle compartment, airbags and vehicle interior padding.<br>ROLLOVER: Injuries and ejection. Test procedures & dummies. Effectiveness of curtain airbags and belts to prevent ejection.<br>REAR IMPACT: Injuries. Test procedures & dummies. Passive and active seat systems for rear impact.<br>PEDESTRIANS AND CYCLISTS impacted by vehicle fronts: Injuries. Test procedures & dummy subsystems representing body parts. Deformable vehicle front and bonnet structures. Compromises between pedestrian, frontal impact, durability and repair costs for marginal accidents (parking).<br><br>8.SAFETY TEST PROCEDURES<br>Review of regulated test procedures, consumer test procedures and best practice for active and passive safety as introduced in previous chapters.<br>o Safety in the vehicle development process.<br>o Subsystem versus full system testing.<br>o Hardware versus virtual testing.<br>o Gaps where accident types and injury types are not well covered.<br>o Gaps where innovative safety systems are not well covered. | |
| **Study Goals** | The student must be able to analyse the potential benefits of current or future active and/or passive safety systems. | |
| **Education Method** | Lectures (4 hours per week)<br><br>Supervised Assignments using sofrware used in the Automotive Industry<br>1) PreScan Assignment: simulate the effect of support systems for close following<br>2) MADYMO Assignment frontal impact, optimise belt & airbag for various impacts & body sizes. | |

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| | Self-study & smaller assignments |
| **Assessment** | Written exam<br><br>Assignments |
| **Enrolment / Application** | Register on Blackboard and mail r.happee@tudelft.nl |
| **Percentage of Design** | 25% |
| **Department** | 3mE Department Biomechanical Engineering |

| **SC4040** | **Filtering & Identification** | **6** |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. M.H.G. Verhaegen | |
| **Instructor** | Dr.ir. J.W. van Wingerden | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | 2<br>3 | |
| **Course Language** | English | |
| **Expected prior knowledge** | BSc-degree in Engineering or Mathematics with basic knowledge of linear algebra, stochastic processes, signals and systems and control theory. | |
| **Course Contents** | The objective of this course is to show the use of linear algebra and its geometric interpretation in deriving computationally simple and easy to understand solutions to various system theoretical problems. Review of some topics from linear algebra, dynamical system theory and statistics, that are relevant for filtering and system identification. Kalman filtering as a weighted least squares problem. Prediction error and output error system identification as nonlinear least squares problems. Subspace identification based on basic linear algebra tools such as the QR factorization and the SVD. Discussion of some practical aspects in the system identification cycle. See also: http:/www.dcsc.tudelft.nl/~sc4040. | |
| **Study Goals** | At the end of the course the student should be able to:<br>Derive the solution of the weighted stochastic and deterministic linear least squares problem.<br>Proof the properties of unbiasedness and minimum variance of the weighted stochastic and deterministic linear least squares problem.<br>Use an observer to estimate the state sequence of a linear time invariant system.<br>Use the Kalman filter to estimate the state sequence of a linear time invariant system using knowledge of the system matrices, the system input and output measurements, and the covariance matrices of the uncertainty of these measurements.<br>Describe the difference between the predicted, filtered and smoothed state estimates.<br>Formulate and solve the Kalman filter problem as a weighted stochastic least squars problem.<br>Use the Kalman filter theory to estimate unknown inputs of a linear dynamical system in the presence of noise perturbations on the model.<br>Use the Kalman filter theory to design filters for detection (sensor, actuator or component) failures in a linear dynamical system in the presence of noise perturbations on the model.<br>Derive subspace identification methods for different noise models and relate the different subspace identification methods via the solution of a linear least squares problem.<br>Implement a least squares solution in matlab for elementary linear estimation and subspace identification problems.<br>Apply the filtering and identification methods to derive a mathematical model from real-life data sequences. In this application the students use the systematic identification cyclic approach to refine the model. | |
| **Education Method** | Lectures 0/4/0/0 | |
| **Literature and Study Materials** | Book Filtering and System Identification: A Least Squares Approach by Michel Verhaegen and Vincent Verdult.<br>ISBN: 13-9780521875127<br><br>Deliverable by the Studentsociety Gezelschap Leeghwater. | |
| **Assessment** | Written exam (open book) and practical exercise. | |
| **Remarks** | The software package Matlab is needed to solve the practical exercise. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4210 | Vehicle Mechatronics | 4 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. E.G.M. Holweg | |
| **Instructor** | Dr. M. Corno | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | In the modern cars, electronic components, hence mechatronic components and systems are more and more embedded in the vehicle, especially in the areas of entertainment, driving comfort, engine management and active safety. Currently about 30% of the cost of a car can be contributed to electronic components and it is expected that this trend will continue in the years to come, since the car manufacturers are further improving the functionality of these systems. The introduction of electronic stability programs (ESP) has greatly contributed to road safety and more cars will be equipped with ESP and more advanced ESP systems are being developed. Besides safety, electronics can also contribute to influencing the driving behaviour of the vehicle, creating an even stronger brand identity (e.g., safety, fun to drive, etc.). In order to accomplish this, new control architectures need to be developed such as Global Chassis Control. It may be clear that by introducing electronics in vehicles it is paramount to focus on the robustness and reliability of embedded mechatronic components and systems.<br>The Vehicle Mechatronics course will focus on this trend with special attention to the integration of the electrical and mechanical domains (mechatronics) and the control aspects of the vehicle and its sub-systems. The following car systems will be reviewed; steering, braking, suspension, engine & powertrain and tires. Special focus will be given to sensors & sensor networks and actuators (e.g., drive-by-wire) within these respective systems. In the design of new vehicle control architectures such as global chassis control, a proper understanding of vehicle dynamics, robustness aspects such as fail safe and fault tolerant behaviour and the mathematical modelling and simulation (e.g., Matlab/Simulink) of the vehicle, its components and the controller shall be addressed. | |
| **Study Goals** | Automotive Sensors<br>Steering Systems (Traditional Mechanical System, Assisted Steering Systems and Steer-by-wire)<br>Braking Systems (Traditional hydraulic brakes, brake-by-wire, introduction to longitudinal braking dynamics and ABS systems)<br>Suspension (Passive, Semi-Active and Active Systems, Design considerations and control logics)<br>Electric and Hybrid Vehicles (actuation, energy storage systems, engine, powertrain and regenerative braking)<br>Design of new vehicle control architectures such as global chassis control<br>Robustness aspects (fail safe and fault tolerant behaviour)<br>Mathematical modelling and simulation | |
| **Education Method** | Lectures | |
| **Assessment** | The exam consist of two written assignments and an oral discussion of the written assignments. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4230TU | Vehicle Dynamics B - Antilock Braking Systems | 3 |
|---|---|---|
| **Responsible Instructor** | Dr. M. Corno | |
| **Instructor** | Prof.dr.ir. E.G.M. Holweg | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/4 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | 4<br>5 | |
| **Course Language** | English | |
| **Course Contents** | The control of longitudinal dynamics is one of the main areas of vehicle dynamics control. Nowadays, electronic Anti-lock Braking Systems (ABS) are a standard for all modern cars. In fact, ABS have been proven to considerably improve the safety of a vehicle in extreme circumstances. From the technological point of view, the design of automatic braking control systems is clearly highly dependent on the braking system characteristics, actuator performance and available measurements.<br>The "Vehicle Dynamics B: Antilock Braking Systems" course will focus on the problem of longitudinal dynamics control. The following topics will be discussed during the lectures:<br>- introduction to braking<br>- longitudinal dynamics: nonlinear model derivation, linearization and stability analysis<br>- braking actuators: current and future braking actuators will be reviewed and discussed from a control oriented point of view;<br>- sensors and identification/estimation problems: the relevant variables needed to control the wheel dynamics will be discussed. Sensors and estimation methods presented.<br>- control algorithms: several approaches are discussed: wheel deceleration control, wheel slip control, mixed wheel slip/ deceleration control and force based control. For each approach examples of control algorithms will be presented. Formal methods (stemming from the fields of linear, nonlinear and hybrid systems control) will be employed to derive and prove their stability and robustness properties. | |
| **Study Goals** | The goal of the course is that of providing the necessary knowledge to design, tune and validate ABS control systems. | |
| **Education Method** | Lectures | |
| **Computer Use** | In working out the problems the computer will be helpful. | |
| **Assessment** | Assignments / Oral examination | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| WB1406-07 | Experimental Dynamics | 3 |
|---|---|---|
| **Responsible Instructor** | D. de Klerk | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | none | |
| **Course Language** | English | |
| **Parts** | The course consists of two parts:<br>- part A Classes<br>- part B Laboratory experiments (four in total) | |
| **Course Contents** | Part A: Theory<br>- How does a modern measurement system work?? In specific how does it minimize desturbances and does it cope with filter effects?<br>- Pitfalls in Frequency Analysis: Descrete algorithms, Leakage, Aliasing. Know it or you'll mess up your experements.<br>- The power of Transfer and Frequency Response Functions (FRF); why are the so usefull?<br>- Experimental Modal Analysis: Does and don't, pitfalls & challenges in practice.<br>- Harmonic excitation (with frequency stepping), impulsive excitation, stochastic excitation.<br>- Sensors, how do they work, what is important when using them.<br>- Rotoranalysis, operational system analysis.<br>- Latest advances in measurement technology.<br><br>Moto: In theory, theory and practice are the same... In practice they are not.<br>This course concentrates on pointing where those differences orignate from, valuable for any who'll perform measurements, needs to analyse measurements or who tries to match his / her simulation to the experiment.<br><br>Part B: Experimental analysis<br>The second part of the course involves working on assigments meant to illustrate concepts described in Part A and to deepen insight.<br>Teams of three students each, carry out multi´ple experiments. Last year students got to simulate in Matlab a measurement system as a first assignment. Their final project involved analyzing measurement data measured by them selves on my car on the Rotterdamsestraatweg. Can it be more exciting? Yes, maybe you have always wanted to analyze a different product like a boat, train, motorbike, music instrument, etc. maybe we can come up with that exciting experiment in this year's course! | |
| **Study Goals** | In general the student is able to perform dynamic measurements, being aware of possible pitfalls.<br><br>More specifically, the student must be able to:<br>1. describe the effects of Quantization, Leakage, Aliasing in measurements and measurement equipment.<br>2. explain the principle of extracting modal parameters (resonance frequency, spring constant, damping ratio) from system response both in the time domain and in the frequency domain<br>3. explain the principle of extracting modal parameters (modal frequencies, modal gains, modal damping ratios) from system response both in the time domain and in the frequency domain<br>4. discuss relative merits of different excitation techniques (shaker with frequency sweep, impact hammer, shaker with random excitation)<br>5. discuss the prinicples and the elative merits of different sensing techniques (strain gauge, seismic mass, piezo crystal, electromagnetic induction, laser vibrometer)<br>6. carry out dynamic experiments, analyze the data, and report and discuss his findings. | |
| **Education Method** | Classes followed by laboratory projects. | |
| **Computer Use** | Matlab<br>Word<br>LaTeX<br>PowerPoint | |
| **Literature and Study Materials** | Course material:<br>- Part A: Course notes<br>- Part B: Laboratory assignments manual<br><br>References from literature:<br>- see the reference list in the Course notes. | |
| **Assessment** | Written report, and oral discussion of experiment activities and of report. | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB1413-04 | Multibody Dynamics B | 4 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. A.L. Schwab | |
| **Course Coordinator** | Ir. J.J.L. Neve | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | none<br>Different, to be announced | |
| **Course Language** | English | |
| **Expected prior knowledge** | wb1113wb, wb1216 | |
| **Course Contents** | In this course we will cover a systematic approach to the generation and solution of equations of motion for mechanical systems consisting of multiple interconnected rigid bodies, the so-called Multibody Systems. This course differs from 'Advanced Dynamics', which mostly covers theoretical results about classes of idealized systems (e.g. Hamiltonian systems), in that the goal here is to find the motions of relatively realistic models of systems (including, for example, motors, dissipation and contact constraints). Topics covered are:<br>-Newton-Euler equations of motion for a simple planar system, free body diagrams, constraint equations and constraint forces, uniqueness of the solution.<br>-Systematic approach for a system of interconnected rigid bodies, virtual power method and Lagrangian multipliers.<br>-transformation of the equations of motion in terms of generalized<br>independent coordinates, and lagrange equations.<br>-Non-holonomic constraints as in rolling without slipping, degrees of freedom and kinematic coordinates.<br>-Unilateral constraints as in contact problems.<br>-Numerical integration of the equations of motion, stability and accuracy of the applied methods.<br>-Numerical integration of a coupled differential and algebraic system of equations (DAE's), Baumgarte stabilisation, projection method and independent coordinates.<br>-Newton-Euler equations of motion for a rigid three-dimensional body, the need to describe orientation in space, Euler angles, Cardan angles, Euler parameters and Quaternions.<br>-Equations of motion for flexible multibody systems, introduction to Finite Element Method approach, Linearised equations of motion.<br><br>Upon request and if time and ability of the instructor allows, related topics are open for discussion. | |
| **Study Goals** | The student is able to find the motions of linked rigid body systems in two and three dimensions including systems with various kinematic constraints, like there are: sliding, hinges and rolling, and closed kinematic chains.<br><br>More specifically, the student must able to:<br>1. derive the Newton-Euler equations of motion for a simple planar system, draw free body diagrams, set-up constraint equations and introduce constraint forces, and demonstrate the uniqueness of the solution<br>2. derive the equations of motion for a system of interconnected rigid bodies by means of a systematic approach: virtual power method and Lagrangian multipliers<br>3. transform the equations of motion in terms of generalized independent coordinates, and derive and apply the Lagrange equations of motion<br>4. apply the techniques from above to systems having non-holonomic constraints as in rolling without slipping, degrees of freedom and kinematic coordinates<br>5. apply the techniques from above to systems having unilateral constraints as in contact problems<br>6. perform various numerical integration schemes on the equations of motion, and predict the stability and accuracy of the applied methods<br>7. perform numerical integration on a coupled system of differential and algebraic equations (DAE's), apply Baumgarte stabilization, the coordinate projection method and transformation to independent coordinates<br>8. derive the Newton-Euler equations of motion for a general rigid three-dimensional body system connected by constraints, identify the need to describe orientation in space<br>describe the orientation in 3-D space of a rigid body by means of: Euler angles, Cardan angles, Euler parameters and Quaternions, derive the angular velocity and accelerations in terms of these parameters and their time derivatives, and their inverse<br>9. derive the equations of motion for flexible multibody systems by means of a Finite Element Method approach, and extend this to linearised equations of motion | |
| **Education Method** | Lectures (2 hours per week) | |
| **Computer Use** | The course is computer-oriented. In doing the assignments you will be using Matlab, Maple or related computer software. | |
| **Literature and Study Materials** | Course material: Arend L. Schwab, `Applied Multibody Dynamics', Delft, 2003<br><br>References from literature:<br>A.A.Shabana, ' Dynamics of multibody systems', Wiley, New York, 1998.<br>E.J.Haug, ' Computer aided kinematics and dynamics of mechanical systems, Volume I: Basic methods', Allyn and Bacon, Boston, 1989.<br>P.E.Nikravesh, ' Computer-aided analysis of mechanical systems', Prentice-Hall, Englewood Cliffs, 1988.<br>M. Géradin, A. Cardano, ' Flexible multibody dynamics: A finite element approach', J. Wiley, Chichester, New York, 2001. | |
| **Assessment** | Final Project | |
| **Remarks** | There will be weekly assignments and a final project. You have to make a report on the final project. In doing the assignments I strongly encourage you to work together. The final project is individual. Check out the up-to-date web page at http://tam.cornell.edu/~als93/ | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

| WB2404 | Man-machine systems | 4 |
|---|---|---|
| **Responsible Instructor** | Ir. J.C.F. de Winter | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | Different, to be announced<br>Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | The entire spectrum between manual and supervisory control is treated.<br><br>The following topics are covered<br>- History and scope of man-machine systems (pre WW2 era, knobs and dials, borrowed engineering models, human-computer interaction)<br>- Information-processing concepts (mental workload, vigilance, situation awareness, stimulus-response compatibility)<br>- Automation (misuse, disuse, abuse of automation, ironies of automation, adaptive automation)<br>- Task analysis<br>- Human error<br>- Organisational factors and cognitive work analysis<br>- Accident analysis and prevention<br>- Simulation and training, augmented feedback, virtual reality, simulators<br><br>Examples and case studies will be provided from e.g., car driving, aviation, medicine, and process control.<br>The course will feature a guest lecture from a specialist in the field. | |
| **Study Goals** | The student should be able to<br>- provide definitions of the key topics of the course<br>- explain and reflect on the differences between manual control and supervisory control<br>- explain how humans can interact with and benefit from automation<br>- explain the disadvantages of automation; explain how automation changes the nature of human work<br>- criticize and interpret existing human-machine-interface designs<br>- select and perform a task analysis<br>- classify different forms of human error<br>- reflect on different human error models<br>- explain how design decisions affect performance, human error, and safety<br>- summarize and interpret cases about accidents<br>- explain how human skills develop and how feedback affects skill acquisition<br>- explain how simulator fidelity and training effectiveness of simulators can be assessed | |
| **Education Method** | Lectures (4 hours per week)<br>Each year an excursion will be held to a research centre or industrial plant to show some of the items discussed during this course. | |
| **Literature and Study Materials** | Powerpoint slides of the lectures, scientific articles, and supplementary materials will be made available on Blackboard. | |
| **Assessment** | Closed-book written exam (50% open questions, 50% multiple choice questions) | |
| **Department** | 3mE Department Biomechanical Engineering | |

| WB3404A | Vehicle Dynamics A | 3 |
|---|---|---|
| **Responsible Instructor** | Ir. E.J.H. de Vries | |
| **Course Coordinator** | Ir. J.J.L. Neve | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | Basic elements of the dynamics of road vehicles (car, truck, motorcycle). Ride vibration response to road unevenness. Sine and stochastic roadprofile. Single, two and three mass/spring/damper systems. Linear and non-linear models. Vibrational modes and stability. Discomfort analysis. System identification. Roadholding: vehicle handling and stability. Response to stear input and side wind. Singel two-wheel vehicle model to discuss effects of tyres, inertia and geometry. Influence of several design variables: steering and wheel suspension, kinematics and compliance, toe angle, camber, roll axis, roll stabilizer, load transfer. Motorcycle stability and modal shapes (brief discussion of results) | |
| **Study Goals** | The student is able to apply dynamics methods and knowledge on vehicle specific problems<br><br>More specifically, the student must be able to:<br>1. quantify comfort and road holding: recognise the paradox for optimal suspension design<br>2. realize that linear models are approximations of reality in many aspects<br>3. employ single mass and higher order models for vertical vibration analysis, and justify the choice for single d.o.f., quarter car or half car model<br>4. implement the most common non linear elements in vehicle(models) and discover some analytical solution methods<br>5. solve non-Linear problems with numerical integration routines<br>6. apply Lagrange method to derive equations of motion<br>7. analyze driving stability in the horizontal plane using Hurwitz criterion<br>8. characterize vehicle handling in terms of under- and oversteer, apply critical and characteristic velocity on the vehicle behaviour<br>9. derive the single track model, linear and including elementary non-linear properties | |
| **Education Method** | Lectures (4 hours per week), practical exercises | |
| **Computer Use** | In working out the problems the computer will be helpful, for some problems essential. MatLab will be used for analysis and simulation | |
| **Literature and Study Materials** | Course material:<br>Lecture notes: Vehicle Dynamics A (pdf on blackboard)<br><br>References from literature:<br>Mitschke, Dynamik der Kraftfahrzeuge<br>Gillespie, Fundamentals of vehicle dynamics 1992<br>Genta, Motor Vehicle Dynamics 1997, 2003, 2006<br>Pacejka, Tyre and Vehicle Dynamics 2002, 2006 (2nd) | |
| **Assessment** | Oral exam, by appointment | |
| **Remarks** | Laboratory project(s):<br>About 7 problems (exercises) are requested to prepare at home. | |
| **Design Content** | The effect of design parameters of wheel suspension and stearing system are discussed. | |
| **Department** | 3mE Department Precision & Microsystems Engineering | |

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|---|---|
| **Year** | **2011/2012** |
| **Organization** | **Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen** |
| **Education** | **Master Mechanical Engineering** |

| **Elective Courses Fundamentals ME-CE** | |
|---|---|
| **Program Coordinator** | Dr. P.S.C. Heuberger |
| **Introduction 1** | Minimal 10 ECTS to select from Fundamentals |

| SC4040 | Filtering & Identification | 6 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. M.H.G. Verhaegen | |
| **Instructor** | Dr.ir. J.W. van Wingerden | |
| **Contact Hours / Week x/x/x/x** | 0/4/0/0 | |
| **Education Period** | 2 | |
| **Start Education** | 2 | |
| **Exam Period** | 2<br>3 | |
| **Course Language** | English | |
| **Expected prior knowledge** | BSc-degree in Engineering or Mathematics with basic knowledge of linear algebra, stochastic processes, signals and systems and control theory. | |
| **Course Contents** | The objective of this course is to show the use of linear algebra and its geometric interpretation in deriving computationally simple and easy to understand solutions to various system theoretical problems. Review of some topics from linear algebra, dynamical system theory and statistics, that are relevant for filtering and system identification. Kalman filtering as a weighted least squares problem. Prediction error and output error system identification as nonlinear least squares problems. Subspace identification based on basic linear algebra tools such as the QR factorization and the SVD. Discussion of some practical aspects in the system identification cycle. See also: http:/www.dcsc.tudelft.nl/~sc4040. | |
| **Study Goals** | At the end of the course the student should be able to:<br>Derive the solution of the weighted stochastic and deterministic linear least squares problem.<br>Proof the properties of unbiasedness and minimum variance of the weighted stochastic and deterministic linear least squares problem.<br>Use an observer to estimate the state sequence of a linear time invariant system.<br>Use the Kalman filter to estimate the state sequence of a linear time invariant system using knowledge of the system matrices, the system input and output measurements, and the covariance matrices of the uncertainty of these measurements.<br>Describe the difference between the predicted, filtered and smoothed state estimates.<br>Formulate and solve the Kalman filter problem as a weighted stochastic least squars problem.<br>Use the Kalman filter theory to estimate unknown inputs of a linear dynamical system in the presence of noise perturbations on the model.<br>Use the Kalman filter theory to design filters for detection (sensor, actuator or component) failures in a linear dynamical system in the presence of noise perturbations on the model.<br>Derive subspace identification methods for different noise models and relate the different subspace identification methods via the solution of a linear least squares problem.<br>Implement a least squares solution in matlab for elementary linear estimation and subspace identification problems.<br>Apply the filtering and identification methods to derive a mathematical model from real-life data sequences. In this application the students use the systematic identification cyclic approach to refine the model. | |
| **Education Method** | Lectures 0/4/0/0 | |
| **Literature and Study Materials** | Book Filtering and System Identification: A Least Squares Approach by Michel Verhaegen and Vincent Verdult.<br>ISBN: 13-9780521875127<br><br>Deliverable by the Studentsociety Gezelschap Leeghwater. | |
| **Assessment** | Written exam (open book) and practical exercise. | |
| **Remarks** | The software package Matlab is needed to solve the practical exercise. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4060 | Model Predictive Control | 4 |
|---|---|---|
| **Responsible Instructor** | Dr.ir. A.J.J. van den Boom | |
| **Contact Hours / Week x/x/x/x** | 0/0/3/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Expected prior knowledge** | Undergraduate curriculum | |
| **Course Contents** | The model predictive control (MPC) strategy yields the optimization of a performance index with respect to some future control sequence, using predictions of the output signal based on a process model, coping with amplitude constraints on inputs, outputs and states. The course presents an overview of the most important predictive control strategies, the theoretical aspects as well as the practical implications, that makes model predictive control so successful in many areas of industry, such as petro-chemical industry and chemical process industry. Hands-on experience is obtained by MATLAB exercises with academic examples and a industrial simulation of MPC on a two-product (binary) distillation column. Contents of the course: General introduction. Differences in models and model-structures, advantages and limitations. Prediction models in state-space setting. Standard predictive control scheme. Relation standard form with GPC, LQPC and other predictive control schemes. Finite/Infinite horizon MPC. Solution of the standard predictive control problem. Stability, robustness, initial and advanced tuning. Robust design in predictive control. See also: http://www.dcsc.tudelft.nl/~sc4060 | |
| **Study Goals** | Study Goals:<br>The student should be able to<br>1. Explain how and why MPC has emerged from industry.<br>2. List the five basic items of MPC and discuss their role.<br>3. Identify, recognize and describe different type of models in MPC and explain when a type of model is suited for a specific application.<br>4. Show that all models can be transformed into a state-space model.<br>5. Understand the concept of prediction in MPC.<br>6. Make a prediction in the noiseless and the noisy case.<br>7. Explain why a standard formulation is desirable.<br>8. Transform any MPC problem into the standard MPC problem.<br>9. Derive the steady-state of a system.<br>10. Solve the finite and infinite horizon problem.<br>11. Derive the realization for the LTI-case and for the inequality constrained case.<br>12. Describe two ways to deal with infeasibility.<br>13. Discuss stability for the LTI case and in the inequality constrained case.<br>14. Describe the use of the end-point constraint and the infinite prediction horizon.<br>15. Give the relation of the MPC scheme and the IMC scheme.<br>16. Motivate the rules-of-thumb for initial tuning and use these rules for tuning an MPC controller.<br>17. Describe the concept of robustness in MPC.<br>18. Motivate and use the rules of robust tuning in MPC.<br>19. Derive an MPC controller for various academic and industrial examples using MATLAB. | |
| **Education Method** | Lectures 0/0/3/0 | |
| **Literature and Study Materials** | Course notes "Model Predictive Control" by Ton van den Boom (TU Delft) 2011. | |
| **Assessment** | Written exam and a homework assignment | |
| **Remarks** | Computer use: for the homework assignment, the use of MATLAB on PC is required. The assignment can be done either at home or at the DCSC laboratory. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4081-10 | Knowledge Based Control Systems | 4 |
|---|---|---|
| **Responsible Instructor** | Prof.dr. R. Babuska | |
| **Instructor** | Ir. I. Grondman | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Course Contents** | Theory and applications of knowledge-based and intelligent control systems, including fuzzy logic control and artificial neural networks:<br>* Introduction to intelligent control<br>* Fuzzy sets and systems<br>* Intelligent data analysis and system identification<br>* Knowledge based fuzzy control (direct and supervisory)<br>* Artificial neural networks, learning algorithms<br>* Control based on fuzzy and neural models<br>* Reinforcement learning<br>* Examples of real-world applications | |
| **Study Goals** | Main objective: understand and be able to apply 'intelligent control' techniques, namely fuzzy logic and artificial neural networks to both adaptive and non-adaptive control.<br><br>After successfully completing the course, the student is able to:<br><br>* Name the limitations of traditional linear control methods and state the motivation for intelligent control. Give examples of intelligent control techniques and their applications.<br><br>* Formulate the mathematical definitions of a fuzzy set and the associated concepts and properties (alpha-cut, support, convexity, normality, etc.), basic fuzzy set-theoretic operators, fuzzy relations and relational composition.<br><br>* Explain the notion of a fuzzy system and define the Mamdani, Takagi-Sugeno and singleton fuzzy model. State and apply the compositional rule of inference and the Mamdani algorithm. Define and apply the center of gravity and the mean of maxima defuzzification method.<br><br>* Describe how fuzzy models can be constructed from data, give examples of techniques for antecedent and consequent parameter estimation. Compute consequent parameters in Takagi-Sugeno fuzzy model by using the least-squares method.<br><br>* Explain the difference between model-based and model-free fuzzy control design. Give the basic steps in knowledge-based fuzzy control design. Define a low-level and a high-level (supervisory) fuzzy controller, explain the differences.<br><br>* Explain the concept of an artificial neural network and a neuro-fuzzy network, give some examples and explain the differences. Define and apply the back-propagation training algorithm. Explain the difference between first-order and second-order gradient methods.<br><br>* Show how dynamics are incorporated into fuzzy models and neural networks, give examples. Discuss how dynamic models can be identified from data.<br><br>* Give block diagrams and explain the notions of inverse-model control, predictive control, internal model control, direct and indirect adaptive control. Explain the meaning of the variables and parameters in recursive least-squares estimation.<br><br>* Explain the motivation and the basic elements of reinforcement learning. Define and explain the concepts of value function, Bellman equation, value iteration, Q-iteration, on-line reinforcement learning algorithms, actor-critic control scheme.<br><br>* Define hard, fuzzy and possibilistic partitions, explain the fuzzy c-means algorithm and its parameters.<br><br>* Implement and apply the above concepts to a simulated nonlinear process or a given data set, using Matlab and Simulink. | |
| **Education Method** | Lectures and two assignments - literature assignment and practical Matlab / Simulink assignment. | |
| **Literature and Study Materials** | Lecture notes: R. Babuska. Knowledge-Based Control Systems. Overhead sheets and other course material (software, demos) can be downloaded from the course Website (www.dcsc.tudelft.nl/~sc4081) and handed out at the lectures. | |
| **Assessment** | Written exam, closed book.<br><br>* SC4081-10 D1 The exam constitute 60% of the final mark<br>* SC4081-10 D2 Literature assignment 20% of the final mark<br>* SC4081-10 D3 Practical Matlab / Simulink assignment 20% of the final mark.<br><br>A mini-symposium is organized in order for the students to present the results of the literature assignment. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| *SC4081-10 D1* | *Knowledge Based Control Systems, Exam* | *3* |
|---|---|---|
| **Responsible Instructor** | Prof.dr. R. Babuska | |
| **Contact Hours / Week x/x/x/x** | See details SC4081-10 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| *SC4081-10 D2* | *Knowledge Based Control Systems, Literature* | *.5* |
|---|---|---|
| **Responsible Instructor** | Prof.dr. R. Babuska | |
| **Contact Hours / Week x/x/x/x** | See details SC4081-10 | |
| **Education Period** | Different, to be announced | |
| **Exam Period** | Different, to be announced | |
| **Course Language** | English | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| *SC4081-10 D3* | *Knowledge Based Control Systems, Matlab* | *.5* |
|---|---|---|
| **Responsible Instructor** | Prof.dr. R. Babuska | |
| **Contact Hours / Week x/x/x/x** | See details SC4081-10 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | Different, to be announced | |
| **Course Language** | English | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4091 | Optimization in Systems and Control | 4 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. B.H.K. De Schutter | |
| **Contact Hours / Week x/x/x/x** | 4/0/0/0 | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | 1<br>2 | |
| **Course Language** | English | |
| **Expected prior knowledge** | Basic knowledge about linear state space models and stability, and basic experience with Matlab | |
| **Course Contents** | In this course we study numerical optimization methods, mainly from a user point of view, and we discuss several applications of optimization in systems and control. First we discuss the basic characteristics and properties of various optimization methods. We also provide guidelines to determine which algorithms are most suited for a given optimization problem. Next, the previously treated optimization methods are used in a multi-criteria controller design application. We also focus on the translation of the design constraints into mathematical constraints. Another important topic is the determination of good initial conditions. For more information, see: http://www.dcsc.tudelft.nl/~sc4091 | |
| **Study Goals** | After this course the students should be able to select the most efficient and best suited optimization algorithm for a given optimization problem. They should also be able to reformulate an engineering problem into a (mathematical) optimization problem starting from the given specifications. They should be able to reduce the complexity of the problem using simplifications and/or approximations so as to augment the efficiency of the solution approach. | |
| **Education Method** | Lectures | |
| **Literature and Study Materials** | Lecture notes "Optimization in systems and control" by T. van den Boom and B. De Schutter, Delft, 2011 + handouts | |
| **Assessment** | written examination (closed book, no calculators) + report on the practical assignment | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4120 | Special Topics in Signals, Systems & Control | 3 |
|---|---|---|
| **Course Coordinator** | Dr. P.S.C. Heuberger | |
| **Instructor** | Prof.dr.ir. P.M.J. Van den Hof | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/2 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Course Contents** | The lecture has a changing content, directed towards the current developments in signal analysis, system identification and control engineering. It either consists of contributions from different lecturers, and is sometimes organized in the form of a seminar sequence with active participation of students.<br><br>Please notice that the course is not offered every year. Check Blackboard for details. | |
| **Study Goals** | Acquire competence to report on a particularly chosen scientific development within signal analysis, system identification or control<br>Identify essentials in an advanced scientific article or book chapter about signals, systems or control<br>Compose a summary with a balanced exposition of generic aspects, details, examples<br>Orally report on results of investigation, including an educated evaluation of the subject<br>Defend presentation and evaluation in a scientific discussion with audience<br>Enter a scientific dispute about the particular topic of specialization of a fellow-student | |
| **Education Method** | Lecture 0/0/0/2 | |
| **Literature and Study Materials** | Lecture notes or book to be announced | |
| **Assessment** | Appointment | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4150 | Fuzzy Logic and Engineering Applications | 3 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. J. Hellendoorn | |
| **Contact Hours / Week x/x/x/x** | 3/0/0/0 | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | 1<br>2 | |
| **Course Language** | English | |
| **Required for** | Core curriculum | |
| **Course Contents** | Fuzzy logic techniques can be applied in various engineering domains, mainly in fields where reasoning under uncertainty plays an important role. This course provides background in fuzzy set theory, fuzzy logic and related soft-computing techniques with applications in control, information and data processing, artificial intelligence and decision making. See also: http:/www.dcsc.tudelft.nl/~sc4150. | |
| **Study Goals** | Main objective: understand fuzzy logic, fuzzy decision making and fuzzy control, and be able to translate linguistic expressions into fuzzy sets and derive conclusions.<br>Understand the difference between fuzziness, probability and possibility.<br>Understand characteristic functions, operations on fuzzy sets and fuzzy relations.<br>Apply the Compositional Rule of Inference and the Generalized Modus Ponens.<br>Analyze the defuzzification procedure.<br>Know fuzzy data bases.<br>Apply Mamdani and Gödel inference for fuzzy control.<br>Understand look-up tables for fuzzy controllers, stability and robustness.<br>Apply sliding mode fuzzy control.<br>Synthesize fuzzy decision making.<br>Know subjectivity and single-step, single-person decision making.<br>Apply measures, weights, and criteria-criteria dependency.<br>Analyze decision operators. | |
| **Education Method** | Lectures | |
| **Literature and Study Materials** | Course notes (sold online via Blackboard) | |
| **Assessment** | Written, open book | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4160 | Modeling and Control of Hybrid Systems | 3 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. B.H.K. De Schutter | |
| **Instructor** | A. Abate | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Expected prior knowledge** | basic systems and control course (such as e.g. SC3020ET, SC4020, SC4031, ...), basic experience with Matlab (for the practical assignment) | |
| **Course Contents** | Hybrid systems are characterized by the interaction of time-continuous models (governed by differential or difference equations) on the one hand, and logic rules and discrete-event systems (described by, e.g., automata, finite state machines, etc.) on the other. In this course we give an overview of the field of hybrid systems ranging from modeling, over analysis and simulation, to verification and control. We particularly focus on modeling, analysis, and control of tractable classes of hybrid systems. | |
| **Study Goals** | After this course the students should be familiar with some basic modeling, analysis and control techniques for hybrid systems, and they should be able to explain in their own words the main ideas of each method and to indicate the major advantages and disadvantages of each method.<br>The students should also be able to apply these techniques on simple case studies. | |
| **Education Method** | Lectures 0/0/4/0 | |
| **Literature and Study Materials** | Lecture notes "Modeling and control of hybrid systems" by B. De Schutter and W.P.M.H. Heemels, Delft 2011 | |
| **Assessment** | written mid-term exam (closed-book, counts for 40% of the final marks) + practical assignment (assessed through written report, counts for 60% of the final marks) | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4240TU | Control Methods for Robotics | 3 |
|---|---|---|
| **Responsible Instructor** | Dr. G.A. Delgado Lopes | |
| **Contact Hours / Week x/x/x/x** | 0/0/4/0 | |
| **Education Period** | 3 | |
| **Start Education** | 3 | |
| **Exam Period** | 3<br>4 | |
| **Course Language** | English | |
| **Expected prior knowledge** | Linear Algebra, Differential Equations, Mechanics | |
| **Course Contents** | This course covers control methods for various classes of robotic systems such as manipulators and mobile robots (legged and wheeled). The control methodologies presented include:<br><br>1. Computed torque control<br>2. Impedance control<br>3. Passivity-based control<br>4. Nonholonomic control<br>5. Learning control<br>6. Distributed control<br>7. Hybrid control & Discrete Event Systems | |
| **Study Goals** | After successfully completing the course, the students should be able to:<br><br>- Identify classes of models for various types of robotic platforms<br>- Identify the workspace and configuration spaces<br>- Apply stability analysis tools<br>- Design interacting motion controllers for manipulator robots<br>- Design gait generators for walking robots<br>- Design stabilizing and tracking controllers for wheeled robots | |
| **Education Method** | Lectures 0/0/4/0 | |
| **Books** | Recommended books:<br>Spong, Hutchinson, Vidyasagar, "Robot Modeling and Control"<br>Murray, Lee, Sastry, "A Mathematical Introduction to Robotic Manipulation"<br>Khalil, "Nonlinear Systems" | |
| **Assessment** | 30% homework, 70% written exam | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| SC4250 | Probabilistic Models in the Life Sciences | 2 |
|---|---|---|
| **Responsible Instructor** | A. Abate | |
| **Course Coordinator** | Dr. P.S.C. Heuberger | |
| **Contact Hours / Week x/x/x/x** | 0/0/0/2 | |
| **Education Period** | 4 | |
| **Start Education** | 4 | |
| **Exam Period** | 4<br>5 | |
| **Course Language** | English | |
| **Expected prior knowledge** | No prior knowledge of Biology is required. Also, the course will provide the notions of statistics needed. Students are instead expected to be conversant with (deterministic) dynamical models (ODE, finite-state automata), and to be proficient with MATLAB. | |
| **Course Contents** | Background: advances in experimental technologies and in computational availability and software have brought to the birth of a discipline -- Systems Biology -- at the intersection between traditional biology, engineering, and the formal sciences. The development of formal models and their analysis/simulation facilitates this integration. This course focuses on the development, the use, and the analysis of stochastic (that is, probabilistic) models in the Life Sciences.<br><br>Theory and Models:<br><br>-- Quick recap of basic probability theory and basics of stochastic processes<br>-- Probabilistic Graphs: theory of Markov Chains, Bayesian and Network inference, Stochastic Petri Networks<br>-- Monte-Carlo Simulations: principles and use<br>-- Random dynamics: from ordinary to stochastic differential equations<br>-- Sensitivity analysis, Robustness<br>-- Putting it all together: Stochastic Hybrid Systems<br><br>Applications in the Life Sciences:<br><br>-- Basics of molecular cell biology<br>-- Phylogeny and simple graphical models<br>-- Intrinsic and extrinsic noise in genetic and regulatory networks<br>-- Chemical and biochemical reaction networks: The Chemical Master Equation, its linear-noise approximation, its Langevin approximation, moment closures<br>-- Chemical and biochemical reaction networks: the Stochastic Simulation Algorithm (Gillespie's SSA)<br>-- Metabolic networks: Michaelis-Menten Enzyme Kinetics<br>-- Particles in a medium: Random walks and Brownian motion<br><br>No prior knowledge of Biology is required. Also, the course will provide the notions of statistics needed. Students are instead expected to be conversant with (deterministic) dynamical models (ODE, finite-state automata), and to be proficient with MATLAB. | |
| **Study Goals** | This course has two principal components: a theoretical and an applicative one (see course contents). On the one hand, students learn the basics of modeling, simulation, and control of stochastic systems. On the other, students will apply these models to case studies from the Life Sciences.<br><br>By taking this course, the student:<br>- will receive a broad introduction to the development and use of (simple) probabilistic models<br>- will learn how to characterize such models, how to simulate them, and how to analyze them<br>- will be exposed to a number of concepts and problems in the Life Sciences that are current focus of research in the field of Systems Biology. This will provide the student some background material to further work on these application themes, or simply to read/learn more about this field.<br><br>The course is tailored both to engineering/math/computer science MSc students with an interest in biology, as well as to students in biochemistry, biology and related disciplines with a keen interest for quantitative and formal approaches in biology. | |
| **Education Method** | Lectures. | |
| **Computer Use** | The final project assignment may be based on Matlab. | |
| **Literature and Study Materials** | Three reference textbooks:<br>1) U. Alon, "An Introduction to Systems Biology". Chapman & Hall/CRC Press, 2007.<br>2) Z. Szallasi, J. Stelling, and V. Periwal, "System Modeling in Cellular Biology - From Concepts to NUts and Bolts". The MIT Press, 2007.<br>3) D.J. Wilkinson, "Stochastic modeling for systems biology". Chapman & Hall/CRC Press, 2006.<br><br>Furthermore, the Instructor will circulate additional material based on original scientific literature. | |
| **Assessment** | The final grade will be based on two parts:<br>1. home work. Students will be assigned a (short) project (possibly done in small groups), based on modeling or on simulation. Alternatively, the student will be assigned some literature study. The outcome will be short report, to be graded by the Instructor.<br>2. in class. Final presentation of the above report in front of class. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |
| **Contact** | Alessandro Abate, a.abate@tudelft.nl<br>DCSC, 3mE, 8C-4-24<br>85606 | |

| WI4218 | Convex Optimization and Systems Theory | 6 |
|---|---|---|
| **Responsible Instructor** | Dr. F. Vallentin | |
| **Instructor** | Dr. J.W. van der Woude | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Expected prior knowledge** | Good knowledge of linear algebra and analysis. | |
| **Course Contents** | In the last twenty years the following paradigm for dealing with problems in systems theory was established: A wide variety of problems arising in systems theory can be reduced to standard convex optimization problems that involve matrix inequalities. These standard problems can be solved efficiently; in theory and in practice.<br><br>The aim of the course is to provide the theoretical background as well as to introduce the practical skills needed for solving problems in systems theory using this new paradigm. For establishing this goal the course is divided into five parts:<br><br>1. Convexity and efficient computation<br><br>We introduce basic notions from convexity and from computational complexity theory. Using this we can distinguish between easy and difficult computational problems.<br><br>2. Modelling of optimization problems as convex optimization problems<br><br>We study methods to show whether an optimization problem allows a convex model or not. We deal with several methods to get convex relaxations of non-convex models.<br><br>3. Solving convex optimization problems<br><br>We introduce efficient, interior-point methods for convex optimization in the case of conic optimization problems. Conic optimization problems are ubiquitous, they include: linear optimization, convex quadratic optimization, semidefinite optimization.<br><br>4. Several problems from systems theory<br><br>We introduce the notions of dissipativity, system norm, robustness and controller synthesis from systems theory. We discuss some common additional requirements that we want to impose on our system.<br><br>5. Using convex optimization in systems theory<br><br>We show how the problems described in 4 can be modelled using linear matrix inequalities. Then one can solve them by efficient methods from convex optimization. | |
| **Study Goals** | After successful participation in the course students will be able to:<br><br>- explain the basic concepts of convexity and complexity theory<br>- give examples of problems in systems theory<br>- apply tools from convex optimization to systems theory<br>- model optimization problem as convex optimization problems<br>- solve convex optimization problems with the help of computer software | |
| **Education Method** | lectures, exercise sessions | |
| **Literature and Study Materials** | S. Arora, B. Barak, Computational Complexity: A Modern Approach, Cambridge University Press, 2009<br><br>A. Barvinok, A Course in Convexity, AMS, 2002<br><br>A. Ben-Tal, A.Nemirovski, Lectures on Modern Convex Optimization. Analysis, Algorithms, and Engineering Applications, MPS-SIAM Series on Optimization, 2001.<br><br>S. Boyd, L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.<br><br>S. Boyd, L. El Ghaoui, E. Feron, V. Balakrishnan,<br>Linear Matrix Inequalities in System and Control Theory, SIAM 1994<br><br>C. Scherer, S. Weiland, Linear Matrix Inequalities in Control, Delft Center for Systems and Control.<br><br>Many of the above references are available online. | |
| **Assessment** | Oral exam (50%), exercises and group projects (50%) | |
| **Remarks** | For questions students may contact the instructors. | |

| WI4221 | Control of Discrete-Time Stochastic Systems | 6 |
|---|---|---|
| **Responsible Instructor** | Prof.dr.ir. J.H. van Schuppen | |
| **Contact Hours / Week x/x/x/x** | 0/0/2/2 | |
| **Education Period** | 3<br>4 | |
| **Start Education** | 3 | |
| **Exam Period** | Exam by appointment | |
| **Course Language** | English | |
| **Expected prior knowledge** | Control and system theory (undergraduate level), linear algebra,differential equations, stochastic processes. | |
| **Course Contents** | Discrete-time stochastic systems, distributions and invariant measures. Stochastic realization. Control with complete observations, optimal control theory, dynamic programming for finite and infinite horizons. Kalman filtering and special cases of filtering of stochastic systems. Control with partial observations, separation property. Elementary game and team problems, decentralized control. | |
| **Study Goals** | Students will be able to explain the fundamental concepts of stochastic systems. They will be able to solve elementary optimal control problems of stochastic systems by dynamic programming. They will be able to apply the Kalman filter.<br>Finally, they will be able to explain the control of stochastic systems with partial observations. | |
| **Education Method** | Lectures/exercises | |
| **Literature and Study Materials** | Notes for this course can be found on the corresponding Blackboard site. | |
| **Assessment** | Oral exam based on lecture notes and on home work sets. | |
| **Remarks** | For questions concerning the course students may contact the responsible instructor.<br>For more details, see also http://homepages.cwi.nl/~schuppen/courses/tudmath/controlstocdt2011s/courseguide.html | |

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|---|---|
| **Year** | **2011/2012** |
| **Organization** | **Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen** |
| **Education** | **Master Mechanical Engineering** |

| **Master year 2** | |
|---|---|
| **Program Coordinator** | Dr. P.S.C. Heuberger |

| ME2200-15 | Traineeship (optional) | 15 |
|---|---|---|
| **Responsible Instructor** | Dr. P.S.C. Heuberger | |
| **Contact Hours / Week x/x/x/x** | x/x/x/x | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | none | |
| **Course Language** | English | |
| **Course Contents** | ME2200-15 is the code for the internship of the track Control Engineering (of the MSc Mechanical Engineering). This internship is optional. Commonly students combine internships with the MSc project. | |
| **Study Goals** | The student has demonstrated his capability, independently and in consultation with specialists, to define, limit, solve and discuss systems and control problems as defined in the internship projectdescription.<br><br>The student has proven to be capable of communicating about his Internship research project both through an oral presentation and a report.<br><br>The student has demonstrated his capability to consider and discuss the technological, ethical and societal impact of his internship work.<br><br>The student has shown his life-long learning competence by investigating the scientific publications related to the problems investigated in his internship thesis and processing this information in his thesis. | |
| **Education Method** | Project | |
| **Assessment** | Report and oral presentation | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| ME2210-15 | Literature Assignment | 15 |
|---|---|---|
| **Responsible Instructor** | Dr. P.S.C. Heuberger | |
| **Contact Hours / Week x/x/x/x** | x/x/x/x | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | none | |
| **Course Language** | English | |
| **Course Contents** | The literature study is typically the initial phase of an MSc Thesis project (ME2290-45), with the purpose to get acquainted with the scientific publications within the realm of the MSc-thesis project, and to prepare for the specific topics to be investigated.<br>The student will need to search for recent publications (i.e. articles, theses, books) that are relevant for the particular thesis project. It is important to be very careful in judging the literature, since not everything written even in high-standard journals is useful - or even correct. In other words, one should be very critical and selective of which publications to use, and one should try to fully understand those that are relevant. See also<br>http://www.dcsc.tudelft.nl/Education/--> Graduation Guide for guidelines to perform literature searches.<br>Moreover the student needs to identify the current issues in his research area in order to avoid performing research on questions that have already been resolved in the literature.<br>Once some well-motivated choices have been made on what is planned to be to investigated, these are summarized in a report. This will then form the basis for the subsequent MSc-project work.<br>At the end of the literature survey period the student has to orally report on the findings of the survey, by means of a formal 20-25 minutes MSc-colloquium presentation. | |
| **Study Goals** | The study goals of the literature study are:<br>o The student is able to search for/identify publications that are relevant to a specific research question<br>o The student is able to create an accurate overview of the state of the art for a specific research question<br>o The student is able to write a report "in his own words", referring to the correct sources where necessary, and with any form of plagiarism. | |
| **Education Method** | The literature study is individual work, under supervison of a daily supervisor and often also a full professor. | |
| **Assessment** | The literature report is assessed by the daily supervisor. Important aspects that are taken into consideration are the contents, the organization and clarity in writing and also the process in which the study is performed. An evaluation form is available from the DCSC education coordinator. | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

| ME2290-45 | MSc Thesis Project | 45 |
|---|---|---|
| **Responsible Instructor** | Dr. P.S.C. Heuberger | |
| **Contact Hours / Week x/x/x/x** | x/x/x/x | |
| **Education Period** | 1 | |
| **Start Education** | 1 | |
| **Exam Period** | none | |
| **Course Language** | English | |
| **Course Contents** | The MSc-thesis work is the final assignment in the MSc-program, during which a student either further develops the theoretical knowledge gained in the literature survey, or applies it in the form of computer simulations or in the form of experiments (depending on the chosen project). The student will set up and carry out a research project in the field of Systems and Control. The subject of research can be provided by the staff or a company, however it is also possible to propose another project. The final project can be carried out within the framework of ongoing research at the university, within a company, within a research institute or at another university.<br>See also http://www.dcsc.tudelft.nl/Education/--> Graduation Guide. | |
| **Study Goals** | The overall objective of this assignment is to demonstrate a sufficient academic level in the field of Systems and Control. See the Teaching and Examination Regulations (TER) for a full description of the learning goals. | |
| **Education Method** | Self study with regular supervision from staff members and professor. | |
| **Assessment** | Written report, oral presentation, oral defense, research process evaluation | |
| **Department** | 3mE Department Delft Center for Systems and Control | |

## A. Abate

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| **Department** | Hybrid & Distributed Sys&Con |
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## Dr.ir. X.J.A. Bombois

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## Prof.ir. O.H. Bosgra

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## Ir. I. Grondman

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**Department** Optimalisatie Systeem Theorie

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**Department** Energy Technology

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**Room** 1-23

## Prof.dr.ir. A. van Keulen

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**Department** Fundamentals of Microsystems

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**Room** 4B-1-32

## T. Keviczky

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**Department** Hybrid & Distributed Sys&Con

**Telephone** +31 (0)15 27 82928
**Room** 8C-3-21

## D. de Klerk

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| **Department** | Engineering Dynamics |
| **Room** | 4A-1-07 |

## Dr.ir. M. Langelaar

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## Prof.dr.ir. G. Lodewijks

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