Optimal Control and Regulation (1004)

Lecturer: Univ.-Prof. Dr. rer. nat. Matthias Gerdts

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: Knowledge of advanced mathematics and numerics, knowledge of control engineering and optimisation are advantageous.

Content:

- Modelling and formulation of optimal control problems
- Necessary conditions for optimal control problems: local and global minimum principle
- Numerical methods for optimal control problems: indirect methods and direct discretisation methods
- Grid-based methods based on the value function; construction of feedback controllers
- Application of the methods in model-predictive control processes
- Application examples and their practical solution

Learning objectives:
In the module, students acquire knowledge of the theory and numerics of optimal control problems and their application in control tasks. In addition, students learn to model practical tasks and solve them with the help of software packages.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral Examination, 30 minutes

English exam possible: oral

Bibliography:

- M. Gerdts: Optimal Control of ODEs and DAEs, De Gruyter, Berlin, 2011.
- L. Grüne, J. Pannek: Nonlinear Model Predictive Control - Theory and Algorithms, 2nd Edition, Springer, 2017.

Filter and estimation methods (1056)

Lecturer: Univ.-Prof. Dr.-Ing. Mirko Mählisch

Workload: 150 hours; Contact hours: 48h; Self-study: 102 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: A good knowledge of the knowledge acquired in the modules 'Digital Control' and 'Modern Methods of Control Engineering' is required (especially discrete-time state space representation), as well as basic knowledge of stochastics and higher mathematics.

Content:
In the filtering and estimation methods module, students gain a detailed insight into methods for the optimal estimation of state variables that cannot be measured directly or only poorly from noisy measured variables.

Based on a repetition of the fundamentals of stochastics, methods for filtering noisy measurement data and for estimating non-measurable state variables from noisy measurement data are presented.

The following topics are covered in detail:

1. Introduction: repetition of the representation of linear, discrete-time systems in state space and observability. Refresher on the basics of stochastics and error modelling. Choice of coordinate systems.
2. Linear estimators: linear equalisation calculation (more equations than unknowns) and linear, weighted equalisation calculation. From this, derivation of the Gauss-Markov estimator and the recursive Gauss-Markov estimator.
3. Repetition of the Luenberger observer in the state space
4. Kalman filter: Starting from the regular, discrete Kalman filter, the extended Kalman filter and the stabilised Kalman filter are discussed. Filter tuning, accuracy, comparison with the observer. Sequential innovation.
5. Introduction to the square root filter. The UD-factorised Kalman filter.
6. Unscented Kalman filter.
7. Particle filter
8. Special topics in filter and estimation theory:
    - Processing of measured values from different points in time.
    - Assignment of real measured values to predicted measured values (which measured value belongs to which object?).
    - Data fusion

Learning objectives:

The students

1. know the main methods for filtering noisy measurement data and for estimating unknown state variables from such data.
2. understand the main differences between the individual methods and recognise their advantages and disadvantages

3. are able to apply the knowledge they have learnt in the subsequent practical course ‘Autonomous Systems’ when setting up an autonomous model vehicle. A simple ‘roadway’ is captured by a camera built into the vehicle, from which the vehicle's state of motion is estimated using the estimation methods learnt. In the competition, student teams optimise these state estimators and the state controllers developed for them to achieve optimum lap times.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Written Examination 75 minutes

English exam possible: oral

Bibliography:

Sensor technology (1087)

Lecturer: Univ.-Prof. Dr.-Ing. Mirko Mählisch

Workload: 120 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: The knowledge acquired in the 'Measurement Technology' module is a prerequisite, as is a good knowledge of basic physical laws, digital electronics and statistics.

Content:
In the 'Sensor Technology for Autonomous Systems' module, students gain an overview of analogue and digital measurement technology as well as detailed insights into the structure and possible applications of sensors and sensor platforms.
Firstly, some basic sensor principles are introduced, after which the main internal and external sensor systems are discussed. The sensor platforms installed in the institute's own vehicle (camera system, LIDAR, inertial platform with dual GPS, ...) are explained in detail as examples.

Starting with an overview of the development and current status of measurement technology, sensor technology and measurement platforms, the following topics are covered:

- Introduction and brief review of :Why do we need sensors, examples of sensors in robots and (autonomous) vehicles, introduction of sensors. Statistical parameters and typical measurement errors including their mathematical description. Sensor models and sensor properties.
- Measurement chain - from the measured variable to the measured value in the computer Signal processing, sampling, sampling theorem, aliasing, analogue-digital converters, digital signal transmission, serial bus systems, digital-analogue converters
- Basic sensor principles; position sensors: Basic sensor principles and effects, such as Hall sensor, inductive sensor, capacitive sensor, magnetoresistive, piezoelectric and piezoresistive effect. Internal sensors: Measurement of positions and velocities.
- Measurement of accelerations: Various principles for measuring accelerations. MEMS sensors. Compass sensors. Rotation rate measurement: Coriolis force principle and Sagnac effect; gyro compass, vibration gyro, MEMS gyro, fibre gyro and ring laser.
- Inertial measurement systems and inertial navigation systems: Inertial measurement systems (IMU): platform and strap-down technology, gimbal lock, typical errors. Inertial navigation systems (INS); types of support: zero update, magnetic field, GNSS (GPS): loose, tight and very tight coupling. Satellite navigation systems such as GPS, Glonass, Galileo.
- External sensors: Landmarks Navigation: Natural and artificial landmarks. Lighthouses, beacons, VOR and DME. Hyperbolic navigation and coastal navigation. Force-torque sensor, 3D space mouse, tactile sensors, proximity sensors
- Distance sensors based on time-of-flight measurement: principle of time-of-flight

measurement: ultrasonic sensors, radar and lidar

- Imaging sensors: video and infrared cameras, HD (high-resolution) 3D lidar systems, optical time-of-flight cameras. Fundamentals of modelling, imaging equations, homogeneous coordinates.
- Further topics: Sensor timing, synchronisation and fusion. Out-of-sequence measurement.

Learning objectives:

The students

- know which essential elements make up the sensors and sensor platforms of an autonomous system,
- understand the functionality of the sensor systems used,

can apply the knowledge they have learnt in the parallel practical course ‘Autonomous Systems’ when building an autonomous model vehicle.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 75 minutes

English exam possible: oral

Bibliography:

- Everett H.R.: Sensors for Mobile Robots. Wellesley: Peters, 1995.

Static and dynamic loading of materials (1088)

Lecturer: Univ.-Prof. Dr. rer. nat. Eric Jägle

Workload: 150 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: Bachelor's programme LRT (in particular lecture on materials science)

Content:

1. Static stress: fracture mechanics
   - Linear elastic fracture mechanics (LEBM), brittle fracture (fundamentals, limits of LEBM, R-curve concept, crack toughness)
   - Yield fracture mechanics (small-range yielding, COD concept, J-integral)
   - Experimental investigation of fracture behaviour
     Fracture toughness of technical materials (metals, polymers, ceramics, composites) and mechanisms for increasing fracture toughness)

2. Dynamic stress: fatigue
   - Fundamentals of material fatigue (phenomenology of fatigue and failure modes, crack formation and growth, residual fracture, cyclic stress intensity factor)
   - Determination of overall service life and component design
   - Experimental investigation of material fatigue
   - Fatigue of technical materials (light metals, fibre composites, metal-polymer composites) and measures to increase service life

3. Time-dependent failure at high temperatures: creep
   - Empirical description, Larson-Miller parameters
   - Different mechanisms of static creep
   - High-temperature materials and measures to increase creep resistance

Learning objectives:

- Students gain an insight into the material behaviour of modern metallic and composite materials under both monotonic and oscillating loads and at elevated temperatures.
- They learn to use fracture mechanics tools to assess the limits of the usability of materials and to estimate the service life of cracked components.
- You will learn about the different types of material failure under cyclic loading (fatigue) and their theoretical description.
- They will learn about the mechanisms of time-dependent plastic deformation at elevated temperatures and will be able to calculate the fatigue strength.
- You will be familiar with the methods of material design to improve fracture toughness, fatigue behaviour and creep rupture strength at high temperatures.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral Examination 30 minutes

English exam possible: oral

Bibliography:

- Rösler, Harders, Bäker: Mechanisches Verhalten der Werkstoffe. Springer Verlag, 6. Auflage, 2019
- Courtney: Mechanical Behaviour of Materials. Waveland Press, 2. Auflage, 2005
- Gross, Selig: Bruchmechanik. Springer Verlag, 6. Auflage, 2016
- Suresh: Fatigue of materials. Cambridge University Press, 2. Auflage, 1998

Structural dynamics (1089)

Lecturer: Univ.-Prof. Dr.-Ing. Philipp Höfer

Workload: 150 hours; Contact hours: 60 hours; Self-study: 90 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: Knowledge of ‘Strength of materials’ and ‘Vibration theory’ is required

Content:
In the "Structural Dynamics" module, students gain in-depth knowledge of the dynamic behaviour of structures under dynamic load. The focus is on the methods for determining the stress under periodic and transient loading with low structural damping.

The module is divided into the following sections:

- Vibrations of spring-mass systems with one degree of freedom
  Free, undamped vibrations
  Forced vibrations
    Analytical solution of simple excitations
    Numerical solution methods
  Weakly damped oscillations

- Vibrations of systems with many degrees of freedom
  Natural frequencies and mode shapes
  Systematic formulation of the equation of motion
  Creation of the stiffness matrix and mass matrix
  Reduction of degrees of freedom
  Orthogonality of eigenvectors, decoupling of the equations of motion
  Damped vibrations, damping models
  Numerical integration of the equation of motion, Newmark-ß method
  Representation of vibrations in state space
  General information on the dynamic analysis of structures

- Approximation methods
  Bending vibrations, torsional vibrations, coupled bending-torsional vibrations
  Ritz method, Galerkin method

Experimental modal analysis

Learning objectives:

After successfully completing the module, students will be able to

- name and explain the main methods for solving the classical vibration equations for structures with low damping and an arbitrary number of degrees of freedom.

- Differentiate between the terms ‘natural frequency’, ‘mode shape’, ‘modal mass’,‘modal stiffness’ and ‘modal damping’. They can correctly categorise tasks in the ‘frequency domain’ or ‘time domain’.
- Explain the difference between analytical and numerical solution methods for vibration equations. They can select the appropriate methods and apply them to simple problems.
- Create a suitable mathematical equivalent model for a given physical equivalent model and solve it using suitable methods.

Use suitable approximation methods for simple tasks in order to be able to quickly make initial statements regarding the dynamic behaviour of structures.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

- Gasch R., Knothe K.: Strukturdynamik. Berlin: Springer-Verlag, 1987.
- Hart G.C., Wong K.: Structural Dynamics for Structural Engineers. New York: John Wiley & Sons, Inc., 1999.
- Craig R.R., Kurdila A.J.: Fundamentals of Structural Dynamics, New Jersey: John Wiley & Sons Inc., 2006.

Lalanne Ch.: Mechanical Vibration and shock Analysis. Volume 1: Sinusoidal Vibration. London: ISTE Ltd. and John Wiley & Sons Inc., 2009.

Vehicle dynamics (1161)

Lecturer: Univ.-Prof. Dr.-Ing. habil. Alexander Lion

Workload: 90 hours; Contact hours: 36 hours; Self-study: 54 hours

ECTS: 3 ECTS

Term: Autumn

Recommended prerequisites: mathematics, technical mechanics.

Content:

- Vertical vibration comfort of motor vehicles, quarter vehicle model
- Calculation models for air springs, elastomer and hydromounts and shock absorbers
- Transverse dynamics of motor vehicles, single-track model, controlled additional steering, steering angle jump, stationary circular driving, oversteer and understeer, driving stability
- Course control of vehicle models
- Linear and non-linear tyre models for lateral dynamics
- Calculation models for longitudinal vehicle dynamics
- Theoretical principles of drive and brake torque distributions

Learning objectives:
Students learn the basic methods and concepts of classical vehicle dynamics in terms of the vertical, lateral and longitudinal behaviour of motor vehicles. After completing the module, they will be able to critically scrutinise and evaluate numerical calculation results from vehicle simulation programmes and check them using simple models.

This lecture forms the basis for Master's theses in the field of vehicle simulation and complements other lectures in the faculty.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

- Richter B.: Schwerpunkte der Fahrzeugdynamik. Köln: Verlag TÜV Rheinland, 1990.
- Willumeit H.-P.: Modelle und Modellierungsverfahren in der Fahrzeugdynamik. Teubner Verlag, 1998.
- Mitschke M., Wallentowitz H.: Dynamik der Kraftfahrzeuge. Springer Verlag, 2004.

Schramm D., Hiller M., Bardini R.: Modellbildung und Simulation der Dynamik von Kraftfahrzeugen. Springer Verlag, 2010.

Methods in product development (1423)

Lecturer: Univ.-Prof. Dr.-Ing. Alexander Koch

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites:

Content:
General view

- Motivation; importance and tasks of product development
- Classification of product development in the market/company/society
- Systems theory approaches to describing technical systems
- Integrated product development

Process design

- Structuring of development processes: operational and strategic process models
- Process design for interdisciplinary development tasks
- Illustration of the phases and description of typical actions in the product development process using an example

Method support in product development

- Structuring of methods on the basis of the problem-solving cycle
- Presentation of methodical procedures for synthesising, analysing and evaluating technical solutions
- Aspects and significance of DfX as an option for knowledge management in development
- Procedure and methods for variant management

Computer support in product development

- Product data management: methods for processing and data and information flows in the development process
- CAx tools for method support; categorisation of CAx tools in the product development process

Learning objectives:

- Imparting knowledge of the fundamentals of development methods in the engineering sciences
- Learning a methodical, targeted approach to developing technical systems
- In addition to the presentation of the methods, knowledge of suitable aids and tools for finding solutions is provided, which are applied using practical examples
- The course aims to provide an overview of the diverse possibilities of computer support in product development and their limitations

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 90 minutes

English exam possible: oral

Bibliography:

- Bender, B.; Gericke, K.: Pahl/Beitz Konstruktionslehre – Methoden und Anwendung erfolgreicher Produktentwicklung. 9. Auflage. Berlin: Springer Vieweg, 2021
- Ehrenspiel, K.; Meerkamm, H.: Integrierte Produktentwicklung – Denkabläufe, Methodeneinsatz, Zusammenarbeit. 6. Auflage. Hanser Fachbuchverlag, 2017
- Lindemann, U.: Methodische Entwicklung technischer Produkte – Methoden flexibel und situationsgerecht anwenden. 3. Auflage. Springer Verlag, 2009
- Rupp, C.; SOPHISTen: Requirements-Engineering und -Management – Das Handbuch für Anforderungen in jeder Situation. 7. Auflage. Carl Hanser Verlag, 2020

Applied AI in decision-making processes (1896)

Lecturer: Juniorprof. Dr.-Ing. Jane Jean Kiam

Workload: 90 hours; Contact hours: 36 hours; Self-study: 54 hours

ECTS: 3 ECTS

Term: Autumn

Recommended prerequisites: Initial programming experience

Content:
The module consists of the lecture "Applied Artificial Intelligence (AI)" and the associated exercises (conceptual design of algorithms and their implementation including elementary programming tasks).

The lecture provides basic knowledge of the following AI approaches to decision support:

1. Basic search algorithms, e.g. Dijkstra, A*, hill climbing, evolutionary algorithms
2. Basics of logic, semantics and ontology:
    - Fundamentals of logic (e.g. first level logic, predicate logic, propositional logic)
    - Knowledge representation
3. Probabilistic approaches, e.g. Bayesian networks, Markov decision processes
4. Planning with uncertainties
    - Partially observable environments
    - Planning and rescheduling
5. Basics of machine learning, e.g. supervised learning, unsupervised learning, reinforcement learning, deep learning
6. Ethical aspects, state of the art, modern application examples

The acquired basic knowledge is deepened in the practice sessions using concrete application examples (especially from aviation) and simple programming tasks.

Learning objectives:
1. Students understand the methodological/algorithmic basics of the most important AI approaches for decision support.
2. Students understand the complexity of implementing the methods and algorithms.
3. Students have an overview of typical fields of application of AI, especially in aviation.

Students are able to conceptualise and implement basic AI approaches for specific application examples

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 25 minutes

English exam possible: oral

Bibliography:

- Ghallab M., Nau D., Traverso P.: Automated Planning and Acting. Cambridge University Press, 2016.

- Russel S., Norvig P.: Artificial Intelligence - A Modern Approach. Pearson Education, 2015.
- Sutton R., Barto A.: Reinforcement Learning - An Introduction. Bradford Books, 2018.

Inertial Navigation and Aviation (2309)

Lecturer: Univ.-Prof. Mag. Dr. habil. Thomas Pany

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: Knowledge from the lecture 'Satellite Navigation'

Content:

1. GNSS in aerospace
    - Use of GNSS within different flight phases
    - Knowledge of the accuracy of GNSS and its mathematical description. Increasing the error tolerance through receiver-internal procedures (RAIM, ARAIM) or local supplementary systems (SBAS, GBAS).
    - GNSS receivers for space travel and support for highly dynamic applications

2. Integrated navigation
    - System concept of integrated navigation
    - Navigation sensors and measured values
    - Kalman filter: general and extended Kalman filter for GNSS/INS integration
    - Strapdown calculation
    - GNSS/INS integration 2D and 3D
    - GNSS/INS error calculation and system design

Learning objectives:

- After successfully completing this course, students will be able to explain the navigation requirements of aviation and the reliability of GNSS.
- They will be able to handle procedures for increasing the reliability of GNSS (RAIM, ARAIM) or present them (SBAS, GBAS) and they will be able to analyse the extent to which the navigation requirements of aviation can be met with them.
- Furthermore, you will be able to define use cases for GNSS in aerospace and analyse various signal processing methods required for this.
- You will be able to describe navigation sensors and integrated navigation systems and design them for a specific application. You will be able to recognise the sensor technologies required for this, in particular for accelerometers and rate-of-rotation sensors.
- You will understand the interaction of the various measured values in an integrated system and the calculation processes of the Kalman filter.
- You will be able to develop a Kalman filter for navigation procedures.
- They remember the strapdown calculation of inertial navigation (INS) and can independently apply a simple coupled GNSS/INS system.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral Examination 30 minutes

English exam possible: oral

Bibliography:

Optional literature recommended:

- K. Wendel, „Integrierte Navigationssysteme: Sensordatenfusion, GPS und Inertiale Navigation“, Walter de Gruyter, 2011.
- P. Groves, “Principles of GNSS, inertial, and multisensor integrated navigation systems”, Artech-House, 2013.
- P. Teunissen, O. Montenbruck (Eds.), „Springer Handbook of Global Navigation Satellite Systems”, Springer 2017.

Image and signal processing for Earth Observation (2500)

Lecturer: Univ.-Prof. Dr.-Ing. habil. Michael Schmitt

Workload: 150 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: Knowledge of mathematics (linear algebra and statistics). Basic knowledge of programming algorithms. Interest in working with image and raster geodata.

Content:

- Fundamentals of signal processing
  Discrete and continuous signals
  Fourier transform and spectrum
  Convolution and correlation
  Basic filters
- Image processing
  Digital representation of images
  Histograms and statistical moments
  Colour spaces and models
  Two-dimensional convolution
  Basic 2D filters
  Image gradients
  Feature extraction
- Machine learning
  Types of machine learning (supervised, unsupervised)
  Data annotation
  Training and evaluation
  Typical models
  Artificial neural networks

Learning objectives:
After completing the module, students will be able to

- explain the overall purpose and methods of automated and computer-aided processing of digital images
- explain the relationship between image and signal processing
- select and apply suitable methods from the fields of image processing, signal processing and machine learning
- implement simple algorithms in a high-level programming language

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 90 minutes

English exam possible: yes (oral or written)

Bibliography:

Computational Fluid Dynamics (3827)

Lecturer: Univ.-Prof. Dr.-Ing. habil Markus Klein

Workload: 150 hours; Contact hours: 48h; Self-study: 102 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: Numerical analysis and basics in fluid mechanics.

Content:

The course starts with examples of CFD applications, followed by the fundamental equations of fluid dynamics, their approximations, and mathematical characteristics. It explores numerical methods like the Finite Difference Method and Finite Volume Method, highlighting their properties and applications. The importance of boundary conditions is discussed, along with time integration methods for unsteady flows. Key solution methods for linear systems of equations and the Navier-Stokes equations for incompressible flows are presented. The course also addresses grid generation, grid properties, and techniques for modeling turbulent incompressible flows, including DNS, LES, and RANS.

Learning objectives:

The numerical treatment of fluid mechanics problems has become an essential tool in various fields of aerospace engineering. The course on Computational Fluid Dynamics introduces students to the methods commonly used by engineers in their day-to-day work. This covers the calculation of incompressible as well as an introduction to the theory behind turbulence modeling.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Oral examination 30 minutes.

English exam possible: yes

Bibliography:

Joel H. Ferziger, Milovan Perić, Computational Methods for Fluid Dynamics, Springer Berlin, Heidelberg, 2002.

Earth Observation (1055)

Lecturer: Univ.-Prof. Dr.-Ing. habil. Michael Schmitt

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Mathematics, experimental physics, measurement technology, programming skills.

Content:

Optical remote sensing

- Optical image generation and acquisition
- Fundamentals of photogrammetry
- Analysing spectral information
- Land cover classifications

Radar remote sensing

- Fundamentals of radar technology
- Synthetic aperture principle
- Properties of SAR images
- SAR interferometry (InSAR)
- Advanced SAR methods

Learning objectives:

After passing the module, students will be able to

- explain and compare modern remote sensing methods and sensors, especially in the field of radar and optical remote sensing
- differentiate between the system technologies and the main evaluation methods using digital data processing
- describe the complete processing chain in the field of radar remote sensing and structure the necessary steps from the raw radar signal to the focussed SAR image, as well as from focussed SAR images to derived products such as elevation or change maps.
- identify the geometric and spectral properties of image data in the field of optical remote sensing and understand how these can be used to derive information through appropriate mathematical modelling.
- name the diverse civil and military applications of earth observation.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 90 minutes

English exam possible: yes (oral or written)

Bibliography:

Aircraft aerodynamics (1063)

Lecturer: Univ.-Prof. Dr. rer. nat. habil. Christian J. Kähler

Workload: 150 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Knowledge of the modules 'Mathematics', 'Fluid Mechanics' and 'Fundamentals of Aerodynamics' is required

Content:

- Compressible flow/aerodynamics
- Arrow wings
- High-lift aids
- Pure supersonic aerodynamics
- Theory of slender bodies
- Aerodynamics of the engine inlet
- Fuselage aerodynamics
- Wing-fuselage combination

Learning objectives:
Students are able to take the influence of compressibility on profile aerodynamics into account.

Students are able to apply the potential equation to compressible flow.

Students are familiar with the difficulties of the wing in transonics.

Students are aware of the effect of the wing sweep.

Students are familiar with the variants of mechanical high-lift aids and their potential-theoretical calculation methods.

Students are familiar with the calculation of flows on compression joints and expansion fans. They understand the calculation of aerodynamic coefficients on airfoils and the basic principles of surface rules.

Students understand the aerodynamics of engine intakes.

Students can understand the flow around simple fuselage geometries with the help of potential theory and are familiar with the problems and countermeasures associated with frictional flow.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 75 minutes

English exam possible: oral

Bibliography:

- Schlichting H., Truckenbrodt E.A.: Aerodynamik des Flugzeuges. Band 1. Springer Verlag, 2000.
- Schlichting H., Truckenbrodt E.A.: Aerodynamik des Flugzeuges. Band 2. Springer Verlag, 2000.
- Bertin J.J., Smith M.L.: Aerodynamics for Engineers. Prentice-Hall, 1989.
- Anderson J.D.: Fundamentals of Aerodynamics. McGraw-Hill Book Company, 1984.

Gas Dynamics (1066)

Lecturer: PD Dr. rer. nat. habil. Sven Scharnowski

Workload: 150 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Basic knowledge of mathematics and physics as well as knowledge as taught in the module "Fluid Mechanics and Aerodynamics".

Content:

- Thermodynamic principles
- The basic gas dynamic equation
- The linearised potential equation
- Vertical compression impact
- Oblique compression impact
- Prandtl-Meyer flow
- Interaction of shocks and expansions
- Characteristic method
- Nozzle flow
- Real gas effects
- Boundary layers in compressible flows
- Test facilities
- Measurement methods of gas dynamics

Learning objectives:

- Students can predict the shape and position of compression shocks and expansion waves occurring in the flow around two-dimensional bodies and the flow through nozzles
- Students can calculate changes in flow variables in two-dimensional compressible flows
- Students can apply the characteristic method to calculate supersonic flows for simple cases
- Students know the main real gas effects and know when they occur and must be taken into account
- Students have basic knowledge of the temperature effects in compressible boundary layer flows
- Students are familiar with the generation of supersonic flow and know examples of the essential measurement technology for analyzing compressible flow

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 90 minutes

English exam possible: oral

Bibliography:

- Anderson, J.D. (2004). Modern Compressible Flow with Historical Perspective, Mc Graw-Hill
- Anderson, J.D. (2006). Hypersonic and hightemperature gas dynamics. American Institute of Aeronautics and Astronautics
- Hirschel, E.H. (2015). Basics of Aerothermodynamics, Springer-Verlag
- Jischa, M. (1982). Konvektiver Impuls-, Wärme- und Stoffaustausch, Vieweg
- Krause, E. (2003). Strömungslehre, Gasdynamik und Aerodynamisches Laboratorium. Springer-Verlag
- Liepmann, H.W., & Roshko, A. (2001). Elements of gasdynamics. Courier Corporation
- Sauer, R. (2013). Theoretische Einführung in die Gasdynamik, Springer-Verlag
- White, F.M. (2016). Fluid Mechanics, in SI Units, Mc Graw-Hill

Modern structural materials (1076)

Lecturer: Univ.-Prof. Dr.-Ing. Philipp Höfer
Univ.-Prof. Dr. rer. nat. Eric Jägle

Workload: 150 hours; Contact hours: 60 hours; Self-study: 90 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Module Materials Science (Bachelor), Module Static and Dynamic Stress on Materials

Content:

1. Material selection
   1. Selection diagrams and material indices, software-based material selection
   2. Simultaneous optimisation of multiple variables
   3. Ecological material selection
   4. Process-related aspects of material selection

2. Metals for lightweight construction
   1. Light metals (Al, Ti, Mg alloys)
   2. High-strength steels
   3. Cellular materials (foams, lattice structures, architectured materials)

3. Fibre-reinforced composites
   1. Classification and basic structure
   2. Fibre materials
   3. Matrix materials
   4. Structural mechanics of FRP (properties and material laws of the UD layer, multi-layer composites, fundamentals of classical laminate theory)
   5. Design & areas of application
   6. Manufacturing processes & quality assurance

Learning objectives:
After completing this module, students will be able to

- systematically select suitable materials for given requirements and assess the overall property profiles of the various materials.
- name important material classes in aerospace, assess their structural properties, and describe the materials science background of material design.
- summarize the basics of design and calculation and assess key factors influencing structural behaviour.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

- Ashby: Materials Selection in Mechanical Design. Spektrum Akad. Verlag, 2006.
- Hornbogen, Eggeler, Werner: Werkstoffe, Springer Verlag, 12. Auflage 2019.
- Polmear, StJohn, Nie, Qian: Light Alloys. Butterworth-Heinemann, 5. Auflage 2017.
- Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden. Springer-Verlag, 2005.

Project management (1079)

Lecturer: Univ.-Prof. Dr.-Ing. Alexander Koch

Workload: 50 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites:

Content:
The module provides students with an introduction to the subject matter, specific problems and solution approaches of project management. In addition to learning methods and techniques, particular attention is paid to a holistic approach that includes organisational, personal, economic and legal aspects. The content of the lectures is deepened using examples and case studies.

The module is divided into the following sections:

- Introduction, discussion of the basics, definitions of terms and delimitations
- Generic process model for project management, tasks and characteristics of the individual phases
- Strategies in project management
- Methods and tools to support the individual phases in project management Application of the findings using selected examples and case studies of project management in the aerospace industry

Learning objectives:
The students

- are familiar with various project management process models.
- are able to distinguish between different project management strategies and assess their advantages and disadvantages.
- acquire skills in the application of methods and tools for project management.
- are able to carry out a project independently from project proposal to project completion.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 90 minutes

English exam possible: oral

Bibliography:

- Project Management Institute: A Guide to the Project: Management Body of Knowledge. (PMBOK Guide) An American National Standard, 4. Edition, ANSI/PMI 99-001-2008.
- Meyer & Reher: Projektmanagement: Von der Definition über die Projektplanung zum erfolgreichen Abschluss; Springer Gabler; 2. Auflage 2020, ISBN: 9783658287627
- Beuth-Verlag, DIN 69901-1, DIN 69901-2, DIN 69901-3, 2009

Space propulsion systems (1081)

Lecturer: Dr. Min Son

Workload: 120 hours; Contact hours: 48 hours; Self-study: 72 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Attendance at the lectures Aerothermodynamics, Space Technology I and II is recommended.

Content:
In the Space Propulsion module, students acquire basic knowledge of space propulsion systems and their diverse areas of application.

1. Students are introduced to the importance of space propulsion systems in solving problems in the field of aerospace engineering.
2. Starting with the theoretical basics, practical problems are discussed, including manufacturing aspects, components and operational aspects. Topics covered include:
   • Liquid rocket propulsion systems
   • Solid rocket propulsion systems
   • Hybrid rocket propulsion systems
   • Airbreathing propulsion systems
   • Electric propulsion systems
   • Future concepts
3. Where possible, an excursion will be organised to visit industrial companies with relevant production facilities.

Learning objectives:
1. Students will be able to classify the importance of space propulsion systems in technical problems with regard to feasibility, technology and future trends.
2. Students will be able to create and calculate propulsion concepts for simple applications.
3. Students will acquire the ability to propose suitable configurations for the respective applications.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written examination 75 minutes

English exam possible: yes (oral or written)

Bibliography:

Additive Manufacturing (1550)

Lecturer: Univ.-Prof. Dr.-Ing. Philipp Höfer
Univ.-Prof. Dr. rer. nat. Eric Jägle
Univ.-Prof. Dr.-Ing. Alexander Koch
Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Knowledge from the modules Materials Science, Modern Structural Materials, Technical Mechanics, Machine Elements and Lightweight Construction is required.

Content:
The following topics are covered in this module:

- Basic concepts and motivation
- Overview of materials used/usable
  - Metals for additive manufacturing
  - Polymers for additive manufacturing
  - Outlook on other material classes (ceramics, composites)
- The material in the manufacturing process
  - Microstructure formation
  - Process-typical defects
- Overview of manufacturing processes
  - Classification and categorisation of processes
  - Process flows
  - Manufacturing data
  - Parameter development
- Development process & design
  - Process overview
  - Design options and guidelines
  - Design for manufacturing
  - Calculation & topology optimization
  - Industry 4.0
  - Quality assurance & reverse engineering

Learning objectives:
After completing this module, students will be able to

- name key additive manufacturing processes and explain how they work and their special features.
- list relevant materials for additive manufacturing and explain their key properties.
- explain the formation of typical material defects based on microstructure formation and evaluate their effects.
- evaluate and select suitable materials for different application scenarios.
- describe the development process, apply design options and guidelines using simple examples, and explain the key differences to conventional manufacturing processes.
- present the procedure for structural calculation and, in particular, topology optimisation.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examintion 30 minutes

English exam possible: oral

Bibliography:

- Gebhart, A.: Additive Fertigungsverfahren. Hanser, 5. Auflage 2016
- Lachmayer, R., Lippert, R.: Entwicklungsmethodik für die Additive Fertigung. Springer Vieweg, 2020

Technical combustion (1897)

Lecturer: Univ.-Prof. Dr.-Ing. habil. Lars Zigan

Workload: 90 hours; Contact hours: 36 hours; Self-study: 54 hours

ECTS: 3 ECTS

Term: Winter

Recommended prerequisites: The modules 'Thermodynamics I/II – Fundamentals of Heat Transfer' and 'Fluid Mechanics' are prerequisites. Knowledge of aerodynamics and gas dynamics is advantageous.

Content:
Combustion remains the most important and widely used energy conversion technology worldwide. Potential environmental damage and limited fossil fuel resources require intensive efforts to better understand combustion processes and thus improve them, for example, to develop advanced combustion methods in propulsion technology, for gas turbines, domestic heating systems, industrial and process combustion systems.

The following topics will be covered in the lecture:

- Thermodynamic fundamentals (concentration terms, calorific values, flame temperatures, conservation equations)
- Efficiencies (thermal, exergetic, combustion efficiency)
- Ignition processes and ignition parameters (deflagration, detonation, explosion, ignition limits, ignition temperatures, ignition delay time, extinguishing distance, etc.)
- Fuels (liquid, solid, gaseous, novel synthetic and biogenic fuels) and combustion-relevant properties
- Flame types (premixed, partially premixed, non-premixed)
- Laminar and turbulent combustion, turbulence variables
- Flame velocity, flame-turbulence interaction, Borghi-Peters range diagram, flame stability and stabilisation methods
- Combustion modelling, introduction to numerical simulation of flows with combustion
- Pollutant formation (nitrogen oxides, soot, carbon monoxide, furans and dioxins) and combustion measures to minimise pollutant emissions
- combustion processes (burner types, gas turbines, engine and rocket propulsion systems)

Learning objectives:

- Students have in-depth technical and methodological expertise in the fields of combustion technology, combustion modelling, measurement technology, pollutant formation and technical applications.
- Students can characterise different types of flames and compare and evaluate technical applications in terms of efficiency and pollutant emissions.
- Students can describe global combustion and simple flames using thermodynamic conservation equations.
- Students are familiar with interdisciplinary working methods at the interface of fluid mechanics, thermodynamics and reaction engineering.

- Students have an understanding of methods of experimental and numerical combustion analysis.
- Students have an overview of the state of research and development in a current field of energy technology.
- Students are familiar with the latest developments in the field of combustion systems in the technical sector and in propulsion technology (e.g. aircraft gas turbines, rockets, engines).Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

Development management (3489)

Lecturer: Univ.-Prof. Dr.-Ing. Alexander Koch

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites:

Content:
Lecture contents

Motivation and introduction

- Classification of development management in corporate activities
- Necessity of development management
- Analysing the boundary conditions from the market and society

Considerations on innovation and technology management

- Contents, challenges and methods of technology management, innovation management and variant management for the strategic and operational design of the product portfolio
- Typical problems and methodological support for decision-making.

Considerations on systems engineering

- Necessity of systems engineering
- Considerations for the design of development processes and associated processes for requirements management, variant management, change management and release processes
- Mapping, analysis and optimisation of development processes
- Contents, necessity and methods for knowledge management, dealing with critical situations and controlling development processes

Exercise contents

Discussion of the content covered in the lecture using case studies

Learning objectives:
Many students on the programme become project leaders or managers in product development or research during the course of their careers. After successfully completing this module, students will be able to

- name the specific challenges and tasks in development management and apply them in such a way that they can successfully manage projects and organisational areas,
- apply the different activities in innovation and technology management as well as in systems engineering, interpret them for different organisational forms and evaluate them according to the social and market situation,

- apply a broad range of methods in order to be able to assess situations in development management and act appropriately and to categorise new experiences and knowledge from practice on the basis of what they have learned.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 90 minutes

English exam possible: oral

Bibliography:

- Bullinger, H.-J.: Einführung in das Technologiemanagement – Modelle, Methoden, Praxisbeispiele. Springer-Verlag, 2013
- Schuh, Günther, Innovationsmanagement: Handbuch Produktion und Management 3. 2. Auflage. Springer Vieweg, 2012
- Ehrenspiel, K.; Meerkamm, H.: Integrierte Produktentwicklung – Denkabläufe, Methodeneinsatz, Zusammenarbeit. 6. Auflage. Hanser Fachbuchverlag, 2017
- Lindemann, U.: Handbuch Produktentwicklung. Hanser Fachbuchverlag, 2016

Computational Fluid Dynamics (3828)

Lecturer: Univ.-Prof. Dr.-Ing. habil Markus Klein

Workload: 150 hours; Contact hours: 48h; Self-study: 102 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Knowledge of numerical mathematics (corresponding to the contents of the Bachelor's and Master's degree programmes). Lecture Computational Fluid Dynamics I.

Content:

- Large Eddy Simulation
- Hybrid RANS-LES method
- Two-phase flows with moving phase boundary
- Particle flows
- Combustion modelling
- Supersonic flows
- Explosions
- Future topics: Fluid-structure interaction, reciprocal heat transfer, Lattice-Boltzmann method, non-Newtonian fluids

Learning objectives:

The lecture "Computational Fluid Dynamics II" familiarises students with advanced topics of flow simulation. In particular, multiphase, supersonic and reactive flows are covered as well as modern methods of turbulence modelling. An outlook on problems with coupled physical mechanisms, such as heat transfer and fluid-structure interaction, rounds off the lecture.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Grade certificate: Portfolio, consisting of the partial performances:

- Completion of a CFD project (net workload: 90 hours) - 80%
- Final presentation 15 minutes - 20%

English exam possible: oral/project work

Bibliography:

- Ferziger J.H., Peric M.: Numerische Strömungsmechanik. Springer Verlag, Berlin Heidelberg, 2007.
- Poinsot T., Veynante D.: Theoretical and Numerical Combustion, Edwards, 2007.
- Tryggvason G., Scardovelli R., Zaleski S.: Direct Numerical Simulations of Gas-Liquid Multiphase Flows. Cambridge University Press, 2011.
- Lee, J.H.S.: The Detonation Phenomenon. Cambridge University Press, 2008.
- Laney, C.B.: Computational Gasdynamics. Cambridge University Press, 1998.

Lightweight structures (1068)

Lecturer: Univ.-Prof. Dr.-Ing. Philipp Höfer

Workload: 150 hours; Contact hours: 60 hours; Self-study: 90 hours

ECTS: 5 ECTS

Term: Spring

Recommended prerequisites: Knowledge of 'strength of materials' and 'lightweight construction' is required.

Content:
In the 'Lightweight Structures' module, students gain in-depth knowledge of lightweight structures. Particular attention is paid to the phenomena of force transmission and the stability of thin-walled structures. An initial insight into the functioning and calculation of membrane circular cylindrical shells is provided.

The module is divided into the following sections:

- Work and energy methods
  - External work and deformation energy
  - Betti's and Maxwell's theorems
  - Force method, displacement coefficients
  - Calculation of statically indeterminate structures

- Load introduction & load transfer in lightweight structures
  - Force introductions
  - Three-belt pulley

- Stability of lightweight structures
  - Bar-spring systems
  - Bifurcation and buckling problems
  - Bar-spring systems
  - Systems with multiple degrees of freedom
  - Combined stresses (Interaction formulas)

- Elastic structures: beams
  - Beams with pre-deformation
  - Approximation methods for beams
  - Elastically supported beams, sandwich buckling
  - Bending-torsional buckling, tilting

- Elastic structures: slabs/shells
  - Slab buckling
  - Partial shell instabilities
  - Buckling of circular cylindrical shells
  - Concept of the supporting width and the tension field

- Statics of circular cylindrical shells
  - Transfer matrix of the membrane shellLearning objectives:

Learning objectives:

After successfully completing the module, students will be able to

1. analyse statically indeterminate structures and determine sectional load distributions and deformations.
2. describe the essential mechanisms that come into play when concentrated forces are applied to thin-walled structures. They can determine the stresses that occur and transfer and assess their effects on practical problems.
3. list the various types of failure of lightweight structures and explain and differentiate between their causes and effects.
4. Explain and apply the calculation methods for discrete and continuous structures.
5. Determine stability-critical loads for bar-like structures and simple thin-walled structures and critically evaluate the results.
6. Explain the mode of action of membrane circular cylindrical shells with and without circumferential stiffeners.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

- Kossira H.: Grundlagen des Leichtbaus. Einführung in die Theorie dünnwandiger stabförmiger Tragwerke. Berlin Heidelberg: Springer Verlag, 1996.
- Wiedemann J.: Leichtbau. Elemente und Konstruktion. Berlin: Springer Verlag, 2007.
- Pflüger A.: Stabilitätsprobleme der Elastostatik. Berlin: Springer-Verlag, 1975.
- Niu M.C.Y.: Airframe Stress Analysis and Sizing. Hong Kong: Hong Kong Conmilit Press Ltd., 1999.

Aerospace Propulsion Systems (1069)

Lecturer: Univ.-Prof. Dr.-Ing. Dragan Kožulović

Workload: 150 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Spring

Recommended prerequisites: Knowledge from the modules ‘Fluid Mechanics’, ‘Gas Dynamics’, “Thermodynamics” and ‘Propulsion Systems’ is required.

Content:
In the Aviation Propulsion module, students acquire in-depth knowledge of turbofan and propeller engines:

- The respective characteristics, areas of application, key figures and aerothermodynamic relationships are explained for both engine types.
- The basics of calculating thrust, efficiency and specific propellant consumption are taught.
- Key parameters influencing engine performance are presented and suitable design trends are derived.

In addition, students in this module acquire basic knowledge about the special features of supersonic flight and the corresponding effects on engine design. Particular attention is paid to the design of suitable supersonic inlets, thrust nozzles and afterburners.

The module concludes with an introduction to the operating behaviour of aircraft engines and associated components. It covers the characteristic maps of compressors and turbines as well as suitable control concepts.

Learning objectives:
Students:

- are familiar with the special features of turbofan and propeller engines,
- can analyse the performance parameters of turbofan and propeller engines and coordinate the individual engine components,
- are familiar with the advantages and disadvantages of different engine types and are able to select suitable engine types for different areas of application,
- understand the special features of supersonic flight and can adapt the aerodynamic design of the engine accordingly,
- understand the characteristic operating behaviour of aircraft engines and can apply suitable control strategies.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written examination 90 minutes

English exam possible: oral

Bibliography:

- Bräunling W.: Flugzeugtriebwerke. Springer Verlag, 2004.
- Hagen H.: Fluggasturbinen und ihre Leistungen. Karlsruhe: Verlag G. Braun, 1982.

- Hünecke K.: Flugtriebwerke. Stuttgart: Verlag Motorbuch, 1978.
- Müller R.: Luftstrahltriebwerke. Grundlagen, Charakteristiken, Arbeitsverhalten. Braunschweig: Vieweg, 1997.
- Münzberg H.G.: Flugantriebe. Berlin: Springer-Verlag, 1972..

Measurement methods in fluid mechanics (1072)

Lecturer: Univ.-Prof. Dr. rer. nat. habil. Christian Kähler

Workload: 150 hours; Contact hours: 48 hours; Self-study: 102 hours

ECTS: 5 ECTS

Term: Spring

Recommended prerequisites: Basic knowledge of physics and measurement technology as well as the lecture 'Fluid Mechanics'.

Content:
Testing plays a central role in fluid mechanics design tasks, whether on a scaled-down model in a wind tunnel or on a full-scale model. The diagnostic tools available for this purpose have developed just as rapidly as the electronics used for fast signal processing and, in particular, laser optics.

The module 'Measurement Methods in Fluid Mechanics' covers the most important mechanical, electrical and optical measurement methods used in research and development today.

- Test facilities for model investigations
- Methods for visualising flows
- Pressure measurement methods
- Force measurement
- Hot wire technique
- Laser two-focus anemometer (L2F)
- Laser Doppler anemometry (LDA)
- Doppler global velocimetry (DGV)
- Particle image velocimetry (PIV)
- Particle tracking velocimetry (PTV)
- Schlieren method
- Interferometer
- Thermography
- Pressure sensitive paint (PSP)

Learning objectives:
- Students are familiar with the basic measuring principles of various mechanical, electrical and optical measuring methods.
- Students are familiar with the advantages and disadvantages of the measuring methods presented and are able to select the appropriate measuring technology for a given practical problem in order to answer fluid mechanics questions.
- Students have an understanding of the economic aspects, i.e. the financial and personnel costs associated with the use of a particular measurement method and the fluid mechanics findings obtained.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

- Eckelmann H.: Einführung in die Strömungsmesstechnik. Teubner, 1997.
- Tropea C., Yarin A.L., Foss J.F.: Springer Handbook of Experimental Fluid Mechanics. Springer Verlag, 2007.
- Raffel M., Willert C., Wereley S., Kompenhans J.: Particle Image Velocimetry. Springer Verlag, 2007.

Aircraft Trajectroy Optimization (1172)

Lecturer: Univ.-Prof. Dr. rer. nat. Matthias Gerdts

Workload: 90 hours; Contact hours: 48 hours; Self-study: 42 hours

ECTS: 3 ECTS

Term: Spring

Recommended prerequisites: Knowledge as taught in modules on ‘Advanced Mathematics’ or ‘Mathematical Methods in Engineering’.

Content:
The module consists of a lecture part, an exercise part and a computer lab for the practical implementation of the lecture content.

Contents of the lectures:

- Modelling and flight dynamics: designations, coordinate systems and transformations, state modelling, equations of motion, forces and moments
- Simulation methods: initial value problems, single-step methods (explicit and implicit Runge-Kutta methods), dependence on parameters
- Optimal control: task definition, transformation techniques, minimum principle and indirect method, discretisation methods, optimisation methods, dependence on parameters

Contents of the exercises:

- Tasks for deepening, illustrating and applying the lecture content
- Numerical solution of optimal control problems in trajectory optimisation with software packages

Learning objectives:
Students are familiar with modelling techniques in flight dynamics and can create aircraft models with varying degrees of detail.

Students are familiar with numerical methods for simulating flight manoeuvres.

Students are familiar with methods for optimal aircraft control and for calculating optimal flight paths and can apply these using software packages.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:

- Gerdts, M. : Optimal control of ODEs and DAEs, DeGruyter Verlag, 2011

Internship in Optimal Control (1355)

Lecturer: Univ.-Prof. Dr. rer. nat. Matthias Gerdts

Workload: 90 hours; Contact hours: 48 hours; Self-study: 42 hours

ECTS: 3 ECTS

Term: Spring

Recommended prerequisites: Knowledge as taught in modules such as 'Advanced Mathematics' or 'Mathematical Methods in Engineering'.

Content:
In the 'Optimal Control' internship, students acquire practical knowledge in the implementation of optimal control algorithms for controlling mobile robots.

The module consists of a short lecture section and a practical section for the practical implementation of the lecture content.

Lecture content:

- Fundamentals of optimal control, modelling, transformation techniques
- Introduction to numerical solution methods for optimal control problems, in particular discretisation methods
- Simple control strategies

Practical component content:

- Tutorial for the OCPID-DAE1 software package
- Implementation of simple optimal control problems using mobile robots.
- Tracking optimal trajectories through simple control strategies using sensors for position determination

Learning objectives:
Students can independently model optimal control problems in robotics and automotive simulation.

Students are familiar with numerical methods for solving optimal control problems and can use software packages such as OCPID-DAE1 to solve specific optimal control problems.

Students can interpret the calculated solutions in terms of feasibility and can implement the solutions in mobile robots.

Students are familiar with simple control methods for tracking a target trajectory and can utilise sensor information.

Teaching Material: English teaching material can be provided as text

Proof of performance: Grade certificate: Portfolio, consisting of the partial performances: written report (net workload: 90h, max. 20 pages)

English exam possible: project work

Bibliography:

Satellite Navigation (2308)

Lecturer: Univ.-Prof. Mag. Dr. habil. Thomas Pany

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Spring

Recommended prerequisites: Knowledge of advanced mathematics (linear algebra) and space systems, basic knowledge of signal processing and electrical measurement technology.

Content:

1. Global Navigation Satellite Systems (GNSS)
   • Reference systems, time systems, satellite orbits, structure of a GNSS
   • Current satellite navigation systems: GPS, Galileo, GLONASS, BeiDou
   Measurement methods (acquisition and tracking of GNSS signals)
   • Position determination via adjustment
   • Accuracy, availability, integrity and continuity
   • Link budget, vulnerability of GNSS (jamming/spoofing)

2. Differential GNSS methods (DGNSS)
   • Introduction, motivation and objectives for DGNSS
   • Observation equations, error budget, single and double differences
   • DGNSS, RTK and PPP
   • Range of applications

As part of the exercises, application-oriented programmes are developed or modified using MATLAB under supervision and executed with real data. A GNSS software receiver is used to understand all aspects of signal processing based on real data. Furthermore, measurements and experimental setups are carried out using the navigation laboratory's equipment (e.g. jamming and spoofing of GNSS).

Learning objectives:
The course has the following learning objectives:

- Graduates will be able to define the elements of global navigation satellite systems (GNSS) (system architecture/segments) as well as their civil and military applications.
- They will be able to describe the functioning of signal processing and positioning conceptually and mathematically and thus assess the vulnerability of GNSS.
- They will be able to explain the performance characteristics and apply them to navigation applications.
- They will understand data processing, algorithms and the error budget of differential GNSS technology, including RTK and PPP, and recall the associated applications in the civil and military sectors.
- They will be able to use software tools in the field of GNSS-signal processing and positioning independently.

Teaching Material: English teaching material can be provided as text

Proof of performance: Oral examination 30 minutes

English exam possible: oral

Bibliography:
Students have access to PowerPoint slides, lecture notes and MATLAB code. The following optional literature is recommended:

- P. Misra, P. Enge, „Global Positioning System; Signals, Measurements, and Performance“, 2nd Edition, Ganga-Jamuna Press.
- K. Borre et al., „A software-defined GPS and Galileo receiver; a single frequency approach“, Birkhäuser.
- H. Dodel, D. Häupler, „Die Satellitennavigation“, Springer Berlin Heidelberg, 2009.
- E. Kaplan, C. Hegarty, “Understanding GPS: principles and applications”, Artech house.
- P. Teunissen, O. Montenbruck (Eds.), „Springer Handbook of Global Navigation Satellite Systems”, Springer 2017