Advanced Engineering Mathematics					AR-101
Rota annually WS	**Duration** 1 Semester	**Semester** 1st (Semester)	**SWS** 5 SWS	**Credit Points** 7	**Workload** 210 h

1	**Modul structure**				
	Course (Abbreviation)	**Type/ SWS**	**Presence**	**Self study**	**Credits**
	a) Advanced Engineering Mathematics (AEM)	Lecture/ 3 SWS	45 h	90 h	4
	b) Advanced Engineering Mathematics (AEM)	Tutorial/ 2 SWS	30 h	45 h	3

2 Language

English

3 Content

1. Linear Algebra: Vector spaces, matrices and equation systems, linear maps, Jordan-, LU-, QR-, and singular value decomposition, numerical aspects.
2. Differential Equation: Linear systems, differential equations with constant coefficients.
3. Laplace-Transform: Definition, convolution and application to differential equations.
4. Differential Calculus with several variables: Derivatives, inverse and implicit functions, Taylor expansion and extreme values.
5. Stability of Differential Equations: Theorems of Ljapunov and Poincaré-Ljapunov.
6. Variational Calculus

Literature:

- Bajpai, Avinash C. , Mathematics for engineers and scientists
- Meyer, R.M., Essential mathematics for applied fields
- Lancaster, P., Tismenetsky, M., The theory of matrices
- Lang, S., Linear algebra
- Slides

4 Goals

The course gives an introduction to fundamental mathematical techniques used in almost every course. Attention is given to the underlying mathematical structure.

5 Examination Requirements

The final exam will be a written (2 hours) exam.

6 Formality of Examination

☒ Module Finals ☐ Accumulated Grade

7 Module Requirements (Prerequisites)

8 Allocation to Curriculum:

Mandatory Course

Program: Automation & Robotics

9 Responsibility/ Lecturer

Dr. P. Furlan/ Dr. P. Furlan

Aspects of Mathematical Modeling					AR-214
Rota annually WS or SS	**Duration** 1 Semester	**Semester** 2^{nd}/3rd (Semester)	**SWS** 3 SWS	**Credit Points** 5	**Workload** 150 h

1	**Modul structure**				
	Course (Abbreviation)	**Type/ SWS**	**Presence**	**Self study**	**Credits**
	a) Aspects of Mathematical Modeling (AMM)	Lecture/ 2 SWS	30 h	70 h	3
	b) Aspects of Mathematical Modeling (AMM)	Tutorial/ 1 SWS	15 h	35 h	2

2 **Language:** English

3 **Content**

Different directions of mathematical modeling techniques are introduced that build on the course Advanced Engineering Mathematics and assume a solid background in mathematics. Among the subjects are the following:

1. Optimization: Theoretical and practical aspects of optimization problems, formulation, optimality conditions, linear programming, discrete optimization.
2. Applied partial differential equations: Prototypes, representation formulae, qualitative and quantitative behavior, conservation laws, elliptic, parabolic and hyperbolic equations, convection-diffusion-reaction systems.
3. Continuum mechanics: Inertia and momentum, equations of motion, external forces, conservation laws, deformations.
4. Modeling: Modeling with differential equations: Autonomous systems, linearization, phase plane analysis, non-dimensionalization, network dynamics, stability, bifurcations. Stochastic modeling: statistical inference, stochastic processes.

Literature:

References will be given in the courses.

4 **Goals**

This course offers an introduction to different fundamental techniques of mathematical modeling and analysis that are useful for the dynamics and control of robotic devices. Tools that allow for the description and control of movement and the interaction with the environment are introduced. The ability to create and use models to estimate qualitatively and quantitatively the behavior of dynamic systems will be trained.

5 **Examination Requirements**

The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

6 **Formality of Examination**

☒ Module Finals ☐ Accumulated Grade

7 **Module Requirements (Prerequisites)**

Course: “Advanced Engineering Mathematics”

8 **Allocation to Curriculum:**

Program: Automation & Robotics, Field of study: Robotics, Process Automation, Cognitive Systems

9 **Responsibility/ Lecturer**

Dean of the Mathematics faculty / Lecturers of the Mathematics faculty

Mathematical Simulation Techniques					AR-308
Rota annually WS or SS	**Duration** 1 Semester	**Semester** 2nd/ 3rd	**SWS** 3 SWS	**Credit Points** 5	**Workload** 150 h

1	**Modul structure**				
	Course (Abbreviation)	**Type/ SWS**	**Presence**	**Self study**	**Credits**
	a) Mathematical Simulation Techniques (MST)	Lecture/ 2 SWS	30 h	70 h	3
	b) Mathematical Simulation Techniques (MST)	Tutorial/ 1 SWS	15 h	35 h	2
2	**Language:** English				

3 **Content:** Discretization and solution techniques for the numerical simulation of problems in continuum mechanics, as well as their efficient treatment on computer systems are introduced. The course Advanced Engineering Mathematics, a solid background in mathematics, and solid programming skills are assumed. Among the subjects are the following:

1. Practical finite elements: Variational formulation of partial differential equations, weak solutions, Ritz-Galerkin techniques, finite element approximation and analysis, numerical integration, boundary approximation, mesh generation, error control and reliability, solution of linear systems.
2. Computational aspects of fluid dynamics: Conservation laws, compressible and incompressible fluids, spatial discretization (FD, FV, FEM), stabilization techniques, explicit and implicit time stepping schemes, treatment of boundary conditions, projection- and operator-splitting -techniques.
3. High performance computing: Parallel computer architecture, performance-oriented programming, sparse numerical linear algebra, Krylov-subspace and multigrid solvers, preconditioning strategies, domain decomposition methods, shared and distributed memory parallelization with OpenMP and MPI, GPU Computing.
4. Approximation theory: Interpolation and approximation, polynomial spaces, splines and Bézier curves, existence and uniqueness, best-approximation properties, quasi-interpolation, quality assessment and error analysis.

Literature: References will be given in the courses.

4 **Goals**

This course provides students with fundamental mathematical simulation techniques that are essential to solve automation problems in robotics as well as in production and engineering processes of all kinds. The entire simulation pipeline is covered in theory and practice. Students are trained to solve real-life complex problems in “Numerics Labs”.

5 **Examination Requirements**

The final exam will be an oral (20 minutes) or written (1.5 hours) exam, depending on the number of participants (form will be announced in the second week of the course).

6 **Formality of Examination**

☒ Module Finals ☐ Accumulated Grade

7 **Module Requirements (Prerequisites)**

Course: “Advanced Engineering Mathematics”, solid programming skills

8 **Allocation to Curriculum:**

Program: Autom. & Robot., Field of study: Robotics, Process Automation, Cognitive Systems

9 **Responsibility/ Lecturer**

Dean of the Mathematics faculty / Lecturers of the Mathematics faculty