

Program overview

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Year 2011/2012
Organization Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen
Education Master Systems and Control

Code	Omschrijving	ECTS	p1	p2	p3	p4	p5
Master SC 2011							
Master Systems and Control 2011							
SC Obligatory Courses							
SC4010	Introduction Project SC	3	█				
SC4025	Control Theory	6	█	█			
SC4040	Filtering & Identification	6		█	█		
SC4050	Integration Project SC	5				█	█
SC4092	Modeling and Nonlinear Systems Theory	4	█	█			
SC Elective Courses							
AE3202-11	Aerospace Flight Dynamics & Simulation, including flighttest	5			█	█	█
AE4301	Automatic Flight Control System Design	3		█	█		
AE4305	Spacecraft Attitude Control Systems	3		█	█		
AE4361-4	Flight and Space Simulation	4				█	█
CIE4801	Transportation and Spatial Modelling	6	█	█			
CIE4821-09	Traffic Flow Theory and Simulation	6			█	█	█
CIE4822-09	Traffic Management and Control	6				█	█
CIE5804-09	Innovations in Dynamic Traffic Management	4				█	█
LM3512TU	Systems Biology	3			█		
ME1100	Automotive Crash Safety; Active & Passive Safety Systems	3				█	█
ME1200	Robust and Multivariable Control Design	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	█	█			
SC4110	System Identification	5			█		
SC4120	Special Topics in Signals, Systems & Control	3				█	█
SC4150	Fuzzy Logic and Engineering Applications	3	█	█			
SC4160	Modeling and Control of Hybrid Systems	3			█	█	█
SC4210	Vehicle Mechatronics	4			█		
SC4230TU	Vehicle Dynamics B - Antilock Braking Systems	3				█	█
SC4240TU	Control Methods for Robotics	3			█	█	█
SC4250	Probabilistic Models in the Life Sciences	2				█	█
WB2303-10	Measurement in Engineering	3				█	█
WB2305	Digital Control	3	█	█			
WB2414-09	Mechatronic System Design	4	█	█			
WB2427	Predictive Modelling	3				█	█
WB4432-05	Process Dynamics and Control	3				█	█
WI4218	Convex Optimization and Systems Theory	6			█	█	█
WI4221	Control of Discrete-Time Stochastic Systems	6			█	█	█
Master year 2 Projects, Assignments, Thesis etc.							
SCP4500-11	Project work	3	█				
SCP4510-11	Literature Assignment	15	█				
SCP4520-11	Internship (optional)	15	█				
SCP4530-42	MSc Thesis Project	42	█				

Year	2011/2012
Organization	Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen
Education	Master Systems and Control

Master SC 2011

Program Coordinator	Dr. P.S.C. Heuberger
Program Title	Master Systems & Control
Program Coordinator	<p>The MSc coordinator is the person for questions or problems related to the individual study programme and for monitoring progress.</p> <p>Every student should consult the MSc coordinator before the end of the first semester to set up an individual study programme using the following ingredients: compulsory courses, current ideas about the theme of the thesis project, the Specialisation Courses that bridge the gap between the compulsory courses and the thesis project and the use of the free elective space. The student submits his/her plan for approval to the Board of Examiners.</p> <p>In order to finish the programme in two years, the student should plan to take an average of 30 credits worth of courses per semester. At the end of the first year, the student and the MSc coordinator will discuss his/her progress and planning.</p> <p>The MSc coordinator is dr. Peter Heuberger Mekelweg 2 Location: 8C, 3rd floor, room 08 Tel: +31 (0)15 27 85331 E-mail: p.s.c.heuberger@tudelft.nl</p>
In association with the University of	<p>Relationship with 3TU graduate school</p> <p>The MSc programme in Systems and Control at Delft University of Technology is part of the 3TU MSc programme in Systems and Control. The other participating groups in this programme are:</p> <ul style="list-style-type: none">Control Systems Technology Group, Department of Mechanical Engineering, Eindhoven University of Technology, http://www.wtb.tue.nlControl Systems Group, Department of Electrical Engineering, Eindhoven University of Technology, http://w3.ele.tue.nl/nl/mbs/cs/Control Engineering Group, Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, http://www.ce.utwente.nl/Mathematical Systems and Control Theory Group, Faculty of Applied Mathematics, University of Twente, http://www.math.utwente.nl/Laboratory of Mechanical Automation, Faculty of Mechanical Engineering, University of Twente, http://www.wa.ctw.utwente.nl/ <p>Relationship with the national graduate school, DISC</p> <p>The MSc is an excellent way of preparing for the PhD programme offered by the national graduate school, DISC (Dutch Institute of Systems and Control). This is housed in the same research center at Delft University of Technology. http://www.disc.tudelft.nl</p>
Introduction 1	<p>What is the 3TU.Federation?</p> <p>The three leading universities of technology in the Netherlands - Delft University of Technology, Eindhoven University of Technology and the University of Twente - have joined forces in the 3TU.Federation (www.3tu.nl).</p> <p>This federation maximizes innovation by combining and concentrating the strengths of all three universities in research, education and knowledge transfer.</p> <p>Within the framework of this cooperation, five joint MSc programmes have been developed that address key issues in engineering and society. These five MSc programmes are:</p> <ul style="list-style-type: none">Construction Management and EngineeringEmbedded SystemsScience Education and CommunicationSustainable Energy TechnologySystems and Control <p>The main advantages for students</p> <p>The 3TU MSc programmes are developed as exclusive programmes of outstanding academic quality that enable you to study at three of the top universities in the Netherlands.</p> <p>These programmes focus on areas of innovation developed with state-of-the-art engineering expertise.</p> <p>You will have the opportunity to acquire qualifications and competences that are in high demand.</p> <p>With successful graduation you will have obtained an outstanding qualification profile. The 3TU masters combine excellent subject based competences, research skills, the capacity for independent analysis and synthesis and an advanced capability to apply knowledge in practice.</p> <p>The core programmes of the 3TU masters are largely identical and can be followed at any of the three locations.</p> <p>The admission procedures, teaching and examination regulations and academic calendars at all three universities have been carefully matched.</p> <p>You benefit from the special strengths of the three universities by choosing a specialization at any of the three locations.</p> <p>You are registered at the location of your choice, but you are automatically co-registered at the other two locations to ensure access to the facilities of all three.</p>
Introduction 2	<p>Universities of Technology in the Netherlands</p> <p>Delft University of Technology (TU Delft) TU Delft (www.tudelft.nl) is an enterprising university at the forefront of technological development. The university trains the engineers of tomorrow by means of its fundamental and applied research and educational programmes. With its broad knowledge base, worldwide reputation and successful alumni, TU Delft contributes significantly to the development of responsible solutions to urgent societal problems worldwide. The university offers 14 BSc and over 35 MSc programmes. With approximately 15,000 students, TU Delft is the nations largest university of technology with the most comprehensive range of engineering courses.</p> <p>Eindhoven University of Technology (TU/e) Eindhoven University of Technology (www.tue.nl) offers high-quality education and research for the advancement of engineering science, the development of societal and technological innovations, and the growth of welfare and prosperity. The Eindhoven region has a global reputation in top technology with a strong concentration of high-tech companies (including electronics giant Philips), R&D and higher education institutes. As a main driving force behind the regions internationally oriented knowledge economy, TU/e focuses on innovation and cutting-edge research. TU/e currently offers 11 BSc programmes and 22 MSc programmes.</p> <p>University of Twente (UT) Based in the Eastern Dutch town of Enschede, the University of Twente (www.utwente.nl) is one of Europes finest educational establishments encouraging research and entrepreneurship in both technology and social sciences. As a young and innovative institute, UT is internationally respected in a broad range of engineering sciences as well as societal and management disciplines, including cross-disciplinary programmes on e.g. health and technology. UT offers 20 BSc programmes and 31 MSc programmes. And because there is more to life than studying, the Netherlands only university with a residential campus has many sports, cultural and training facilities.</p> <p>More information?</p>

For more information visit www.3tu.nl

Additional information can be obtained from:

Delft: MSc Coordinator, dr. Peter Heuberger p.s.c.heuberger@tudelft.nl

Eindhoven: Master S&C Information point, mastersc@tue.nl

Twente: dr. Jan Willem Polderman, j.w.polderman@math.utwente.nl

Delft Center for Systems and Control (DCSC)

Introduction 3

The MSc programme in Systems and Control began in September 2003. It is taught by the Delft Center for Systems and Control (DCSC) within the Faculty of Mechanical Engineering and Marine Technology. DCSC is a merger of the three former systems and control groups in the faculties of Mechanical Engineering and Marine Technology (OCP), Information Technology and Systems (ITS) and Applied Sciences (TNW). For more information, visit www.dcsc.tudelft.nl.

The DCSC team consists of four full-time professor and three part-time professors. Every MSc student has one of these professors or an associate professor as their formal thesis supervisor.

> Prof. O.H. Bosgra

Modelling, identification, control and model-based optimisation; applications in mechanical servo systems and industrial production processes.

> Prof. P.M.J. van den Hof

Model-based measurement and control, system identification, signal processing and data-based control; applications in industrial production processes, oil/gas reservoir engineering, and physical imaging systems.

> Prof. M. Verhaegen

Data driven control, system identification, distributed control, Fault Detection and Fault Tolerant Control with application to control for image processing, windenergy and vehicle mechatronics

> Prof. R. Babuska

Computational intelligence and machine learning techniques for modeling and control of nonlinear systems. Fuzzy systems, neural networks, reinforcement learning. Applications in robotics and mechatronics.

> Prof. B. De Schutter

hybrid and discrete event systems, multi-level and multi-agent control, model predictive control, optimisation, traffic control, transportation networks, water networks, electricity networks, logistics.

> Prof. J. Hellendoorn

Hierarchical and predictive/anticipative control and decision making, computational intelligence (fuzzy logic, neural networks), traffic applications, condition monitoring.

> Prof. E.G.M. Holweg

Intelligent Automotive Systems.

In consultation with the MSc academic counsellor, the student chooses a thesis from a list of available projects posted on the internet. Also listed is the name of the day-to-day supervisor who will coach the student throughout the project.

Most MSc theses fall within the scope of an ongoing research project at the Delft Center for Systems and Control. Alternatively, projects may also be chosen in co-operation with one of the following research groups affiliated to the MSc programme.

> Mechatronic System Design (3mE-PME)

> Biomechanical Engineering (3mE-BmechE)

> Control and Simulation (AE)

> Mathematical System Theory (EEMCS)

> Process & Product Engineering (AS-PPE)

> Bioprocess Technology (AS-BPT)

> Dynamic Traffic Management (CivE-DTM)

> Reservoir Engineering (CivE)

Program Goals

The MSc programme in Systems and Control covers the analysis and design of reliable and high-performance measurement and control strategies for a wide variety of dynamic technological processes. It centres on fundamental generic aspects of systems and control engineering and stresses the multidisciplinary nature of the field, with applications in mechanical engineering, electrical engineering, applied physics, aerospace engineering and chemical engineering among them the following.

- High-accuracy positioning and motion-control systems, mechatronics, microsystems, production systems, robotics and smart structures.

- Petrochemical, chemical, physical and biotechnological production processes.

- Transportation systems (automotive, railway, logistics, aerospace).

- Infrastructure networks (water, electricity)

- Physical imaging systems (acoustic and optical imaging).

- Adaptive optincs

- Energy conversion and distribution.

- Biomedical systems, System biology.

The programme brings together issues of physical modelling, experiment design, signal analysis and estimation, model-based control design and optimisation, hardware and software in a study of systems of high complexity and of different kinds, such as linear and nonlinear dynamics, hybrid and embedded systems, and ranging from small-scale microsystems to large-scale industrial plants, structures, and networks.

Exit Qualifications

The MSc Systems and Control graduate possesses the following knowledge and skills.

1. Knowledge of engineering sciences (electrical engineering, mechanical engineering, applied physics, mathematics) in breadth and in depth, and the ability to apply this to systems and control engineering at an advanced level.

2. Scientific and technical knowledge of systems and control engineering, in breadth and in depth, and the skills to use this effectively. The discipline is mastered at different levels of abstraction, including a reflective understanding of its structure and its relationships with other fields, and to some extent this knowledge reaches the forefront of scientific or industrial research and development. Moreover, the knowledge possessed can form the basis for innovative contributions to the discipline in the form of new designs or the development of new knowledge.

3. Thorough knowledge of paradigms, methods and tools, as well as the skills to apply that knowledge actively in analysis, modelling, simulation, design and the conduct of research pertaining innovative, technologically dynamically systems, with an appreciation of different areas of application.

4. The ability to solve technological problems independently and in a systematic way, by means of problem analysis, formulating subproblems and providing innovative technical solutions, including in new and unfamiliar situations. A professional attitude towards identifying and acquiring new expertise, towards monitoring and critically evaluating existing knowledge, towards planning and carrying out research, towards adapting to changing circumstances and towards integrating new knowledge with an appreciation of its ambiguity, incompleteness and limitations.

5. The ability to work both independently and in multidisciplinary teams, interacting effectively with specialists and taking initiatives where necessary.

6. The ability to communicate effectively about his or her work in the English language, to both professionals and non-specialists, including the ability to make presentations and produce reports on, for example, solutions to problems, conclusions, knowledge and considerations.

7. The ability to evaluate and assess the technological, ethical and social impact of his or her work, and to take responsibility with regard to sustainability, economy and social welfare.

8. The willingness to maintain his or her professional competence independently, through life-long learning.

<p>Program Structure 1</p>	<p>Lecture courses (60 EC)</p> <p>These are divided in four components.</p> <ul style="list-style-type: none"> - Compulsory courses (24 EC). - Elective Systems and Control courses selected from a list provided (at least 20 EC). - "Free" elective technical courses, chosen by agreement with the MSc thesis supervisor (at least 13 EC). - At least 3 EC should be devoted to non-technical courses. For student starting their MSc programme after August 31,2011, these courses should contain at least one course on societal and ethical aspects of research. A list with examples courses can be obtained from the education coordinator. <p>Most courses are assessed by means of an oral or written examination.</p> <p>Assignments (60 EC)</p> <p>The assignments are carried out during the second year of the MSc programme, in most cases on an individual basis.</p> <p>They may include the following.</p> <ul style="list-style-type: none"> - An optional traineeship in industry or a project assignment defined in consultation with an external party (industry, research institute, etc.). This is worth 15 EC. If the MSc thesis is prepared in co-operation with and at the premises of an external party, the traineeship component may be combined with the thesis. - Project work (seminars, project meetings, presentations) (3 EC). - Preparation of MSc thesis project (literature survey) (15 EC). - MSc thesis project (42 EC, or 27 EC when combined with an industrial traineeship). <p>The assignments are assessed on the basis of a written report and, possibly, an oral presentation.</p> <p>The thesis project is the final assignment in the MSc programme.</p> <p>The student prepares this thesis as a report of his or her research project. The thesis work is assessed on the basis of an oral presentation by the student and an oral examination before an MSc examining board composed of at least three members of the academic staff, including the thesis supervisor. The examining board may also include external examiners from research institutes or from industrial partners. See section 1.5 for the assignments requirements.</p> <p>Study programme and general structure</p> <p>Systems and Control offers an MSc course of two years. Each course year is divided into two semesters and each semester consists of two periods. Each period includes seven weeks of lectures, one so-called white week (lectures allowed, exams generally not) followed by two examination weeks.</p> <p>For those subjects for which written examinations are held, the student will get at least one opportunity per year to do a resit. Resits are generally held in the first period after the regular period for a certain examination. Resits for the examinations held in period 2B are scheduled for the second half of August.</p> <p>The study load of a course is expressed in European Credits. This is a result of the European Credit Transfer System (ECTS), which encourages acknowledgement of study results between higher education institutions within the European Union. The study load for one educational year is 60 EC. These ECs give an indication of the weight of a certain part of the course. One EC involves approximately 28 hours of study. These 28 hours include all time spent on the course: lectures, self-education, internship, practicals, examinations, etc.</p> <p>Fail or Pass Regulation</p> <p>To pass a course or assignment, a grade of at least 6 is necessary. The grades are rounded off to half points, so 5.5, 6.0, 6.5 etc.</p> <p>With Honours Regulation</p> <p>At the discretion of the Board of Examiners, a candidate for the Masters degree can receive the designation cum laude if he or she meets the following conditions:</p> <ol style="list-style-type: none"> a) the mark awarded to the components specified in the Master's examination implementation procedures shall average no less than 8, excluding the Masters Thesis and Literature Study in a list that contains no marks below 6; This average is weighted with respect to the number of ECs. b) the candidate concerned shall have completed the Masters degree programme in no more than three years; c) the mark awarded for the thesis project shall be no less than 9; d) the examiner of the graduation assignment shall have submitted a proposal for the award of cum laude. <p>Transferring from HBO to TUD</p> <p>See the information under <Education Type> "Pre-masters Program" and <Education> Pre-master Systems and Control.</p>
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Year
Organization
Education

2011/2012
Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen
Master Systems and Control

SC Obligatory Courses

Program Coordinator Dr. P.S.C. Heuberger

Introduction 1 Curriculum

The compulsory component of the curriculum, as shown in the table below, consists of three basic courses in key areas of systems and control: Physical modelling for systems and control, signal analysis and filtering, and control theory. There are also two compulsory project components. The first is an introductory project in which basic knowledge and skills in systems and control, including the required background in mathematics and engineering subjects, are refreshed and brought to the same level for all incoming students. The second is an integration project performed in the laboratory, in which the knowledge acquired during the compulsory courses is applied to real-world situations.

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. 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, 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 analysis. 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. A written test may be part of the assessment. 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 2	
Course Language	English	
Course Contents	<ul style="list-style-type: none"> - State-space description of multivariable linear dynamic systems, interconnections, block diagrams - Linearization, equilibria, stability, Lyapunov functions and the Lyapunov equation - Dynamic response, relation to modes, the matrix exponential and the variation-of-constants formula - Realization of transfer matrix models by state space descriptions, coordinate changes, normal forms - Controllability, stabilizability, uncontrollable modes and pole-placement by state-feedback - LQ regulator, robustness properties, algebraic Riccati equations - Observability, detectability, unobservable modes, state-estimation observer design - Output feedback synthesis (one- and two-degrees of freedom) and separation principle - Disturbance and reference signal modeling, the internal model principle 	
Study Goals	<p>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:</p> <ul style="list-style-type: none"> - Translate differential equation models into state-space and transfer matrix descriptions - Linearize a system, determine equilibrium points and analyze local stability - Describe the effect of pole locations to the dynamic system response in time- and frequency-domain - Verify controllability, stabilizability, observability, detectability, minimality of realizations - Sketch the relevance of normal forms and their role for controller design and model reduction - Describe the procedure and purpose of pole-placement by state-feedback and apply it - Apply LQ optimal state-feedback control and analyze the controlled system - Reproduce how to solve Riccati equations and describe the solution properties - Explain the relevance of state estimation and build converging observers - Apply the separation principle for systematic 1dof and 2dof output-feedback controller design - 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	<p>B. Friedland, Control System Design: An Introduction to State-space Methods. Dover Publications, 2005</p> <p>K.J. Astrom, R.M. Murray, Feedback Systems: An Introduction for Scientists and Engineers, Princeton University Press, Princeton and Oxford, 2009 http://www.cds.caltech.edu/~murray/amwiki/index.php?title=Main_Page</p>	
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	

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 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	<p>At the end of the course the student should be able to:</p> <ul style="list-style-type: none"> Derive the solution of the weighted stochastic and deterministic linear least squares problem. Proof the properties of unbiasedness and minimum variance of the weighted stochastic and deterministic linear least squares problem. Use an observer to estimate the state sequence of a linear time invariant system. 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. Describe the difference between the predicted, filtered and smoothed state estimates. Formulate and solve the Kalman filter problem as a weighted stochastic least squares problem. Use the Kalman filter theory to estimate unknown inputs of a linear dynamical system in the presence of noise perturbations on the model. 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. Derive subspace identification methods for different noise models and relate the different subspace identification methods via the solution of a linear least squares problem. Implement a least squares solution in matlab for elementary linear estimation and subspace identification problems. 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. ISBN: 13-9780521875127	
Assessment	Deliverable by the Studentsociety Gezelschap Leeghwater.	
Remarks	Written exam (open book) and practical exercise.	
Department	The software package Matlab is needed to solve the practical exercise.	
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) Physical Modeling for System and Control (SC4032) Filtering and Identification (SC4040)	
Assessment	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. 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 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	<p>Based on the analogies between the physical laws and energy flows of electrical, mechanical, hydraulic, and thermal components, a systematic modeling 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.</p> <p>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.</p> <p>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.</p> <p>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.</p> <p>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.</p>	
Study Goals	<p>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.</p> <p>After successful completion of the course, the student is able to</p> <ul style="list-style-type: none"> - construct models of systems from the knowledge of physics, with an emphasize on the internal energy of the system. - write models of systems described by differential and algebraic equations in a control systems form. - distinguish between linear and nonlinear systems properties. - decide when to apply the linear and when to apply the nonlinear theory. - determine several stability properties for nonlinear systems. - apply dissipativity and passivity concepts for stabilization and to analyze input-output stability. - determine controllability and observability properties for nonlinear systems. - 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	

Year
Organization
Education

2011/2012
Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen
Master Systems and Control

SC Elective Courses

Program Coordinator	Dr. P.S.C. Heuberger
Introduction 1	
Introduction 2	<p>Profiles</p> <p>To facilitate the choice of elective DCSC courses, the subsequent list provides an indication of how they could be distributed over the following four profiles</p> <p>A) Systems and Control Theory B) Mechatronic Systems C) Process Control and Optimization D) Information Technology and Control</p> <p>ABCD Code Course A.CD - SC4060 Model predictive control .CD - SC4081-10 Knowledge based control systems A.CD - SC4091 Optimization in systems and control ABC. - SC4110 System identification A... - SC4120 Special topics in signals, systems and control A..D - SC4150 Fuzzy logic for engineering applications A..D - SC4160 Modeling and control of hybrid systems .B.. - SC4210 Vehicle mechatronics .B.. - SC4230TU Vehicle Dynamics B_ABS .B.. - SC4240TU Control methods for Robotics .B.. - WB2303 Measurement theory and practice .BCD - WB2305 Digital control .B.. - WB2414-09 Mechatronic system design AB.. - ME1200 Robust multivariable control design ..C. - WB4432-05 Process dynamics and control</p> <p>Courses in A) put a particular emphasis on the fundamentals in systems and control with an explicit orientation towards research. Courses in B) and C) are suited for developing expertise concerning control systems in tow conceptually different application domains. Courses in D) are directed towards the relation of control with information technology.</p> <p>This distribution is only meant to provide orientation for the composition of an individual course program and does in no way impose any formal restrictions.</p>
Program Structure 1	At least 20 EC should be taken from the selective list of systems and control courses.

AE3202-11	Aerospace Flight Dynamics & Simulation, including flighttest	5
Responsible Instructor	Dr.ir. A.C. in 't Veld	
Instructor	Dr.ir. E. Mooij	
Contact Hours / Week x/x/x/x	0/0/6/0	
Education Period	3	
Start Education	3	
Exam Period	3 5	
Course Language	English	
Course Contents	Derivation and analysis of the stability and dynamic behavior of aerospace vehicles, taking into account the effects of different altitude/velocity combinations.	
Study Goals	<p>At the end of this course, the student will be able to:</p> <ol style="list-style-type: none"> 1. Determine the stability properties and characteristic motions of aerospace vehicles 2. Predict rotational motion of aerospace vehicles by means of simulation 3. Master reference frames + transformations 4. Utilize Euler angles 5. Derive and linearize the Equations of Motion 6. Determine static and dynamic stability properties 7. Separate symmetric/asymmetric E.O.M 8. Calculate and interpret Eigenvalues and Eigenmodes 9. Apply theory to different altitude/velocity regimes 10. Identify the effect of different vehicle configurations 	
Education Method	Lecturing and self study	
Assessment	Written exam	
Remarks	<p>This course is the last in a series of three. It is preceded by Aerospace Design and Systems Engineering Elements I (AE1201) in BSc year 1 and followed by Aerospace Design and Systems Engineering Elements I (AE2101) in BSc year 2 The course is preceding the Design Synthesis (AE3200).</p>	
Set-up	<p>During the course students attend active lectures that cover relevant topics. Students are expected to have read the related course material in advance of class sessions; class sessions then consist of introduction of new theory, and exploration of the implications of the theory using real-life examples.</p>	

AE4301	Automatic Flight Control System Design	3
Responsible Instructor	Dr.ir. E. van Kampen	
Responsible Instructor	Dr.ir. M.M. van Paassen	
Contact Hours / Week x/x/x/x	0/4/0/0	
Education Period	2	
Start Education	2	
Exam Period	2 3	
Course Language	English	
Required for	AE4303	
Expected prior knowledge	The following prior knowledge is required: AE3302 AE2204	
Parts	<ol style="list-style-type: none"> 1. Introduction: Course use and arrangement <ol style="list-style-type: none"> a. Why automatic flight control systems? b. Function of the flight control system in civil aviation c. Recapitulation of theory on flight dynamics d. Review of the different frames of reference: wind, stability, body and geodetic etc. e. Non-linear equations of motion of rigid aircraft. f. Trim and linearization of the non-linear equations of motion. g. The linearized longitudinal aircraft dynamics using a statespace representation and the equivalent frequency domain form. 2. Recapitulation of systems and control theory <ol style="list-style-type: none"> a. From aircraft dynamics to differential equation a. Laplace transformation c. Elementary closed loop systems d. Transfer functions in Matlab 3. Poles and zeros <ol style="list-style-type: none"> a. First order systems b. Second order systems c. Pole placement for simple systems 4. Root locus method <ol style="list-style-type: none"> a. Characteristic equation b. Angle and magnitude conditions c. Root locus in Matlab 5. State space formulation <ol style="list-style-type: none"> a. Controllability, observability b. Ackerman's formula c. LQR 6. Basic controllers: P,PI,PD,PID 7. Frequency response <ol style="list-style-type: none"> a. Bode plots b. Bode plots in Matlab 8. Polar plots (Nyquist) 9. Performance and handling qualities <ol style="list-style-type: none"> a. The military specifications (MIL-SPEC) handling quality criteria b. The Control Anticipation Parameter (CAP) c. Gibsons Phase rate and Frequency criterion 10. Dynamic stability augmentation <ol style="list-style-type: none"> a. yaw dampers b. pitch dampers c. phugoid dampers 11. Static stability augmentation <ol style="list-style-type: none"> a. angle of attack feedback to improve static margin b. load factor feedback to improve manoeuvre margin c. sideslip feedback to improve directional static stability 12. Basic longitudinal autopilot modes <ol style="list-style-type: none"> a. pitch attitude hold mode b. altitude hold mode c. airspeed hold mode (using autothrottle) d. vertical speed 13. Basic lateral autopilot modes <ol style="list-style-type: none"> a. roll angle hold mode b. coordinated roll angle hold mode c. turn rate at constant altitude and speed d. heading angle hold mode 14. Longitudinal and lateral guidance modes <ol style="list-style-type: none"> a. glideslope hold mode b. automatic flare mode c. localizer hold mode d. VOR hold mode 	
Course Contents	<p>Classical control is still predominantly used in aerospace industry for the design and analysis of automatic flight control systems. Various existing control systems such as Stability Augmentation Systems (SAS), Control Augmentation Systems (CAS) and fly-by-wire systems are reviewed in detail. The emphasis of the course lies in demonstrating, through application of classical frequency domain and state space techniques, how to design systems that fulfill the requirements imposed by the aviation authorities, with emphasis on understanding the benefits and limitations of such systems.</p>	
Study Goals	<p>After this course the student should be able to:</p> <ul style="list-style-type: none"> - substantiate the function of a Flight Control System(FCS) in civil/military aviation. 	

	<ul style="list-style-type: none"> - apply the theory of flight dynamics and control to FCS design. - verify if a given FCS satisfies the handling qualities criteria. - design static and dynamic stability augmentation systems. - design all longitudinal and lateral autopilot modes.
Education Method	Lectures with computer demonstrations
Literature and Study Materials	<p>Course material to support the exercises will be posted on the blackboard.</p> <p>Recommended literature</p> <ul style="list-style-type: none"> - M.V. Cook, Principles in flight dynamics, Edward Arnold, London, 1997 ISBN 0-340-63200-3. - B.L. Stevens, F.L.Lewis, Aircraft control and simulation, Wiley, New York, 1992 ISBN 0471613975. - J. Roskam, Airplane flight dynamics and control Part II, , ISBN 1-8845885-18-7.
Assessment	Written closed-book examination
Remarks	Some chairs may require students to perform a laboratory exercise or practical in conjunction with this course.
Set-up	At the end of each lecture, a simple take home assignment is given in order to gain experience in working with the course material. There will be a written examination at the end of the course. The related practical AE4301P, in which a control system must be designed that satisfies certain desired requirements, follows at the end of the second semester.

AE4305	Spacecraft Attitude Control Systems	3
Responsible Instructor	Dr. Q.P. Chu	
Contact Hours / Week x/x/x/x	0/4/0/0	
Education Period	2	
Start Education	2	
Exam Period	2	
Course Language	English	
Required for	AE4305P	
Expected prior knowledge	AE2204 AE4301 AE4301P	
Parts	<p>Week arrangement</p> <p>Week 1. Introduction to spacecraft dynamics and control, Rotational kinematics with quaternions</p> <p>Week 2. Rigid body dynamics</p> <p>Week 3. Spacecraft attitude determination techniques and attitude estimation</p> <p>Week 4. Attitude control actuators</p> <p>Week 5. Spacecraft passive attitude control</p> <p>Week 6. Spacecraft active attitude control with momentum based actuators</p> <p>Week 7. Advanced control techniques for spacecraft attitude control</p>	
Course Contents	<p>Spacecraft attitude control is one of the most important subsystems for most space vehicles. It controls the orientation and rotational rate of the spacecraft to a required accuracy. The attitude control system uses attitude sensors and control actuators to determine and correct the attitude errors of the spacecraft. Unlike the flight dynamics in the third education year, the rotational kinematics of space vehicles in this course is thoroughly taught using quaternion algebra, in order to give a more general technique in modelling spacecraft rotational motion without having mathematical singularities. State estimation techniques such as Kalman filter and extended Kalman filter are introduced for estimating spacecraft attitude from attitude sensors. Several techniques in sensor integration and data fusion are also taught for enhancing the performance of the attitude determination system. Control actuators include reaction wheels, momentum biased wheels, thrusters, magnetic coils and Control Moment Gyros (CMGs). The single gimbal CMGs with their applications to spacecraft attitude control is specifically addressed. The course discusses not only the passive attitude control concepts but more dedicates to active attitude control system designs. Particularly the quaternion feedback control technique is enhanced. Conventional design of spacecraft attitude control systems is based on the linear control theory. In this lecture advanced control techniques such as Nonlinear Dynamic Inversion (NDI) is also introduced for highly manoeuvrable spacecraft.</p>	
Study Goals	Students will be able to acquire classical and advanced techniques for spacecraft attitude control.	
Education Method	Lecture	
Literature and Study Materials	<p>Q.P. Chu, Spacecraft Attitude Dynamics and Control, Lecture notes, Faculty of Aerospace Engineering, Delft University of Technology.</p> <p>Recommended literature</p> <ul style="list-style-type: none"> M.J. Sidi, Spacecraft dynamics and control, a practical engineering approach, Cambridge Univ. Press, Cambridge, 1997 ISBN 0521550726. B. Wie, Space vehicle dynamics and control, AIAA Education Series, AIAA Inc., 1998 . 	
Assessment	Take-home assignments	
Remarks	<p>Examination: (3 ECTS):</p> <p>Take-home exercises of spacecraft attitude control systems with specified requirements and MATLAB simulations will be asked to complete after the course.</p>	

AE4361-4	Flight and Space Simulation	4
Responsible Instructor	Ir. O. Stroosma	
Instructor	Dr.ir. M.M. van Paassen	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	4	
Course Language	English	
Expected prior knowledge	AE3302 or AE3202 AE3359 AE4304 AE4360 AE4393	
Parts	A combination of lectures and group sessions for which attendance is mandatory. Students perform an individual assignment to become familiar with the programming environment, and with programming in C++. As a group, the students design and implement a larger simulation. During the group sessions students discuss simulation preliminary design, perform a paper simulation session in which the designed simulation is evaluated, and assure compatibility between the simulations of the different groups. For the implementation of the simulation, students can organize their own time. A report on the simulation is due 4 weeks after the end of the lecture period.	
Course Contents	<p>The lectures comprise:</p> <ol style="list-style-type: none"> 1. Introduction, simulator types, training simulators, research simulators. Overview of simulator systems. 2. Vehicle dynamics modeling and simulation. 3. Real-time programming and distributed simulation 4. Delft University Environment for Communication and Activation (DUECA). 5. Motion systems and cueing. 6. Control loading and force feedback. 7. Visual display systems. <p>The lecture series is complemented with a practical, in which students program, demonstrate and document a distributed simulation with an aerospace theme. Presence at all lectures and group sessions is mandatory.</p>	
Study Goals	<p>The student has an understanding of flight simulation techniques.</p> <p>The student knows the characteristics of flight simulation hardware and software.</p> <p>The student can actively apply the theory of rigid body (including aircraft) dynamics (AE3302,AE4304) in simulation.</p> <p>The student can combine the modeling of dynamical systems with numerical integration routines.</p> <p>The student can use quaternions to represent the attitude of rigid bodies.</p> <p>The student can implement simulation models using software languages and tools (C++, Simulink / Real-Time Workshop).</p> <p>The student can create 3D models for computer visualization and connect these visualization to a real-time simulation.</p> <p>The student can (in a team) implement a real-time simulation on distributed, multi-platform hardware, using advanced software tools.</p>	
Education Method	Lecture and practical assignment	
Literature and Study Materials	Handouts and electronic material are available on BlackBoard.	
Assessment	Construction of a working flight simulation and essay/report	
Set-up	Students are challenged to create a working simulation. In small groups, under supervision of a tutor, students are responsible for a part of the simulation. The simulation is programmed and implemented on distributed (PC) hardware.	

CIE4801	Transportation and Spatial Modelling	6
Responsible Instructor	Dr. M.C.J. Bliemer	
Contact Hours / Week x/x/x/x	6/0/0/0 + 4/0/0/0	
Education Period	1	
Start Education	1	
Exam Period	1 2	
Course Language	English	
Course Contents	<p>1. Objectives of modelling in transport and spatial planning. Model types. Theory of travel and locational behaviour. System description of planning area. Theory of choice models. Aggregate and disaggregate models. Mode choice, route choice and assignment modelling. Locational choice modelling. Parameter estimation and model calibration. Cases and exercises in model application;</p> <p>2. Role of models in transportation and spatial systems analysis; model types; designing system description of study area (zonal segmentation, network selection); role of shortest path trees;</p> <p>3. Utility theory for travel and location choice; trip generation models, trip distribution models; applications;</p> <p>4. Theory of spatial interaction model; role of side constraints; distribution functions and their estimations; constructing base matrices and estimating OD-tables;</p> <p>5. Theory of individual choice models;</p> <p>6. Disaggregated choice models of the logit and probit type for time choice, mode choice, route choice and location choice;</p> <p>7. Integrated models (sequential and simultaneous) for constructing OD-tables;</p> <p>8. Equilibrium theory in networks and spatial systems;</p> <p>9. Route choice and assignment; derivation of different model types (all-or-nothing model, multiple route model, (stochastic) equilibrium model); assignment in public transportation networks; analyses of effects;</p> <p>10. Calibration of parameters and model validation; observation, estimation, validation; estimation methods;</p> <p>11. Individual exercise computing travel demand in networks; getting familiar with software; computing all transportation modelling steps; analyse own planning scenarios; writing a report.</p>	
Study Goals	<p>1. Insight in the function of mathematical models in transportation and spatial planning;</p> <p>2. Knowledge of theoretical backgrounds of models;</p> <p>3. Knowledge of application areas of models;</p> <p>4. Ability to develop one's own plan of analysis for model computations;</p> <p>5. Ability to apply models on planning problems;</p> <p>6. Ability to present outcomes of model computations.</p>	
Education Method	Lectures, exercise, practical	
Literature and Study Materials	<p>Obligatory lecturenote(s)/textbook(s):</p> <ol style="list-style-type: none"> 1. Lecture notes Transportation Modeling 2. Lecture notes Spatial Modeling 3. Manual of exercises in Omnitrans 	
Assessment	<p>Obligatory other materials: Transparancies and other material o-n Blackboard</p> <p>Written exam (open questions, closed book) and practical with written report</p>	
Remarks	<p>The individual exercise must be completed and the deadline for handing in the report is week 7. The exercise grade will remain for a maximum of 13 months.</p> <p>NB: In case the exercises are not completed in time, one will not be allowed to make the final written exam.</p>	
Judgement	Written exam (3/4) + written report about exercise (1/4)	

CIE4821-09	Traffic Flow Theory and Simulation	6
Responsible Instructor	Prof.dr.ir. S.P. Hoogendoorn	
Contact Hours / Week x/x/x/x	0/0/6/0 + 0/0/4/0	
Education Period	3	
Start Education	3	
Exam Period	3 4	
Course Language	English	
Course Contents	<p>Part 1 of the lectures discusses fundamental traffic flow characteristic, introducing traffic flow variables speed, density, and volume. Their definitions are presented, and visualization/analysis techniques are discussed and empirical facts are presented.</p> <p>Part 2 pertains to the empirical relation between the flow variables.</p> <p>Part 3 discusses bottleneck capacity analysis.</p> <p>Part 4 presents shockwave analysis, which is one of the techniques available to analyze oversaturated traffic systems.</p> <p>Part 5 presents a review of macroscopic traffic flow models and their principal properties, as well as innovative macroscopic traffic flow models developed at Delft University of Technology. It shows how macroscopic models are derived from microscopic principles. Furthermore, traffic flow stability issues are discussed as well as numerical solution approaches.</p> <p>Part 6 handles microscopic traffic flow characteristics, such as headways, speeds, etc.</p> <p>Part 7 provides an overview of human factors relevant for the behaviour of drivers. This part discusses the different levels of the driving task execution, responses times, etc.</p> <p>Part 8 discusses car-following models and other approaches describing the lateral driving task.</p> <p>Part 9 pertains to general gap-acceptance modelling and lane-changing.</p> <p>Part 10 presents an in-depth discussion of microscopic simulation models. Different approaches to microscopic model derivation are discussed as well.</p> <p>Part 11 discussed microscopic models for pedestrian flow behaviour.</p>	
Study Goals	<ol style="list-style-type: none"> 1. Gain insight into theory / modelling of traffic flow operations (generic); 2. Learn to apply theory and mathematical models to solve practical problems; 3. Gain experience with using simulation programmes for ex-ante assessment studies. 	
Education Method	Lectures, computer assignments	
Literature and Study Materials	<p>Lecture notes available via blackboard</p> <p>Old examinations</p> <p>Recommended lecturenote(s)/textbook(s): May, A. (1990) Traffic Flow Fundamentals Prentice-Hall</p>	
Assessment	Written examen, open questions and practical (groups of 3 students)	
Remarks	Written exam >5 and practical >5	
Judgement	Calculation: 2/3 written exam and 1/3 practical	

CIE4822-09	Traffic Management and Control	6
Responsible Instructor	Dr.ir. A. Hegyi	
Instructor	Ir. T.H.J. Muller	
Instructor	Dr.ir. A.M. Salomons	
Contact Hours / Week x/x/x/x	0/0/0/2 + 0/0/0/4 (computerpracticum)	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Course Contents	<p>The central topic of this course is the design, optimization, simulation and evaluation of traffic control in urban areas and on freeways.</p> <p>This includes the following subtopics:</p> <ul style="list-style-type: none"> - queuing, delays and capacity of signalized and unsignalized intersections,- advanced local intersection control, - transit priority control, - coordinated urban network control, - freeway control: ramp metering, dynamic speed limits, route guidance, - control objectives for urban and freeway traffic control, - introduction to control theory. <p>The course includes an extensive exercise in which the students design and evaluate an intersection controller in a microscopic traffic flow simulation program.</p>	
Study Goals	<p>After completing the course the students are expected to be able to:</p> <ul style="list-style-type: none"> - design, explain, simulate and evaluate intersection control programs, - apply the criteria to decide whether or not signalization is necessary for safety or capacity reasons, - explain the main approaches for coordinated urban traffic control, - calculate the capacities of a roundabout, - explain the various approaches for ramp metering, route guidance and variable speed limit control on freeways. Discuss the design considerations that lead to the alternative approaches. Discuss the advantages/disadvantages of the alternative approaches. Specify the mathematical form of the control approaches. 	
Education Method	Lectures, exercise	
Course Relations	CIE4822-09 uses CIE4821-09	
Literature and Study Materials	Lecture notes on Blackboard. Please note that the lecture notes are revised, so please, download the latest version. There may be handouts during lecture. All handouts will be put on Blackboard for download.	
Assessment	Written exam (open questions), and a report of the exercise. The report is discussed individually with one of the instructors.	
Remarks	<p>Exercise should be completed with grade ≥ 5.</p> <p>Time between exercise report and examination no longer than 13 months.</p>	
Judgement	Calculation of final grade: 2/3 written examination and 1/3 exercise report.	

CIE5804-09	Innovations in Dynamic Traffic Management	4
Responsible Instructor	Dr.ir. J.W.C. van Lint	
Contact Hours / Week x/x/x/x	0/0/0/4	
Education Period	4	
Start Education	4	
Exam Period	4 5	
Course Language	English	
Expected prior knowledge	CIE5804 uses CIE4801 CIE5804 uses CIE4821	
Course Contents	<p>Note on beforehand: this course will be given TWICE in 2011/12. The regular course is scheduled in Q4, but this year an extra (compact) version will be given in Q2 as a courtesy for students who planned to follow the course but cannot attend in Q4 due to the planning of their Msc thesis. Note that there in Q2 only a few lectures will be scheduled these will be announced via BB only! Below follow two descriptions of the NEW and OLD course. Although these descriptions appear different, the underlying material is largely the same. The differences lie in the order in which the material is presented and the applications used to illustrate the concepts</p> <p>NEW course (Q4 2012) This course overviews innovations in dynamic (network) traffic management, and particularly in the application of integrated and coordinated traffic management in networks. How we can we control and manage the operations in traffic networks to mitigate the large economical and environmental problems that result from congestion and gridlock?</p> <p>The course contains the following components (1) The dynamics of network traffic operations, underlying causes (capacity drop, spillback, selfish route choice behavior) and why traffic management is essential to resolve these problems (2) Dutch and international traffic management policies and practices: the GGB(+) approach, and how it fits in the larger context of ITS (intelligent transportation systems) (3) System response to traffic (and demand) management in terms of people, planet and profit: efficiency versus robustness and reliability and how we can assess these ex ante and ex post (4) Traffic management as a control process: basic theory and principles (this component is also part of CIE4822) (5) Traffic monitoring and traffic state estimation / prediction (6) Traffic management as a control process: application examples (dynamic speed limits and route guidance) (7) Integrated network management design principles (8) Integrated network management applications (including assignment)</p> <p>OLD course (Q2 2011) This course overviews innovations in dynamic (network) traffic management, and will focus on the application of Intelligent Transport Systems (Services) - ITS - for road transport networks. The course has three main content components: general material, material focused on methodological aspects and material which illustrates these concepts by concrete applications and case studies of ITS</p> <p>General: - State of the art ITS for road transport - System response to ITS (people, planet, profit) - Use and validity of simulation models for ex ante assessment of ITS - Sustainable network traffic management, the "GGB" approach, i.e. the Dutch planning and design methodology for ITS and network (traffic) management</p> <p>Methodological: - ITS as a control process - Traffic monitoring, traffic state estimation prediction</p> <p>Applications: - Advanced traveler information systems (ATIS) - Advanced (network) traffic management (ATMS) - Advanced driver assistance systems (ADAS)</p>	
Study Goals	<p>Again here we differentiate between the new (Q4) and old (Q2) course</p> <p>NEW course (Q4) The goal of the course is to learn why and how traffic management is conditional to the efficient operations of traffic in networks and to apply this knowledge in the design of an integrated network management plan for a concrete traffic network. Specifically:</p> <ul style="list-style-type: none"> - Students learn the dynamics of network traffic operations (network fundamental diagram) and their underlying causes (spillback, capacity drop, user optimal routing) - Students learn the trade off between efficiency and reliability and the underlying causes (stochasticity in demand and supply) - Students learn the basic principles (dos and donts) of assessing traffic management measures both ex ante and ex post - Students learn how to view traffic management as a control process and become familiar with the basic terminology of control theory (Note: TIL students can get more in depth knowledge of control theory in other courses within specialization O, T&P (& TIL) students can also follow CIE4822) - Students become familiar with the ingredients and workings of advanced traffic management: monitoring, state estimation and prediction and optimization of control algorithms and learn to apply these through concrete examples - Students learn how to design an integrated network management plan for a concrete case <p>OLD course (Q2) The goal of the course is to learn how Intelligent Transportation Systems (Services) - ITS - affects traffic flow operations on road transport networks in terms of amongst other things efficiency and reliability of road transport infrastructure. Specifically:</p> <ul style="list-style-type: none"> - Students learn how to classify different ITS and identify the main (methodological and technical) characteristics of these (different categories of) ITS. - students learn - through examples - how these ITS work in practice, what are the main components and systems involved and needed for their operation. - Students learn which effects these different categories of ITS may have on road transport systems in terms of traffic flow operations, the environment, reliability, route choice or otherwise. - Students learn which simulation models and tools are appropriate and valid for the planning and ex ante evaluation of these different categories of ITS. - Students learn how ITS must be viewed and understood as a control system and learn the basics of control theory applied to ITS - Students learn - through an exercise - how to assess an example ITS system quantitatively, and learn to write a (brief) scientific report discussing these results. 	
Education Method	lectures individual (or group) exercises	

Literature and Study Materials	syllabus: Innovations in Dynamic Traffic Management, available ONLY via Blackboard.
Assessment	Written exam Report exercise
Judgement	Written exam (67%) and report exercise (33%), both should be > 5. Note: for the OLD course (Q2): If students fail the offered written exam in Januari there is a possibility for an oral exam in FEB/March 2012.

LM3512TU	Systems Biology	3
Responsible Instructor	S.A. Wahl	
Contact Hours / Week x/x/x/x	0/0/32/0	
Education Period	3	
Start Education	3	
Exam Period	none	
Course Language	English	
Course Contents	<p>Systems biology is an integrated approach of experimental and mathematical methods that aims a comprehensive understanding of how biological functions arise and how they are regulated. Transcription, signaling and metabolism in living cells influence each other by various regulatory mechanisms. For the unraveling of the regulation of cellular metabolism different platforms have been developed, named omics technologies e.g. metabolomics, transcriptomics, genomics and proteomics. To aid the interpretation of the obtained omics data, numerous mathematical modelling approaches have been developed. The course introduces the measurement technologies and mathematical approaches for the purpose of:</p> <ul style="list-style-type: none"> - Quantification of metabolic fluxes, - Identification of enzyme kinetic properties under in-vivo conditions, - Design of organisms with enhanced properties. <p>The course presents:</p> <ul style="list-style-type: none"> - Techniques to quantify intracellular fluxes, e.g: - Metabolic flux analysis (MFA) and ¹³C labelling techniques, - Flux balance analysis for genome scale models - Calculation of elementary flux modes - An overview of experimental perturbation techniques and their information content - Techniques for global and targeted metabolome measurements - Heatmaps for the interpretation of omics-data. - Measurement techniques and data interpretation for protein and transcript levels - Thermodynamic aspects of metabolism and gene regulation - Principles/ Modelling of signal transduction - System wide modelling techniques (Elementary mode analysis, linear programming, MCA) - Parameter identification with their problems and solutions 	
Study Goals	<p>After this course the students should be able to:</p> <ul style="list-style-type: none"> - Translate the relevant properties of a biological system into a proper mathematical model and set up a simulation - Parameterize this model by choosing proper experimental design, measurement techniques and mathematical procedures - Apply the obtained model for (re)design of biological systems with the aim to alter and/or improve their properties (e.g. product formation) - Use mathematical models to create hypotheses on unknown molecular interactions (gene annotation, metabolite protein/ enzyme interactions, protein/ protein and protein DNA interactions) - Reconstruct models published in system biology journals and apply these to modified conditions. 	
Education Method	Lectures and computer exercises	
Assessment	Case study on modeling (published model will be reconstructed and evaluated)	

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 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: - vehicle dynamics control - human machine interfacing and - injury biomechanics.	
Course Contents	Active safety (accident prevention) Passive safety (injury reduction)	
Course Contents Continuation	<p>1.THE ROAD SAFETY PROBLEM Introduction of the course stating the problem in terms of: o Fatalities, injuries and vehicle damage in a national and international perspective. o Breakdown into injuries of car occupants, pedestrians, cyclists, motorcyclists and others.</p> <p>Road Safety Countermeasures Pre-crash, In-crash and Post-crash measures (Haddon Matrix). o Vehicle safety technologies (which are the focus of this course) o Road infrastructure o Enforcement of speed, alcohol and other regulations o Education</p> <p>The Young Driver Problem & Driver Education o High accident rates, countermeasures and training.</p> <p>2.ACCIDENT CAUSATION The majority of road accidents is caused by one or more human errors. o Perception, decision and execution errors. o Perception of speed, direction and distance, awareness, reaction times & failure to act.</p> <p>3.ACTIVE SAFETY 1 DRIVER ASSISTANCE SYSTEMS & OBSTACLE DETECTION o Driver assistance systems such as (adaptive) cruise control, brake assist, steering assist. o Capabilities of radar and wireless communication to detect obstacles & improve traffic flow. o Automation versus support, driver acceptance, trust and overreliance.</p> <p>4.ACTIVE SAFETY 2 - VEHICLE DYNAMICS CONTROL The role of tyre, suspension, steering and braking systems. o Non-linear tyre properties in longitudinal and lateral slip (Moores Circle). o Antilock Braking Systems (ABS) Electronic Stability Control (ESC/ESP). o Real World Benefits ABS & ESC.</p> <p>5.CRASH DUMMIES & INJURY CRITERIA Crash dummies for the various crash test scenarios. o Biofidelity: the biomechanical basis of crash test dummies. o Injury severity scales (AIS, MAIS,), injury criteria and tolerances and their derivation from biomechanical testing and real accidents. o Computer simulation o Detailed biomechanical models representing the real human body.</p> <p>6.PASSIVE SAFETY 1 FRONTAL IMPACT 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. o Injuries to car occupants in Frontal Impact. o Vehicle structural crash; optimal energy dissipation, compartment integrity. o Triggering of belt pretensioner and airbag(s). o Adaptation of belt and airbag operation towards crash conditions and occupant size and position. o Test procedures and design methods.</p> <p>7.PASSIVE SAFETY 2 OTHER IMPACT MODES SIDE IMPACT: Injuries. Test procedures & dummies. Protection offered by the protective vehicle compartment, airbags and vehicle interior padding. ROLLOVER: Injuries and ejection. Test procedures & dummies. Effectiveness of curtain airbags and belts to prevent ejection. REAR IMPACT: Injuries. Test procedures & dummies. Passive and active seat systems for rear impact. 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).</p> <p>8.SAFETY TEST PROCEDURES Review of regulated test procedures, consumer test procedures and best practice for active and passive safety as introduced in previous chapters. o Safety in the vehicle development process. o Subsystem versus full system testing. o Hardware versus virtual testing. o Gaps where accident types and injury types are not well covered. o Gaps where innovative safety systems are not well covered.</p>	
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)	
	Supervised Assignments using software used in the Automotive Industry 1) PreScan Assignment: simulate the effect of support systems for close following 2) MADYMO Assignment frontal impact, optimise belt & airbag for various impacts & body sizes.	

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

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. sc4022/sc4025	
Course Contents	<p>This course replaces the former courses on Multivariable Control Systems (wb2421) and Robust Control (wb2415).</p> <p>Contents:</p> <ul style="list-style-type: none"> · Recap on background in linear systems theory and classical feedback control · Multivariable system control: Nyquist, interaction, decoupling · Directionality in multiloop control, gain and interaction measure · Stabilizing controllers and the concept of the generalized plant · Parametric uncertainty descriptions, approximations · The general framework of robust control · Robust stability analysis · Nominal and robust performance analysis · Excursion: The algebraic Riccati equation · The H-infinity control problem and its solution in terms of Riccati equations · The structured singular value: Definition of μ, properties, computation, bounds · μ synthesis, DK-iteration, role of uncertainty structure. · Design of robust controllers, choice of performance criterion and weights 	
Study Goals	<p>The student is able to reproduce theory and apply computational tools for robust controller analysis and synthesis.</p> <p>More specifically, the student must be able to:</p> <ol style="list-style-type: none"> 1. substantiate relation between frequency-domain and state-space description of dynamical systems 2. define stability and performance for multivariable linear time-invariant systems 3. construct generalized plant for complex system interconnections 4. describe parametric and dynamic uncertainties 5. translate concrete controller synthesis problem into abstract framework of robust control 6. reproduce definition, properties and computation of the structured singular value 7. master application of structure singular value for robust stability and performance analysis 8. sketch derivation and precisely formulate the solution of the H-infinity control problem 9. specify the role of Riccati equation within H-infinity control 10. design robust controllers on the basis of the H-infinity control algorithm 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	<p>Course material: S. Skogestad, I. Postlethwaite, Multivariable Feedback Control, 2nd Edition. John Wiley & Sons, 2005.</p> <p>References from literature: K. Zhou, J.C. Doyle, K. Glover, Robust and optimal control, Prentice Hall, 1996 D.-W. Gu, P.Hr. Petkov, M.M. Konstantinov, Robust Control Design with Matlab. Springer Verlag, London, UK, 2005</p>	
Assessment	Written exercise and oral examination	
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 4	
Course Language	English	
Expected prior knowledge	Undergraduate curriculum	
Course Contents	<p>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</p>	
Study Goals	<p>Study Goals: The student should be able to</p> <ol style="list-style-type: none"> 1. Explain how and why MPC has emerged from industry. 2. List the five basic items of MPC and discuss their role. 3. Identify, recognize and describe different type of models in MPC and explain when a type of model is suited for a specific application. 4. Show that all models can be transformed into a state-space model. 5. Understand the concept of prediction in MPC. 6. Make a prediction in the noiseless and the noisy case. 7. Explain why a standard formulation is desirable. 8. Transform any MPC problem into the standard MPC problem. 9. Derive the steady-state of a system. 10. Solve the finite and infinite horizon problem. 11. Derive the realization for the LTI-case and for the inequality constrained case. 12. Describe two ways to deal with infeasibility. 13. Discuss stability for the LTI case and in the inequality constrained case. 14. Describe the use of the end-point constraint and the infinite prediction horizon. 15. Give the relation of the MPC scheme and the IMC scheme. 16. Motivate the rules-of-thumb for initial tuning and use these rules for tuning an MPC controller. 17. Describe the concept of robustness in MPC. 18. Motivate and use the rules of robust tuning in MPC. 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 4	
Course Language	English	
Course Contents	<p>Theory and applications of knowledge-based and intelligent control systems, including fuzzy logic control and artificial neural networks:</p> <ul style="list-style-type: none"> * Introduction to intelligent control * Fuzzy sets and systems * Intelligent data analysis and system identification * Knowledge based fuzzy control (direct and supervisory) * Artificial neural networks, learning algorithms * Control based on fuzzy and neural models * Reinforcement learning * Examples of real-world applications 	
Study Goals	<p>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.</p> <p>After successfully completing the course, the student is able to:</p> <ul style="list-style-type: none"> * Name the limitations of traditional linear control methods and state the motivation for intelligent control. Give examples of intelligent control techniques and their applications. * 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. * 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. * 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. * 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. * 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. * Show how dynamics are incorporated into fuzzy models and neural networks, give examples. Discuss how dynamic models can be identified from data. * 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. * 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. * Define hard, fuzzy and possibilistic partitions, explain the fuzzy c-means algorithm and its parameters. * 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.dsc.tudelft.nl/~sc4081) and handed out at the lectures.	
Assessment	<p>Written exam, closed book.</p> <ul style="list-style-type: none"> * SC4081-10 D1 The exam constitute 60% of the final mark * SC4081-10 D2 Literature assignment 20% of the final mark * SC4081-10 D3 Practical Matlab / Simulink assignment 20% of the final mark. <p>A mini-symposium is organized in order for the students to present the results of the literature assignment.</p>	
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 4	
Course Language	English	
Department	3mE Department Delft Center for Systems and Control	

SC4081-10 D2	<i>Knowledge Based Control Systems, Literature</i>	.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	<i>Knowledge Based Control Systems, Matlab</i>	.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	<i>Optimization in Systems and Control</i>	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 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.dsc.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	

SC4110	System Identification	5
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	<p>Experimental modelling of dynamic systems; methodology. Discrete-time signal- and system-analysis. Identification of transferfunctions. Representations of linear models; black-box models. Identification of prediction-error-methods; least squares-method. Approximation modelling; algorithms. Experiment design and data-analysis. Identification in time- and frequency-domain; closed-loop identification; model validation; Matlab toolbox; laboratory assignment.</p>	
Study Goals	<p>General learning objectives</p> <p>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.</p> <p>Detailed learning objectives:</p> <ol style="list-style-type: none"> 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 2) The student is able to specify the bias and variance properties of models identified by the ETFE identification method. 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. 4) The student is able to specify different linear model structures, and to characterize their computational and statistical properties in prediction error identification. 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. 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. 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. 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. 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). <p>Required level for the assignment</p> <ol style="list-style-type: none"> 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 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	
Literature and Study Materials	Assignment form: final project on a laboratory setup followed by an oral examination	
Prerequisites	lecture notes and slides	
Assessment	Basics in linear algebra and signal theory	
Assessment	Oral and project	
Assessment	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	

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	<p>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.</p> <p>Please notice that the course is not offered every year. Check Blackboard for details.</p>	
Study Goals	<p>Acquire competence to report on a particularly chosen scientific development within signal analysis, system identification or control</p> <p>Identify essentials in an advanced scientific article or book chapter about signals, systems or control</p> <p>Compose a summary with a balanced exposition of generic aspects, details, examples</p> <p>Orally report on results of investigation, including an educated evaluation of the subject</p> <p>Defend presentation and evaluation in a scientific discussion with audience</p> <p>Enter a scientific dispute about the particular topic of specialization of a fellow-student</p>	
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 2	
Course Language	English	
Required for	Core curriculum	
Course Contents	<p>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.dsc.tudelft.nl/~sc4150.</p>	
Study Goals	<p>Main objective: understand fuzzy logic, fuzzy decision making and fuzzy control, and be able to translate linguistic expressions into fuzzy sets and derive conclusions.</p> <p>Understand the difference between fuzziness, probability and possibility.</p> <p>Understand characteristic functions, operations on fuzzy sets and fuzzy relations.</p> <p>Apply the Compositional Rule of Inference and the Generalized Modus Ponens.</p> <p>Analyze the defuzzification procedure.</p> <p>Know fuzzy data bases.</p> <p>Apply Mamdani and Gödel inference for fuzzy control.</p> <p>Understand look-up tables for fuzzy controllers, stability and robustness.</p> <p>Apply sliding mode fuzzy control.</p> <p>Synthesize fuzzy decision making.</p> <p>Know subjectivity and single-step, single-person decision making.</p> <p>Apply measures, weights, and criteria-criteria dependency.</p> <p>Analyze decision operators.</p>	
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 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. 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	

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	<p>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.</p> <p>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.</p>	
Study Goals	<p>Automotive Sensors Steering Systems (Traditional Mechanical System, Assisted Steering Systems and Steer-by-wire) Braking Systems (Traditional hydraulic brakes, brake-by-wire, introduction to longitudinal braking dynamics and ABS systems) Suspension (Passive, Semi-Active and Active Systems, Design considerations and control logics) Electric and Hybrid Vehicles (actuation, energy storage systems, engine, powertrain and regenerative braking) Design of new vehicle control architectures such as global chassis control Robustness aspects (fail safe and fault tolerant behaviour) Mathematical modelling and simulation</p>	
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 5	
Course Language	English	
Course Contents	<p>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.</p> <p>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:</p> <ul style="list-style-type: none"> - introduction to braking - longitudinal dynamics: nonlinear model derivation, linearization and stability analysis - braking actuators: current and future braking actuators will be reviewed and discussed from a control oriented point of view; - sensors and identification/estimation problems: the relevant variables needed to control the wheel dynamics will be discussed. Sensors and estimation methods presented. - 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	

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 4	
Course Language	English	
Expected prior knowledge	Linear Algebra, Differential Equations, Mechanics	
Course Contents	<p>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:</p> <ol style="list-style-type: none"> 1. Computed torque control 2. Impedance control 3. Passivity-based control 4. Nonholonomic control 5. Learning control 6. Distributed control 7. Hybrid control & Discrete Event Systems 	
Study Goals	<p>After successfully completing the course, the students should be able to:</p> <ul style="list-style-type: none"> - Identify classes of models for various types of robotic platforms - Identify the workspace and configuration spaces - Apply stability analysis tools - Design interacting motion controllers for manipulator robots - Design gait generators for walking robots - Design stabilizing and tracking controllers for wheeled robots 	
Education Method	Lectures 0/0/4/0	
Books	<p>Recommended books:</p> <p>Spong, Hutchinson, Vidyasagar, "Robot Modeling and Control"</p> <p>Murray, Lee, Sastry, "A Mathematical Introduction to Robotic Manipulation"</p> <p>Khalil, "Nonlinear Systems"</p>	
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 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	<p>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.</p> <p>Theory and Models:</p> <ul style="list-style-type: none"> -- Quick recap of basic probability theory and basics of stochastic processes -- Probabilistic Graphs: theory of Markov Chains, Bayesian and Network inference, Stochastic Petri Networks -- Monte-Carlo Simulations: principles and use -- Random dynamics: from ordinary to stochastic differential equations -- Sensitivity analysis, Robustness -- Putting it all together: Stochastic Hybrid Systems <p>Applications in the Life Sciences:</p> <ul style="list-style-type: none"> -- Basics of molecular cell biology -- Phylogeny and simple graphical models -- Intrinsic and extrinsic noise in genetic and regulatory networks -- Chemical and biochemical reaction networks: The Chemical Master Equation, its linear-noise approximation, its Langevin approximation, moment closures -- Chemical and biochemical reaction networks: the Stochastic Simulation Algorithm (Gillespie's SSA) -- Metabolic networks: Michaelis-Menten Enzyme Kinetics -- Particles in a medium: Random walks and Brownian motion <p>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.</p>	
Study Goals	<p>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.</p> <p>By taking this course, the student:</p> <ul style="list-style-type: none"> - will receive a broad introduction to the development and use of (simple) probabilistic models - will learn how to characterize such models, how to simulate them, and how to analyze them - 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. <p>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.</p>	
Education Method	Lectures.	
Computer Use	The final project assignment may be based on Matlab.	
Literature and Study Materials	<p>Three reference textbooks:</p> <ol style="list-style-type: none"> 1) U. Alon, "An Introduction to Systems Biology". Chapman & Hall/CRC Press, 2007. 2) Z. Szallasi, J. Stelling, and V. Periwal, "System Modeling in Cellular Biology - From Concepts to NUTs and Bolts". The MIT Press, 2007. 3) D.J. Wilkinson, "Stochastic modeling for systems biology". Chapman & Hall/CRC Press, 2006. 	
Assessment	<p>Furthermore, the Instructor will circulate additional material based on original scientific literature.</p> <p>The final grade will be based on two parts:</p> <ol style="list-style-type: none"> 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. 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 DCSC, 3mE, 8C-4-24 85606	

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 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.	
	Topics include:	
	General performance characteristics of measurement instruments.	
	Elements in measurement systems: Sensors, Signal conditioning and Signal processing.	
	Electronics used in measurement systems and EMC. Signal manipulation and transmission, filtering, noise suppression, amplitude modulation.	
	Measurement uncertainty, error sources, correction methods. Interfering and modifying error sources.	
	Calibration, traceability and standards.	
	Dynamics of measurement systems and measurement of dynamics. Transfer functions in the frequency and time domain.	
	Measuring devices for both linear and angular motion (displacement, velocity, acceleration)	
	Force, torque and pressure sensors.	
	Strain gauge principles	
	Optical measurement systems, encoders and laser interferometry	
Study Goals	<ul style="list-style-type: none"> * 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. * The student will be capable of applying the basic principles of measurement of mechanical magnitudes. * The student will be capable of determining the suitable measurement systems for a given metrology problem. * 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	

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 3	
Course Language	English	
Expected prior knowledge	wb2207 and wb2420 or sc4025	
	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: 1. describe the essential differences between continuous time and discrete-time control 2. transform a continuous time description of a system into a discrete-time description 3. calculate input-output responses for discrete-time systems 4. analyse the system characteristics of discrete-time systems 5. employ a pole-placement method on a discrete-time system 6. implement an observer to calculate the states of a discrete time system 7. apply optimal control on discrete-time systems 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: Lecture notes are made available on Blackboard References from literature: K.J. Astrom, B. Wittenmark 'Computer-controlled Systems', Prentice Hall ,1997, 3rd edition B.C. Kuo 'Digital Control Systems', Tokyo, Holt-Saunders, 1980 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	

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 3	
Course Language	English	
Required for	All PME students	
Expected prior knowledge	Bsc Mechanical Engineering, Electrical Engineering or Physics. ME1611-10 (Physics for mechanical Engineers) and SC4026 (Control system Design) is needed as preparation	
Course Contents	<p>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).</p> <p>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.</p> <p>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.</p> <p>The course covers four main subjects:</p> <ol style="list-style-type: none"> 1: Dynamics of motion systems in the time and frequency domain of actively controlled motion systems. It includes transfer functions represented in Bode plots. 2: Motion control with PID-feedback, and model based feedforward. 3: Electromechanical Actuators, both electromagnetic and piezoelectric 4: Analog electronics, operational amplifiers and power electronics used for driving actuators. <p>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.</p> <p>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.</p>	
Study Goals	<p>The student can analyze active dynamic systems by means of bode diagrams.</p> <p>The student can solve new mechatronic problems in a structured way, starting with the required function.</p> <p>The student will be able to understand the role of different disciplines that are used in mechatronic systems in their mutual relationship.</p> <p>The student will be able to determine the optimal combination of the different disciplines to achieve a specific controlled motion function.</p>	
Education Method	<p>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).</p> <p>The lectures will be aiming at introducing the material and make the students learn by intensive studying and practicing in individual exercises.</p>	
Computer Use	No computers will be used nor will the emphasis lay on exact calculated values.	
Literature and Study Materials	<p>A reader is in concept published on blackboard. When possible in time it will be made available in printed form as a book.</p> <p>The presentations will also be published on blackboard</p>	
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	<p>The course gives methods to design complex systems by following the System Engineering guidelines of INCOSE. Clearly distinguishing requirements and specifications.</p> <p>Further it is focusing on mechatronic concept design by optimally combining different disciplines and pinpointing (dynamic) interactions between the different elements of a system</p>	
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.	

WB2427	Predictive Modelling	3
Responsible Instructor	Dr.ir. R.A.J. van Ostayen	
Instructor	Prof.dr.ir. J. van Eijk	
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	Steps in a Modelling Activity Stepwise Refined Modelling Practical Modelling Mixed Dynamics/Control Simulations Effect of Modal Truncation and Accuracy Model Reduction Techniques Static Reduction Techniques Component Mode Techniques	
Study Goals	The student is going to be able to model (lump sum) some high precision engineering applications (positioning and vibration isolation) with structural resonances using 20-sim or Simulink, and is able to modify and optimize the mechanical structure for better performances	
Education Method	Lecture and computer room exercises	
Literature and Study Materials	Machine Dynamics in Mechatronics Systems - An Engineering Approach (Rankers)	
Assessment	Oral	
Percentage of Design	30%	
Design Content	System level design and modelling - Improving mechanical design	
Department	3mE Department Precision & Microsystems Engineering	

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 5	
Course Language	English	
Course Contents	<p>Introduction Overview of the process and energy industry Design versus operation, batch and continuous operation Objectives of process control</p> <p>Modeling System boundary, conservation laws and constitutive equations Degrees of freedom (DOFs) Examples: stirred tank (reactor), furnace, distillation column Differential and algebraic equations (DAEs) Simulation and analysis of DAEs Common causes for nonlinearities and linear model development Model representations: State space and IO forms Laplace transformation and analysis (poles, zeros, stability) Common building blocks of transfer functions Model approximation and reduction</p> <p>Control Instrumentation: sensors, actuators, control systems Process and Instrumentation Diagrams (P&IDs) Feedback and feedforward control approaches Control in the Laplace domain - PID control: tuning and practical aspects (scaling, tamed D-action, etc.) - Internal Model Control (IMC) and direct synthesis - Extensions: ratio, feedforward, cascade, override, split-range Interaction: pairing (RGA) and decoupling Plantwide control: production rate control, quality control and recycles Batch control and Sequential Function Charts (SFCs) Optimization: Model Predictive Control (MPC), Real Time Optimization (RTO) and Scheduling and Planning (S&P)</p>	
Study Goals	<p>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.</p> <p>More specifically, the student must be able to:</p> <ol style="list-style-type: none"> 1. Have a general understanding of process operation. 2. Develop models of a process and analyze its dynamic properties. 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	<p>Course material: Slides Standard text book see below (not obligatory)</p> <p>References from literature: Process Dynamics and Control, Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp.</p>	
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	

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 4		
Start Education	3		
Exam Period	Exam by appointment		
Course Language	English		
Expected prior knowledge	Good knowledge of linear algebra and analysis.		
Course Contents	<p>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.</p> <p>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:</p> <ol style="list-style-type: none"> 1. Convexity and efficient computation <p>We introduce basic notions from convexity and from computational complexity theory. Using this we can distinguish between easy and difficult computational problems.</p> <ol style="list-style-type: none"> 2. Modelling of optimization problems as convex optimization problems <p>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.</p> <ol style="list-style-type: none"> 3. Solving convex optimization problems <p>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.</p> <ol style="list-style-type: none"> 4. Several problems from systems theory <p>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.</p> <ol style="list-style-type: none"> 5. Using convex optimization in systems theory <p>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.</p>		
Study Goals	After successful participation in the course students will be able to:		
	<ul style="list-style-type: none"> - explain the basic concepts of convexity and complexity theory - give examples of problems in systems theory - apply tools from convex optimization to systems theory - model optimization problem as convex optimization problems - solve convex optimization problems with the help of computer software 		
Education Method	lectures, exercise sessions		
Literature and Study Materials	<p>S. Arora, B. Barak, Computational Complexity: A Modern Approach, Cambridge University Press, 2009</p> <p>A. Barvinok, A Course in Convexity, AMS, 2002</p> <p>A. Ben-Tal, A.Nemirovski, Lectures on Modern Convex Optimization. Analysis, Algorithms, and Engineering Applications, MPS-SIAM Series on Optimization, 2001.</p> <p>S. Boyd, L. Vandenberghe, Convex Optimization, Cambridge University Press, 2004.</p> <p>S. Boyd, L. El Ghaoui, E. Feron, V. Balakrishnan, Linear Matrix Inequalities in System and Control Theory, SIAM 1994</p> <p>C. Scherer, S. Weiland, Linear Matrix Inequalities in Control, Delft Center for Systems and Control.</p> <p>Many of the above references are available online.</p>		
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 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. 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. For more details, see also http://homepages.cwi.nl/~schuppen/courses/tudmath/controlstocdt2011s/courseguide.html	

Year 2011/2012
Organization Werktuigbouwkunde, Maritieme Techniek & Technische Materiaalwetenschappen
Education Master Systems and Control

Master year 2 Projects, Assignments, Thesis etc.

SCP4500-11	Project work	3
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	<p>This project is an intrinsic part of the second year programme of the MSc Systems and Control. It encompasses 3 formal colloquium presentations (Literature colloquium, Introductory colloquium and Final Graduation colloquium) and 2 less formal MSc Workshop presentations. Next to these presentations the students have to attend 10 colloquia sessions and 7 MSc Workshops (including those where they give their own presentations. Attendance is monitored.</p> <p>MSc workshops are organized on the morning of each last Friday of the month (excl. July and August) and consist of 5-8 student presentations (10 minutes + 10 minutes discussion). In most cases a presentation of an external speaker from industry with a systems and control background, is included. Colloquia sessions are organized throughout the year and are published on the DCSC website and communicated to 2nd year students by email.</p>	
Study Goals	<p>The student is capable of</p> <ul style="list-style-type: none"> - compressing large quantities of research information into a short presentation - performing a lively and interesting presentation adapted to the knowledge level of the audience - demonstrating a balance between presenting the main aspects and sufficient detail of the topic - applying multi-media aids to support the presentation adequately - participating on an adequate academic level with a sufficient critical attitude in in-depth discussions about his/her own presentations/subjects as well as about presentations/subjects by others. 	
Education Method	self study, participation in colloquia and workshops	
Assessment	The colloquia are assessed by means of an evaluation form. Students can request this form from the education coordinator or their supervisor. Attendance at colloquia and workshops is monitored.	
Department	3mE Department Delft Center for Systems and Control	

SCP4510-11	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	<p>The literature study is typically the initial phase of an MSc Thesis project (SCP4530-11), 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. 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 Graduation Guide for guidelines to perform literature searches.">http://www.dsc.tudelft.nl/Education/--> Graduation Guide for guidelines to perform literature searches. 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.</p> <p>Once some well-motivated choices have been made on what is planned to be investigated, these are summarized in a report. This will then form the basis for the subsequent MSc-project work.</p> <p>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 (see also SCP4500-11)</p>	
Study Goals	<p>The study goals of the literature study are:</p> <ul style="list-style-type: none"> o The student is able to search for/identify publications that are relevant to a specific research question o The student is able to create an accurate overview of the state of the art for a specific research question 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 supervision 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	

SCP4520-11	Internship (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	SCP4520-11 is the code for the internship of the MSc Systems and Control. This internship is optional. Commonly students combine internships with the MSc project. This code is meant for students that started their MSc after September 1, 2011.	
Study Goals	<p>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.</p> <p>The student has proven to be capable of communicating about his Internship research project both through an oral presentation and a report.</p> <p>The student has demonstrated his capability to consider and discuss the technological, ethical and societal impact of his internship work.</p> <p>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.</p>	
Education Method	Project	
Assessment	Report and oral presentation	
Department	3mE Department Delft Center for Systems and Control	

SCP4530-42	MSc Thesis Project	42
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	<p>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. See also http://www.dcsc.tudelft.nl/Education/--> Graduation Guide.</p> <p>The student will be supervised by a DCSC staff member, a full professor, a company supervisor (if applicable) and often also by a PhD student.</p>	
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

Unit	Mech, Maritime & Materials Eng
Department	Hybrid & Distributed Sys&Con
Telephone	+31 (0)15 27 85606
Room	8C-4-24

Dr.ir. D.A. Abbink

Unit	Mech, Maritime & Materials Eng
Department	Biomechatronics & Biorobotics
E-mail	D.A.Abbink@tudelft.nl
Telephone	+31 (0) 15 27 82077
Room	5A-1-03

Prof.dr. R. Babuska

Unit	Mech, Maritime & Materials Eng
Department	Intelligent Control & Robotics
E-mail	R.Babuska@tudelft.nl
Telephone	+31 (0)15 27 85117
Room	8C-3-18

Dr. M.C.J. Bliemer

Unit	Civiele Techniek & Geowetensch
Department	Transportplanning
E-mail	M.C.J.Bliemer@tudelft.nl
Telephone	+31 (0)15 27 84874
Room	HG 4.10.1

Dr.ir. X.J.A. Bombois

Unit	Mech, Maritime & Materials Eng
Department	Model-based Measurem & Contr
E-mail	X.J.A.Bombois@tudelft.nl
Telephone	+31 (0)15 27 85150
Room	8C-2-20

Dr.ir. A.J.J. van den Boom

Unit	Mech, Maritime & Materials Eng
Department	Hybrid & Distributed Sys&Con
E-mail	A.J.J.vandenBoom@tudelft.nl
Telephone	+31 (0)15 27 84052
Room	8C-3-09

Prof.ir. O.H. Bosgra

Unit	Mech, Maritime & Materials Eng
Department	Support Delft Cent Syst & Cont
Telephone	+31 (0)15 27 85610
Room	8C-2-17

Dr. Q.P. Chu

Unit	Luchtvaart- & Ruimtevaarttechn
Department	Control & Simulation
E-mail	Q.P.Chu@tudelft.nl
Telephone	+31 (0)15 27 83586
Room	LB 0.27

Dr. M. Corno

Unit	Mech, Maritime & Materials Eng
Department	Systems and Control
Telephone	+31 (0)15 27 85242
Room	8C-4-25

Prof.dr.ir. B.H.K. De Schutter

Unit	Mech, Maritime & Materials Eng
Department	Hybrid & Distributed Sys&Con
E-mail	B.DeSchutter@tudelft.nl
Telephone	+31 (0)15 27 85113
Room	8C-2-11

Dr. G.A. Delgado Lopes

Unit	Mech, Maritime & Materials Eng
Department	Intelligent Control & Robotics
Telephone	+31 (0)15 27 85489
Room	8C-3-19

Prof.dr.ir. J. van Eijk

Unit	Mech, Maritime & Materials Eng
Department	Mechatronic Systems Design
Telephone	+31 (0)15 27 85396
Room	5A-0-28

Ir. I. Grondman

Unit	Mech, Maritime & Materials Eng
Department	Intelligent Control & Robotics
Telephone	+31 (0)15 27 83371
Room	8C-3-17

Dr.ir. R. Happee

Unit	Mech, Maritime & Materials Eng
Department	Biomechatronics & Biorobotics
Telephone	+31 (0)15 27 83213
Room	5A-1-09

Dr.ir. A. Hegyi

Unit	Civiele Techniek & Geowetensch
Department	Transportplanning
E-mail	A.Hegyi@tudelft.nl
Telephone	+31 (0)15 27 89644
Room	HG 4.45

Prof.dr.ir. J. Hellendoorn

Unit	Mech, Maritime & Materials Eng
Department	Support Delft Cent Syst & Cont
Telephone	+31 (0)15 27 89007
Room	8C-2-12

Dr. P.S.C. Heuberger

Unit	Mech, Maritime & Materials Eng
Department	Support Delft Cent Syst & Cont
E-mail	P.S.C.Heuberger@tudelft.nl
Telephone	+31 (0)15 27 85331
Room	8C-3-08

Prof.dr.ir. E.G.M. Holweg

Unit	Mech, Maritime & Materials Eng
Department	Systems and Control
Telephone	+31 (0)15 27 89007
Room	8C-2-12

Prof.dr.ir. S.P. Hoogendoorn

Unit	Civiele Techniek & Geowetensch
Department	Transportplanning
E-mail	S.P.Hoogendoorn@tudelft.nl
Telephone	+31 (0)15 27 85475
Room	HG 4.21

Dr.ing. D. Jeltsema

Unit	Elektrotechn., Wisk. & Inform.
Department	Optimalisatie Systeem Theorie
E-mail	D.Jeltsema@tudelft.nl
Telephone	+31 (0)15 27 89277
Room	HB 04.140

Dr.ir. E. van Kampen

Unit	Luchtvaart- & Ruimtevaarttechn
Department	Control & Simulation
Telephone	+31 (0)15 27 87147
Room	LB 0.22

T. Keviczky

Unit	Mech, Maritime & Materials Eng
Department	Hybrid & Distributed Sys&Con
Telephone	+31 (0)15 27 82928
Room	8C-3-21

Dr.ir. J.W.C. van Lint

Unit	Civiele Techniek & Geowetensch
Department	Transportplanning
E-mail	J.W.C.vanLint@tudelft.nl
Telephone	+31 (0)15 27 85061
Room	HG 4.33

Dr.ir. E. Mooij

Unit	Luchtvaart- & Ruimtevaarttechn
Department	Astrodynamic & Space Missions
Telephone	+31 (0)15 27 89115
Room	9.19

Ir. T.H.J. Muller

Unit	Civiele Techniek & Geowetensch
Department	Transportplanning
E-mail	T.H.J.Muller@tudelft.nl
Telephone	+31 (0)15 27 85288
Room	HG 4.28

Prof.ir. R.H. Munnig Schmidt

Unit	Mech, Maritime & Materials Eng
Department	Mechatronic Systems Design
Telephone	+31 (0)15 27 86663
Room	4B-1-29

Dr.ir. R.A.J. van Ostayen

Unit	Mech, Maritime & Materials Eng
Department	Mechatronic Systems Design
E-mail	R.A.J.vanOstayen@tudelft.nl
Telephone	+31 (0)15 27 81647
Room	4B-1-28

Dr.ir. M.M. van Paassen

Unit	Luchtvaart- & Ruimtevaarttechn
Department	Control & Simulation
E-mail	M.M.vanPaassen@tudelft.nl
Telephone	+31 (0)15 27 85370
Room	LB 0.28

Dr.ir. A.M. Salomons

Unit	Civiele Techniek & Geowetensch
Department	Transportplanning
E-mail	A.M.Salomons@tudelft.nl
Telephone	+31 (0)15 27 88556
Room	HG 4.30

Prof.dr.ir. J.H. van Schuppen

Unit	Elektrotechn., Wisk. & Inform.
Department	Optimalisatie Systeem Theorie
Telephone	+31 (0)15 27 87293
Room	HB 04.050

W.M. van Spengen

Unit	Mech, Maritime & Materials Eng
Department	Micro and Nano Engineering
Room	4B-1-23

Ir. O. Stroosma

Unit	Luchtvaart- & Ruimtevaarttechn
Department	Control & Simulation
E-mail	O.Stroosma@tudelft.nl
Telephone	+31 (0)15 27 85344
Room	SIM 0.03

R. Toth

Unit	Mech, Maritime & Materials Eng
Department	Model-based Measurem & Contr
E-mail	R.Toth@tudelft.nl
Telephone	+31 (0)15 27 85246
Room	8C-2-18

Dr. F. Vallentin

Unit	Elektrotechn., Wisk. & Inform.
Department	Optimalisatie Systeem Theorie
Telephone	+31 (0)15 27 86262
Room	HB 04.120

Prof.dr.ir. P.M.J. Van den Hof

Unit	Mech, Maritime & Materials Eng
Department	Model-based Measurem & Contr
Room	-

Unit	Technische Natuurwetenschappen
Department	IST/Algemeen
Telephone	+31 (0)15 27 84509
Room	-

Dr.ir. A.C. in 't Veld

Unit	Luchtvaart- & Ruimtevaarttechn
Department	Control & Simulation
E-mail	A.C.intVeld@tudelft.nl
Telephone	+31 (0)15 27 82594
Room	LB 0.23

Prof.dr.ir. M.H.G. Verhaegen

Unit	Mech, Maritime & Materials Eng
Department	Systems and Control
E-mail	M.H.G.Verhaegen@tudelft.nl
Telephone	+31 (0)15 27 85204
Room	8C-2-24

S.A. Wahl

Unit	Technische Natuurwetenschappen
Department	BT/Bioprocetechnologie
Telephone	+31 (0)15 27 83193
Room	2.513

Dr.ir. J.W. van Wingerden

Unit	Mech, Maritime & Materials Eng
Department	Systems and Control
E-mail	J.W.vanWingerden@tudelft.nl
Telephone	+31 (0)15 27 81720
Room	8C-3-13

Ir. J.C.F. de Winter

Unit	Mech, Maritime & Materials Eng
Department	Medical Instruments
Telephone	+31 (0)15 27 86794

Room 5A-2-05

Dr. J.W. van der Woude

Unit	Elektrotechn., Wisk. & Inform.
Department	Optimalisatie Systeem Theorie
E-mail	J.W.vanderWoude@tudelft.nl
Telephone	+31 (0)15 27 83834
Room	HB 04.130
