Fakultät Technologie und Bionik
Faculty of Technology and Bionics

HOCHSCHULE RHEIN-WAAL
Rhine-Waal University of Applied Sciences

Module Description

of the study course

„Bionics/Biomimetics M.Sc.“

Rev. 1. Stand: 18.03.2014

Contents

Module “Bionics of Locomotion and Control”

Module name	Bionics of Locomotion and Control
Module code	M_BB_101
Courses (Where applicable)	Bionics of locomotion and control Case studies of bionic implementations
Semester	Winter Semester
Module coordinator	Prof. Dr. William Megill
Lecturer	Prof. Dr. William Megill Prof. Dr. Neil Shirtcliffe
Language	English
Timetabled hours (HPW)	Bionics of locomotion and control Lectures 2 HPW Laboratory 1 HPW Case studies of bionic implementations Seminar 2 HPW
Workload	75 h Attendance 35 h Self-study 40 h Exam preparation
Creditpoints	5
Module objectives	The students have acquired knowledge and techniques to understand and classify movement processes in biologie so that these can be transfered to a technical context.
Content	Bionics of Locomotion and Control Biomimetic principles will be developed starting from animal examples and leading to novel machine implementations. Locomotion in fluids; drag, propulsion and lift; efficient & tuned body design; fluid-structure interaction; scaling principles; great flight diagramme; terrestrial locomotion; importance of resonance and timing Case studies of Bionic Implementations Students will research applications examples from the Bionics and Biomimetics literature, analyse, and present their

	work by preparing a lecture and leading a discussion work-shop.
Assessment	Bionics of Locomotion & Control: oral or written exam, lab reports Case Studies: Class presentation, report (testat)
Forms of media	Tafel, PowerPoint / PC-Projektor, Bionics laboratories
Literature	• BK Ahlborn – Zoological Physics. Springer. • Y. Bar-Cohen Biomimetics Biologically Inspired Technologies. CRC Press, 2006, ISBN: 978-0-8493-3163-3 • A. von Gleich, C. Pade, U. Petschow, E. Pissarskoi Potentials and Trends in Biomimetics. Springer Ber-lin, 2010. ISBN: 978-3-642-05245-3 • J.-Ch. Zufferey Bio-inspired Flying Robots. CRC Press, 2008. ISBN: 978-2-940222-19-3 • J. Ayers, J. L. Davis, A. Rudolph (Eds.) Neurotechnology for biomimetic robots. MIT Press, 2002. ISBN: 0-262-01193-X

Module „Energy and Environment“

Module Name	Energy and Environment
Module Code	M_BB_102
Courses (where applicable)	Energy in biological and technical systems Life in Moving Fluids
Semester:	Winter semester
Module Coordinator	Prof. Dr.-Ing. Joachim Gebel
Lecturer(s)	Prof. Dr. Georg Bastian Prof. Dr.-Ing. Joachim Gebel
Language	English
Timetabled hours	Energy in biological and technical Systems Lectures 1 HPW Laboratory 1 HPW Life in Moving Fluids Lecture: 1 HPW
Workload	45 h Attendance 75 h Self--Study 30 h Exam preparation
Credit Points	5
Module Objectives	Students understand the underlying physics of energy conversion, and have a solid knowledge of the engineering and biological systems which harness it. They have an intuitive feeling for the behavior of fluids under biologically interesting circumstances, and are able to apply engineering fluid mechanics to biology. They are able to apply Bernoulli’s equation, Hagen-Poiseuille equation and Stoke’s law properly. They understand the relationship between fluid flow and biological design such as jet propulsion, biological pumps, swimming, blood flow, and surface waves.
Content	Energy in biological and technical Systems Fundamentals: Energy, Force, Power Thermodynamic Considerations

	Carbon cycle and biomass Solar energy, photosynthesis and photovoltaics Energy storage, batteries and fuel cells Energy in biological and technical Systems (Laboratory) Practical introduction to energy conversion: Stirling motor, organic solar cells, thermoelectric modules, field trip to a energy generation plant. Life in Moving Fluids 1. What is a Fluid? 2. Equation of Continuity 3. Pressure and Equation of Momentum 4. Equation of Motion 5. Drag, Scale, and the Reynolds Number 6. The Drag of Simple Shapes and Sessile Systems 7. Shape and Drag: Motile Animals 8. Velocity Gradients and Boundary Layers 9. Life in Velocity Gradients 10. Making and Using Vortices 11. Lift, Airfoils, Gliding, and Soaring 12. The Thrust of Flying and Swimming 13.
Assessment	Oral or written exams
Forms of media	Whiteboard, powerpoint; Computer lab, Fluids lab
Literature	Energy in biological and technical Systems • Energies (0-262-69235-X) • Dynamic energy budget theory for metabolic organisation 978-0-521-13191-9 Life in Moving Fluids: Steven Vogel Life in Moving Fluids: The Physical Biology of Flow Publication Date: April 1, 1996 ISBN-13: 978-0691026169 Edition: 2nd Revised Herbert Oertel jr, Sebastian Ruck Bioströmungsmechanik: Grundlagen, Methoden und Phänomene

	Vieweg+Teubner; 2. Auflage, 2012 ISBN-13: 978-3-8348-1765-5 Mark Denny Air and Water: The Biology and Physics of Life's Media American Society of Zoologists. Meeting, 1988 Ausgabe illustriert, Neuauflage Verlag Princeton University Press, 1993 ISBN 0691025185, 9780691025186

Module „Mechanics and Control“

Module name:	Mechanics and Control
Module code:	M_BB_103
Courses (where applicable):	Mechanics and control Locomotion in animals and technology
Semester:	Winter semester
Module coordinator:	Prof. Dr.-Ing. Thorsten Brandt
Lecturer:	Prof. Dr.-Ing. Thorsten Brandt Prof. Dr.-Ing. Dirk Nissing Prof. Dr. William Megill
Timetabled hours:	Mechanics and control Lecture 1 HPW Laboratory 1 HPW Locomotion in animals and technology Lecture 1 HPW
Workload	45 h Attendance 75 h preparation and homework 30 h exam preparation
Credits	5
Module objectives:	After successfully finishing the module, students are able to understand special concepts of mechanics and controls and are able to apply them to biological and technical systems. The students understand the constraints of the evolution of biological systems as well as bionic applications. The students are able to characterize biological systems based on their mechanical and dynamical properties and to abstract from these systems as a first step towards a technical implementation.
Content:	Mechanics and control Kinematics of multiple-link mechanisms are described by means of translational and rotational transformations. The description is based on homogeneous coordinates and relies on the Denavit-Hartenberg convention. Forward and inverse kinematics of kinematic chains is covered on position and on velocity level. Formulations for the equations of

	motion are introduced. Based on this, principal concepts of controls are introduced and applied for electrical drives. Advantages and drawback of different implementation, e.g. with respect to the overall systems behavior and to complexity, are discussed. Practical examples in the controls lab and mechatronics are examined. As part of the practical different experiments based on industrial robots are performed and discussed with respect to kinematics and controls. Locomotion in Animals and Technology: Physiological fundamentals of biological locomotion; Terrestrial movement, swimming, and flying; importance of resonance, especially in terrestrial locomotion and flight Alongside the technical applications and animal examples, the underlying physics will be taught, specifically mecahnics, fluid dynamics and energy use. Traditional wheel based robots will be contrasted against biological models.
Assessment:	Oral or written exam
Forms of media:	Whiteboard, PowerPoint, Projector , practical in the controls lab
Literature	Mechanics and Control: • Mark W. Spong; Seth Hutchinson; Mathukumalli Vidyasagar: Robot Modeling and Control, Wiley & Sons, 2006, ISBN: 978-0471649908 • John J. Craig: Introduction to Robotics: Mechanics and Control, Pearson Education, 3rd Edition, 2009, ISBN-10: 8131718360 Locomotion in animals and technology • G. Taylor, M. S. Triantafyllou, C. Tropea (Eds.) Animal locomotion. Springer Berlin, 2010. ISBN: 978-3-642-11632-2 • R. McNeill Alexander Animal Mechanics. Blackwell Science, 1983. ISBN: 978-0632009565 • C. McGowan A practical guide to vertebrate mechanics. Cambridge University Press, 1999. ISBN: 0-521-

	57194-4 • R. McNeill Alexander Principles of animal locomotion. Princeton University Press, 2006. ISBN: 978-0-691-12634-0 • L. Maddock, Q. Bone, J. M. V. Rayner (Eds) Mechanics and physiology of animal swimming. Cambridge University Press, 1994. ISBN 0-521-46078-6 • P.K. Kundu, I. M. Cohen, P.S. Ayyaswamy Fluid Mechanics. Academic Press, 2010. ISBN: 978-0-12-381399-2 • R. Liebe (Ed.) Flow Phenomena in Nature, Vols. 1 and 2. WIT Press, 2006. ISBN: 1-84564-001-2

Module „Development and Management“

Module name	Development and Management
Module code	M_BB_104
Courses (where Applicable)	Mythbusters in bionics Biomimetic product design Patenting & technology transfer
Semester	Winter Semester
Module coordinator	Prof. Dr. William Megill
Lecturer(s)	Prof. Dr. William Megill Prof. Dr. Julien Vincent N.N.
Timetables hours	Mythbusters in Bionics Lecture 1HPW Biomimetic product design Lecture 1 HPW Patenting & technology transfer Lecture 1 HPW
Workload	45 h Attendance 60 h Self Study 45 h Exam Preparation
Credit Points	5
Module Objectives	The students know the difference between real biomimetics and marketing stories. They know the steps in a technical development process. They understand the importance of communication and interdisciplinary collaboration in the success of design projects. They are able to make use of tools to identify a customer’s requirements, and of other tools to develop new ideas and potentials. At the end of the course, the students should be able to apply biomimetic design rules to development projects.
Content	Mythbusters, bionics and philosophy What is biomimetic, and what isn’t; Convergent evolution in

	biology and technology; bionics as a marketing tool; Nature isn't always best; contrasts in philosophies & approaches of engineering and biology; communication issues in inter-disciplinarity. Biomimetic Product Design: • The development process • Design methodology VDI 2220 • Top-down and bottom-up-approach • Competition evaluation, red sea/blue sea model • Organisation of development processes (over-the-wall-approach, simultaneous engineering, integrat-ed product and process planning) • Tools for evaluation of design: SWOT-Analysis, QFD, Success factor analysis • Tools for product innovation Lateral Thinking, TRIZ, 635-Method • „Design" in nature: constant stress goal • Material addition and replacement • Development of new products using biomimetic in-ventions Patenting & Technology Transfer Patents and Patent Law: • Prerequisites for patenting • Inventor's concept • Worker as inventor – legal aspects • Biotechnology patents • Patent process • Infringing on a patent - consequences • European and international patent law Technology Transfer • Bringing innovation to market • Challenges of intellectual property protection • The role of the engineer in tech transfer
Assessment	Mythbusters in bionics: attestation Biomimetic product design: attestation Patenting & technology transfer: attestation
Forms of media:	Whiteboard, powerpoint.

Literature	Biomimetic product design: • G. Pahl, W. Beitz, J. Feldhusen, K.H. Grote Engineering Design – A Systematic Approach, ISBN 978-1-84628-318-5, Springer, 2007 • David G. Ullman The mechanical Design Process, Fourth Edition, ISBN 978-0-07-297574-1, McGraw-Hill Higher Education, 2010 • G. Specht, C. Beckmann, J. Amelingmeyer F&E-Management – Kompetenz im Innovationsmanagement, 2. Auflage, ISBN 978-3-7910-1726-8, Schäffer-Poeschel, 2002 • G. Mattheck Design in Nature – Learning from Trees, ISBN 978-3540-629375, Springer, 1998 Patenting & technology transfer: • Georg Weber, Gerd A. Hedemann, Helge B. Cohausz: Patentstrategien. Heymanns-Verlag. ISBN 978-3452254429. • Witte / Vollrath: Praxis der Patent- und Gebrauchsmusteranmeldung. Heymanns-Verlag. ISBN 978-3452264428. • Avery N. Goldstein: Patent Law for Scientists and Engineers. CRC Press. ISBN 978-0824723835. • Howard B. Rockman: Intellectual property law for engineers and scientists. John Wiley & Sons. ISBN 978-0471449980.

Module „Applied Research Project A“

Module name	Applied Research Project A
Module code	M_BB_105
Courses (where applicable)	Scientific Methods and Writing Applied Research Project A
Semester	Winter or Summer Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Project subject dependent
Timetabled hours	Scientific Methods and Writing Lecture: 1 HPW Project A Project Work 4 HPW
Work load	75 h Attendance 75 h Self-study
Credit Points	5
Module objective	Students have experience of project related work and the practical implementation of their acquired knowledge. They can find required information independently using a variety of sources (literature research, internet, specialists, etc). They can document and present their work in a professional manner.
Content	Scientific Methods and Writing Students know the fundamental principles of scientific Investigation and can use these in their own work. They understand not only the methodology, but also the importance of the ethics of scientific work, e.g. copyright, citations, plagiarism, etc. Project A Planning, completion, documentation, and presentation of a first independent research project. The focus is on on surveying the literature, on developing theory and hypotheses, and on proposing a methodology. Initial experimental work may be part of the project, but not required. The student should either present his/her own results, or predict what would be obtained. Results or predicted results

	should be discussed in the context of the scientific literature, and a report/proposal prepared. Projects are supervised by individual professors and span the range of research and development activities underway in the faculty. Projects can also be undertaken in collaboration with industry.
Assessment	Scientific Methods and Writing: Attestation Applied Research Project A: Report, Attestation.
Forms of media	Whiteboard, powerpoint, laboratories.
Literature	Scientific literature.

Module “Bionics of Materials and Structures”

Module name	Bionics of Materials and Structures
Module code.	M_BB_106
Courses (where applicable)	Structural Biomaterials Case studies of bionic implementations
Semester	Winter Semester
Module Coordinator	Prof. Dr. Neil Shirtcliffe
Lecturer(s)	Prof. Dr. Neil Shirtcliffe
Timetabled Hours	Structural Biomaterials Lecture 2 HPW Laboratory 1 HPW Case studies of bionic implementations Seminar 2 HPW
Workload	75 h Attendance 35 h Self study 40 h Exam preparation
Credit Points	5
Module Objectives	Students will master the materials science and engineering concepts of biological, bio-inspired, and bio-compatible materials in animals, plants and biomimetic applications.
Course content	Structural Biomaterials Hooke’s Law and elastic materials; Proteins; Sugars & fillers; Hydrostatic skeletons and shock absorbers; Stiff materials – fibrous composites; Biological ceramics; Biomimetic materials; Biocompatibility Case studies of Bionic Implementations Students will research application examples from the Bionics and Biomimetics literature, analyse, and present their work by preparing a lecture and leading a discussion workshop.
Assessment	Structural Biomaterials: oral or written exam, lab reports Case Studies: presentation, report, class participation, at-

	testation
Forms of Media	Whiteboard, PowerPoint / PC-Projector/Laboratory
Literature	Structural Biomaterials JFV Vincent (2012) Structural Biomaterials, 3rd Ed. Princeton UP. Case Studies Online and printed journals and books

Module “Materials in Structures”

Module name	Materials in Structures
Module code.	M_BB_107
Courses (where applicable)	Advanced Materials Science Materials in Design
Semester	Winter Semester
Module Coordinator	Prof. Dr.-Ing. Raimund Sicking
Lecturer(s)	Prof. Dr.-Ing Raimund Sicking Prof. Dr.-Ing. Peter Kisters
Timetabled Hours	Advanced Materials Science Lecture: 1 HPW Laboratory: 1 HPW Materials in Design Lecture: 1 HPW
Workload	45 h Attendance 75 h Self-Study 30 h Exam preparation
Credit Points	5
Module Objectives	Students will have an advanced understanding of materials microstructures, properties and of how to use classical, modern and novel materials in engineering design.
Course content	Advanced Materials Science Metal and ceramic structures, phase diagrams, structural changes, heat treatment, case studies on steel and light metals, review on polymers, fibre reinforced plastics and hard metals, production aspects, exemplary value chain considerations Materials in Design Stresses, strains, and geometry; Material properties; the design process; selecting materials; Ashby charts; soft-ware; selection for x: mechanical match; cost, usability, availability

Assessment	Written or oral examination; lab reports
Forms of Media	Whiteboard, powerpoint. Materials laboratory. Microscopy laboratory. Computer labs.
Literature	• Michael F. Ashby, David R. H. Jones: Engineering Materials 2 – An Introduction to Microstructures, Processing and Design, 3rd edition, 2006, ISBN-13 978-0-7506-6381-6 • C. Barry Carter, M. Grant Norton: Ceramic Materials, 2nd edition, 2013, ISBN 978-1-4614-3522-8, Springer • Donald R. Askeland: Materialwissenschaften, 1st edition, 1996, ISBN 978-3-8274-2741-0, Spektrum • ASM International, Harry Chandler (Editor): Heat Treater´s Guide – Practices and Procedures for Irons and Steels, 2nd edition, 2010, ISBN-13 978-0-87170-520-4 • Richard G. Budynas: Shigley's Mechanical Engineering Design, Student international edition, 8th revised edition, ISBN 978-0071268967, McGraw-Hill College, 2009 • Cecil Jensen, Jay D. Helsel, Dennis R. Short: Engineering Drawing & Design, 7th revised edition, McGraw-Hill Higher Education, 2007 Ehrlenspiel et al.: Cost-Efficient Design, ISBN 978-3-642-07100-3, Springer Verlag, Berlin Heidelberg, 2010

Module “Joining Materials”

Module name	Joining Materials
Module code.	M_BB_108
Courses (where applicable)	Joining Technologies Biojoining & Bioinspired Materials
Semester	Winter Semester
Module Coordinator	Prof. Dr.-Ing. Raimund Sicking
Lecturer(s)	Prof. Dr.-Ing. Raimund Sicking Prof. Dr. Amir Fahmi
Timetabled Hours	Joining Technologies Lecture 1 HPW Laboratory 1 HPW Biojoining & Bioinspired Materials Lecture 1 HPW
Workload	45 h Presence 75 h Self study 30 h Exam preparation
Credit Points	5
Module Objectives	Students will understand traditional engineering joining technologies used for different conventional materials, and how biological materials grow and resorb in response to stress and other forces. The students will be able • To design properties of active materials based on proved concept from nature • To fabricate different types of bio-inspired structured materials at different dimensions • To define process and methodologies to synthesizing bio-inspired nanomaterials • To integrate bio-inspired functional component within interdisciplinary design work • To understand the limitation to mimic the nature at defined dimensions and length scales to design new or improve new functional structured materials In the interplay between the two module elements, they will

	develop an appreciation for the challenges and opportunities offered by biomimetic joining techniques
Course content	Joining Technologies Welding, soldering, brazing of metals; gluing, bonding of plastics and composites; mechanical joining techniques (rivets, bolts, clinching); stress concentrations; load transfer across joints; corrosion hotspots; combined processing Biojoining & Bioninspired Materials • The course offer overview in wide range of functional bio-inspired materials and their composition, structure, and properties. • It defines methodologies and pathway in the molecular designs of biomineralisation • The primary theme in course is bio-inspired structures via self-assembly process and mechanism at different dimensions and length scales. • It describes process and mechanism of nanoparticle formation in mesoscopic arrays toward transformations across extended length macro-scales as key challenge in the design of advanced functions. • The course demonstrates characterisation techniques for wide range of bio-inspired structures and properties
Assessment	Oral or written exams; lab reports
Forms of Media	Whiteboard, powerpoint; materials laboratory
Literature	• Singh M, Ohji T, Asthana R, Mathur S (2011) Ceramic integration and joining technologies: from Macro to Nanoscale. Wiley • M. F. Ashby, D. R. H. Jones: Engineering Materials 2 – An Introduction to Microstructures, Processing and Design, 3rd edition, 2006, ISBN-13 978-0-7506-6381-6 • H. J. Fahrenwaldt, V. Schuler: Praxiswissen Schweißtechnik – Werkstoffe, Prozesse, Fertigung; 4th edition, 2011, ISBN 978-3-8348-1523-1, Vieweg+Teuber • AWS C3 Committee on Brazing and Soldering: Brazing Handbook, 5th edition, 2012, ISBN 978-0-87171-046-8, AWS • H. Schoer: Schweißen und Hartlöten von Aluminiumwerkstoffen, 2nd edition, 2002, ISBN 3-87155-190-2, DVS-

	Verlag In addition current conference proceedings and other publications will be used. Bioinspired intelligent nanostructured interfacial materials Lei Jiang, Lin Feng Bio-Inspired Materials Synthesis by Yanfeng Gao Biological and bioinspired materials and devices Joanna Aizenberg,

Module „Bionics of Sensing“

Module name	Bionics of Sensing & Structures
Module code.	M_BB_109
Courses (where applicable)	Bionics of sensing Advanced studies in Biomimetics
Semester	Summer Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Prof. Dr. William Megill Prof Julian Vincent, with guest lecturers from several universities
Timetabled Hours	Bionics of sensing & structures Lectures 2 HPW Laboratory 1 HPW Advanced studies in Biomimetics Seminars 2 HPW
Workload	75 h Attendance 45 h Self-study 30 h Exam preparation
Credit Points	5
Module Objectives	Students understand the fundamentals of sensors and sensing in biological and technical systems. They appreciate the challenges of applying biomimetic solutions to real technical problems.
Course content	Bionics of Sensing The sensing systems which are required to transduce sensory signals will be introduced in a step by step manner. Especial attention will be paid to the fundamentals of neural perception and processing. Electronic sensor circuits will be introduced and built so that measurements can be made. Advanced Studies in Biomimetics An online and videoconference course shared with stu-

	dents and taught by lecturers from several universities worldwide Topics vary each week depending on the lecturer, and cover areas of advanced biomimetic theory and practice, drawing primarily on the lecturers' active research.
Assessment	Bionics of Sensing and structures: written or oral Exam, lab reports Advanced Studies: Attendance & term paper (Attestation)
Teaching Resources	PowerPoint, Whiteboard, Bionics Laboratories, Videoconferencing suite
Literature	Bionics of sensing: • F. G. Barth, J. A. C. Humphrey, T. W. Secomb (Eds.): Sensors and Sensing in Biology and Engineering. Springer Berlin, 2003. ISBN: 978-3-211-83771-9 • Y. Bar-Cohen: Biomimetics Biologically Inspired Technologies. CRC Press, 2006, ISBN: 978-0-8493-3163-3 • J. Ayers, J. L. Davis, A. Rudolph (Eds.): Neurotechnology for biomimetic robots. MIT Press, 2002. ISBN: 0-262-01193-X Advanced Studies: Online reources

Module „Sensors“

Module name	Sensors
Module code.	M_BB_110
Courses (where applicable)	Biomimetic sensors Ambient intelligent systems
Semester	Summer semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Prof. Dr.-Ing, Stefanie Dederichs Prof. Dr.-Ing. Ivan Volosyak
Timetabled Hours	Biomimetic sensors Lectures 1 HPW Laboratory 1 HPW Ambient intelligent systems Lectures 1 HPW
Workload	45 h Attendance 75 h Self-study 30 h Exam preparation
Credit Points	5
Module Objectives	Biomimetic Sensors The students master the fundamentals of sensing, both in biological and technical systems. They are familiar with different sensor systems and can evaluate their suitability for specific applications. They understand the principles of biological sensing and can use these to solve challenges in technical systems. Ambient Intelligent Systems: Students can derive concrete architectures from the fundamental principles of ambient intelligent systems. They are able to conceive and design machines using appropriate communication structures and sensor systems. They understand the safety and social aspects of ambient intelligent systems and networks, and can describe the risks

	involved.
Course content	Biomimetic Sensors: Model systems will be used to teach the fundamentals of sensory systems in animals. The most important sensing systems will be introduced in increasing order of complexity. The technology and physics of specified biomimetic applications will be described and explained. Ambient intelligent systems: • The concept of ambient intelligence • Environmental warning and interaction with technical systems • Location awareness • Communication networks in ambient systems. • Structure of ambient intelligence • Safety and social aspects
Assessment	Written or oral exam; term paper
Forms of Media	Whiteboard, powerpoint, Computer lab, bionics lab
Literature	Biomimetic Sensors: • Y. Bar-Cohen Biomimetics Biologically Inspired Technologies. CRC Press, 2006, ISBN: 978-0-8493-3163-3 • F. G. Barth, J. A. C. Humphrey, T. W. Secomb (Eds.): Sensors and Sensing in Biology and Engineering. Springer Berlin, 2003. ISBN: 978-3-211-83771-9 Ambient Intelligent Systems: • Andrew S. Tanenbaum, Marrten van Steen Distributed Systems - Principles and Paradigms, Prentice Hall, 2006 • Stefan Poslad Ubiquitous Computing - Smart Devices, Environments and Interactions, Wiley, 2009 • Werner Weber, Jan Rabaey, Emile H.L. Aarts Ambient Intelligence, Springer, 2005 • Hideyuki Nakashima, Hamid Aghajan**,** Juan Carlos Augusto Handbook of Ambient Intelligence and Smart Environments, Springer, 2009

Module „Sensor Fusion“

Module name	Sensor Fusion
Module code.	M_BB_111
Courses (where applicable)	Statistical Sensor Fusion Brain-Computer Interfaces
Semester	Summer Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Prof. Dr. William Megill Benjamin Williamson Prof. Dr.-Ing. Ivan Volosyak
Timetabled Hours	Statistical Sensor Fusion Lectures 1 HPW Brain-Computer Interfaces Lectures 1 HPW Laboratory 1 HPW
Workload	45 h Presence 75 h Preparation & Study 30 h Examination preparation
Credit Points	5
Module Objectives	Statistical Sensor Fusion: Students understand the current state of the art in statistical sensor fusion, in both theory and practice, using non-linear filters and Bayesian predictions to solve localisation, navigation and tracking problems. Brain Computer Interfaces: The students understand the fundamentals of electrical potentials in the human brain which can be detected with non-invasive and invasive methods. They can derive, from first principles, real architectures for modern Brain-Computer Interfaces. They are able to design and build, using specialized communications structures and sensors, systems for, among other things, the support of physically

	handicapped individuals. They appreciate the safety and social aspects of modern Brain-Computer Interfaces and can name the relevant risks.
Course content	Statistical Sensor Fusion: Sensor fusion as information merger; sensor characterization; linear and non-linear estimation, with a focus on sensor network applications; general non-linear filter theory; variants of the Kalman filter and the particle filter. Complexity and implementation issues; Simultaneous localisation and mapping (SLAM); real-world applications in Matlab & Labview. Brain Computer Interfaces: • Human body as electrical system • The concept of a Brain-Computer Interface • Data collection with non-invasive methods, in particular Electroencephalograms (EEG) • Fundamentals of EEG • Applications of BCIs for communication with and control of external machines • SSVEP, P300 and ERD/ERS based BCI
Assessment	Written or oral exam
Forms of Media	Powerpoint, whiteboard, Bionics laboratory, BCI laboratory
Literature	Statistical Sensor Fusion: • Gustafsson F (2010) Statistical sensor fusion. Gazelle Publishing. • Mitchell HB (2007) Multi-sensor data fusion: An Introduction. Springer Verlag Brain Computer Interfaces: • Jonathan R. Wolpaw, Elizabeth W. Wolpaw Brain-Computer Interfaces – Principles and Practice, Oxford University Press, 2012 • Kevin Roebuck Brain-Computer Interface – High-impact Emerging Technology, Tebbo, 2011 • Gerwin Schalk, Jürgen Mellinger A practical Guide to Brain-Computer Interfacing with BCI2000, Springer, 2010 • Brendon Z. Allison, Stephen Dunne et al. Towards Practical Brain-Computer Interfaces, Springer, 2012

Module „Applied Research Project B“

Module name	Applied Research Project B
Module code.	M_BB_112
Courses (where applicable)	Science and Project Management Research Project B
Semester	Summer or Winter Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Any professor
Timetabled Hours	Science and Project Management Lecture: 1 HPW Research Project B Project work 4 HPW
Workload	75 h Attendance 75 h Self Study
Required Prerequisite	Project A
Credit Points	5
Module Objectives	Science and Project Management Students master the fundamentals of project planning up to and including network analysis and resource allocation. They are able to monitor progress during a project and to complete risk assessments. They appreciate the specific requirements of scientific projects, in particular those supported by public funding. Project B Students should be able to design and carry out an initial independent research project, following the steps of the Scientific Method, and using project management tools as appropriate. In contrast to Project A, here the goal is for the student to obtain his/her own results and analyse them appropriately, then set them into their research or development context. The combination of Project A and Project B should prepare the student for the more substantial work which is the MSc

	thesis.
Course content	Science and Project Management • Fundamentals of project management • Stakeholder involvement • Project planning under specified constraints • Project execution and financial controlling • Risk management and worker motivation • Project review • Special requirements of scientific projects • Public funded projects: consortium building, funding, reporting. Project B This is an individual research project, conducted under the supervision of a professor and possibly an industrial partner, which the student should research the context of, design the methods for, and carry out mostly independently. The results obtained should be analysed and set into the relevant research or development context. The project can have a scientific research focus, or an engineering development one. It can be done in conjunction with an industrial partner, but a professor must be part of the supervisory team.
Assessment	Science and Project Management : Attestation Research Project B: Report/Attestation
Forms of Media	Whiteboard, powerpoint. Laboratories
Literature	Science and Project Management Gauch HG (2002) Scientific Method in Practice. Cambridge UP. Research Project B Tailored to each individual project. Google scholar, Web of Science Journals & monographs as appropriate

Module „Bionics of behaviour and sociology“

Module name	Bionics of Behaviour
Module code.	M_BB_113
Courses (where applicable)	Bionics of behaviour and sociology Advanced studies in Biomimetics
Semester	Summer Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	NN Prof Dr. William Megill Prof. Dr. Julien Vincent
Timetabled Hours	Bionics of behaviour and sociology Lecture 2 HPW Laboratory 1 HPW Advanced studies in Biomimetics Seminar 2 HPW
Workload	75 h Attendance 35 h Self-study 40 h Exam preparation
Credit Points	5
Module Objectives	Students understand the fundamentals of animal ethology, human sociobiology and robot “social behaviour”. They understand how these fields are studied, what the central tenets are, and what the limitations are. They appreciate the challenges of applying biomimetic solutions to real technical problems.
Course content	Bionics of Behaviour and Sociology Introduction to the concepts of animal and human behaviour; Tinbergen and ethology; human sociology; applications to biology; human-machine interaction; machine behaviour; robot social systems; biomimetic applications Advanced Studies in Biomimetics An online and videoconference course shared with stu-

	dents and taught by lecturers from several universities worldwide Topics vary each week depending on the lecturer, and cover areas of advanced biomimetic theory and practice, drawing primarily on the lecturers' active research.
Assessment	Bionics of Behaviour: written or oral Exam, lab reports Advanced Studies: Attendance & term paper (Attestation)
Forms of Media	Board, PowerPoint / PC-Projector, Videoconferencing suite
Literature	Textbook TBD; Online resources

Module “Business Biomimetics”

Module name	Business Biomimetics
Module code.	M_BB_114
Courses (where applicable)	Bionics for business processes Bionics in Design and Production
Semester	Summer Semester
Module Coordinator	Prof. Dr.-Ing. Peter Kisters
Lecturer(s)	External Lecturer Prof. Dr.-Ing. Peter Kisters Prof. Dr.-Ing. Alexander Klein
Timetabled Hours	Bionics for business processes Lecture: 1 HPW Bionics in Design and Production Lecture: 1 HPW Exercise:: 1 HPW
Workload	45 h Attendance 75 h Self-study 30 h Exam preparation
Credit Points	5
Module Objectives	The students appreciate typical applications of bionics in business processes, product development and industrial production. They understand that bionics is a trans-disciplinary approach which can be inspiring and helpful in non-traditional applications such as business management and development as well as in classical engineering business tasks such as component development, recycling, manufacturing technology and production management. They are also aware that biomimetics does not represent the universal solution to all problems. As a typical example for the limit, the different tolerable defect ratios in classical engineering and biology are known.
Course content	Business Biomimetics: Business management models; problems faced by business; biomimetic inspiration for business processes; using

	biology to overcome resistance; case studies of business biomimetics applications Biomimetics in Design and Production: Design: 1) Comparison of bionic concepts and engineering concepts: self-healing vs. repair, growth vs. shaping 2) Influencing stress and strain with bionic concepts 3) Substitution of material and lightweight design Production: • Manufacturing technology (biomimetic approaches in manufacturing technologies for production of conventional products) • Manufacturing of bionic products • Biomimetics in production management and quality management
Assessment	Written or oral exam
Forms of Media	presentation (MS power point, flipchart, whiteboard), Exercise:s in computer labs, eventually video conference suites
Literature	Hopp, Wallace J. ; Spearman, Mark L.: Factory Physics. 3rd edition McGraw-Hill, 2011 Lödding, Hermann: Handbook of Manufacturing Control Springer, 2013 Nyhuis, Peter; Wiendahl, Hans-Peter: Fundamentals of Production Logistics. Springer, 2008 Richard G. Budynas: Shigley's Mechanical Engineering Design, Student international edition, 8th revised edition, ISBN 978-0071268967, McGraw-Hill College, 2009 Ehrlenspiel et al.: Cost-Efficient Design, ISBN 978-3-642-07100-3, Springer Verlag, Berlin Heidelberg, 2010

	Claus Mattheck: Design in Nature – Learning from trees, ISBN 3-540-62937-8, Springer-Verlag, Berlin Heidelberg New York, 1998 Werner Nachtigall: Bionik: Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler, 2. Auflage, ISBN 3-540-43600-X, Springer-Verlag, Berlin Heidelberg New York, 2002 Werner Nachtigall: Biologisches Design: systematischer Katalog für bionisches Gestalten, ISBN 3-540-22789-X, Springer-Verlag, Berlin Heidelberg New York, 2005

Module “Systems and Organisation”

Module name	Systems and Organisation
Module code.	M_BB_115
Courses (where applicable)	Self organisation Social Systems
Semester	Summer Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	External Lecturer
Timetabled Hours	Self organization Lecture: 1 HPW Social Systems Lecture: 1 HPW Exercise: 1 HPW
Workload	45 h Attendance 75 h Self study 30 h Exam preparation
Credit Points	5
Module Objectives	Students appreciate the complexity of multi-agent interactions and the development of social behaviour in animals, humans and robots. They understand self-organisation as an extension of self-assembly, and appreciate its opportunities, challenges and limits.
Course content	Self organization Multi-agent interaction at all scales, from molecules to organisms and ecosystems, from programs to robots and systems; self-assembly; rules and algorithms; underlying paradigm of biology – directed and undirected evolution; top-down, bottom-up or wasp waist systems control Social Systems Sociobiology in animal systems; evolution and sociobiology: selfish gene and altruism; communication systems; maintenance of social structure; social units; human social behaviour: competition, collaboration, co-creation, the wisdom of crowds, learning systems, stakeholder engagement

	(from change management); robotic social systems; collaborative working; simple agent complex behaviour
Assessment	Oral or written exam
Forms of Media	Presentation (Board, PowerPoint, Flipchart, Whiteboard), Practical Work at PC (Computerlab)
Literature	Online resources

Module „Master thesis“

Module name	Master‘s thesis
Module code.	M_BB_116
Courses (where applicable)	
Semester	3th Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Project dependent
Timetabled Hours	none
Workload	360 h
Credit Points	27
Module Objectives	The students - Demostrate their capability to work independently on a subject in alignment with their course of studies, meeting all topical and scientific requirements in a limited period of time - Are able to organize their workflow in order to meet the demands of the problems formulated in their theses, as well as to monitor progress and make necessary amendments Are able to document their approach and their results to meet the requirements of a scientific publication
Course content	Thesis content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment	Written thesis in the range of 40–100 pages.
Forms of Media	-
Literature	Depends on topic

Module „Colloquium“

Module name	*Colloquium*
Module code.	M_BB_117
Courses (where applicable)	
Semester	3th Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Supervisor of master thesis
Timetabled Hours	none
Workload	90 h
Credit Points	3
Module Objectives	Students • Defend the results of the maaster thesis • Place their work in a context of practical application and present their results in proper form for the audience. They motivate their approach and make estimations, how assumptions and simplifications may affect the validity of their results Are able to analyze questions concerning their thesis and results and answer them properly in the context of professional and extra-professional reference
Course content	Content is aligned with the content of the master thesis, in addition methodological discussions
Assessment	Oral exam
Forms of Media	•
Literature	

Electives:

Module “Computation and Modeling”

Module name:	Computation and Modeling
Module code:	M_BB_E_1
Courses (where applicable):	Modelling and simulation Artificial Intelligence
Semester:	Winter Semester
Module coordinator:	Prof. Dr.-Ing. Thorsten Brandt
Lecturer:	Prof. Dr.-Ing. Thorsten Brandt Prof. Dr. Matthias Krauledat
Timetabled hours:	Modelling and simulation Lecture: 1 HPW Excercise 1 HPW Artificial Intelligence Lecture: 1 HPW
Workload	45 h Attendance 75 h self-study 30 h Exam Preparation
Credits	5
Module objectives:	After successfully finishing the module, students are able to model multi-domain continuous dynamic systems and hybrid systems and to simulate these with relevant methods. By this, students should be enabled to select suitable simulation methods for dynamical systems, to create and simulate corresponding models with these as well as mastering the application of numerical solution methods for differential equations and differential-algebraic equations. Furthermore students should be able to correctly interpret simulation results and to estimate their accuracy after completing the module. Students understand the information processing in biological systems and learn the basic methods of artificial intelligence. Students are able to understand the basic principles of typical artificial neural networks and apply them to solve practical problems.

Content:	Modelling and simulation The course covers the fundamental methodology of Modelling and Simulation of dynamic systems (lecture) and applications (tutorial) Contents in detail: • Definitions, general concepts • Methods of modelling of dynamic systems • Set-up and solving differential and differential-algebraic equations • Numerical and analytical methods for solving linear and non-linear state equations In the tutorial examples such as prey-predator models are covered by using MATLAB/Simulink. Artificial Intelligence The course introduces students to the biological and mathematical backgrounds of artificial neural networks and provides an overview of the typical neural network architectures and training algorithms with the help of concrete practical examples.
Assessment:	Oral or written exams
Forms of media:	Whiteboard, PowerPoint, Computer lab
Literature	Modelling and simulation: • M. Ben Amar, A. Goriely, M. M. Muller : New Trends in the Physics and Mechanics of Biological Systems, Oxford University Press, 2011, ISBN: 0199605831 • M.L. Tsetlin : Automaton Theory and Modelling of Biological Systems, Academic Press Inc., 1974, ISBN-10: 0127016503 • F.E. Cellier: Continuous System Modeling, Springer Verlag, 1991, ISBN-10: 0387975020 • H. Bossel: Systemdynamik. Braunschweig, Wiesbaden: Vieweg, 1987, ISBN-10: 3833409843 • M. Gipser: Systemdynamik und Simulation, Teubner Verlag, 1999, ISBN-10: 3519027437 Artificial Intelligence: • R. Pfeifer, Ch. Scheier: Understanding Intelligence. MIT Press, 2001. ISBN: 978-0-262-66125-6 • S. Russell, P. Norvig. Artificial Intelligence – a Modern Approach. Pearson, 2010. ISBN-10: 0132071487

	• S. Haykin. Neural Networks and Learning Maschines. Pearson, 2009. ISBN-10: 0131293761

Module “Materials Applications”

Module name	Materials Applications
Module code.	M_BB_E_2
Courses (where applicable)	Biomedical Applications of Materials Simulating Biomaterials
Semester	Winter Semester
Module Coordinator	Prof. Dr. Alexander Struck
Lecturer(s)	Prof. Dr. Neil Shirtcliffe Prof .Dr. Alexander Struck
Timetabled Hours	Biomedical Applications of Materials Lectures 1 HPW Simulating Biomaterials Lectures 1 HPW Exercise: 1 HPW
Workload	45 h Attendance 75 h Self Study 30 h Exam preparation
Credit Points	5
Module Objectives	Students should develop a familiarity with the constraints and opportunities of traditional, modern and novel materials for biomedical applications, and understand the complexities of modeling soft materials.
Course content	Biomedical Applications of Materials Biocompatible materials; body reactions to materials; mechanical properties; stress shadowing, concentration and relief; interfacial properties – biological and mechanical; design of implants; metal-composite-bone interfaces; biocompatible polymers; smart stents and drug release implants; biomimetic concepts Simulating Biomaterials Review of simulation models on micro-, meso-and macroscales; Solid-liquid interfaces, porous transport; Tissue reaction, interface of soft and solid matter; Scaffolding

	structures and influence on biomatter; Modelling biomimetic materials
Assessment	Oral or written exams; Lab reports
Forms of Media	Whiteboard, powerpoint. Computer lab.
Literature	Online resources

Module „Material und Funktion“

Module name	Materials and Function
Module code.	M_BB_E_3
Courses (where applicable)	Finite element modeling Intelligent materials
Semester	Summer semester
Module Coordinator	Prof. Dr. Alexander Struck
Lecturer(s)	Prof. Dr.-Ing. Henning Schütte Prof. Dr. Alexander Struck
Timetabled Hours	Finite element modeling Lecture: 1 HPW Exercise: 1 HPW Intelligent materials Lecture: 1 HPW
Workload	45 h Attendance 75 h Self Study 30 h Exam preparation
Credit Points	5
Module Objectives	Students are able to relate the theoretical background of finite element calculations to the interpretation of the results. They know how finite element models are calculated, and they are familiar with several forms of analysis. They can analyse numerical deviations, and are critical of FEM results. They have strategies available to improve the quality of their results, and reduce the computation overhead of their models by making use of symmetries. They understand material properties and the concept of intelligent materials, and can use both in new applications.
Course content	Finite-Element Methods: • Overview and point of simulation tools in the development process • Theoretical foundations of finite element analysis. • Comparison with analytical and numerical calculation processes.

	• Steps of finite element calculation • Element types and estimator functions • Degrees of freedom and topology • Linear and nonlinear calculation • Geometry clean-up • Preprocessing • Solution • Postprocessing • Temperature fields • Topological optimisation Intelligent Materials: • Fundamentals of material properties • Concept of intelligent materials • electronic/optical/mechanical materials • tunable material properties
Assessment	Written or oral exams, attestation
Forms of Media	Powerpoint, whiteboard, computer lab
Literature	Finite Element Method: • Daryl L. Logan A First Course in the Finite Element Method, 5th Edition, ISBN 978-0-495-66827, Cengage Learning, 2011 • Nam-Ho Kim, Bhavani V. Sankar Introduction to Finite Element Analysis and Design, ISBN 978-0-470-12539, Wiley and Sons, 2009 • Ergogan Madenci, Ibrahim Guven The Finite Element Method and Applications in Engineering Using ANSYS, Corrected and 4th printing, ISBN 978-0-387-28289-3, Springer, 2007 Intelligent Materials • Intelligent Materials, M. Shahinpoor et al., RCS Publishing, ISBN 978-0-85404-335-4

Module „Behaviour und Evolution“

Module name	Behaviour and Evolution
Module code.	M_BB_113
Courses (where applicable)	Evolutionary algorithms Emergent Effects
Semester	Summer Semester
Module Coordinator	Prof. Dr. Achim Kehrein
Lecturer(s)	Prof. Dr. Achim Kehrein Prof. Dr. Alexander Struck
Timetabled Hours	Evolutionary algorithms Lectures 1 HPW Exercise: 1 HPW Emergent Effects Lectures 1 HPW
Workload	45 h Presence 75 h Self study 30 h Exam preparation
Credit Points	5
Module Objectives	Students learn conceptual technical optimisation following the principles of biological evolution, and are able to apply them to new problems. Students understand the concept of emergent complex behaviour in systems of simple agents.
Course content	Evolutionary algorithms: • Classification, reproduction, mutation, recombination, and selection. • Genetic algorithms, evolutionary strategies, evolutionary programming. • Population dynamics, strategies and competition. • Examples in Matlab Emergent Effects • Conceptual models of intelligence • Criteria of intelligence • Emergence

	• Decentralization models, cellular automata • Agents and environment • Examples in biology • Agent principles • Self organization and control • Simulation techniques • Applications in bionics and technology
Assessment	Oral or written Exam, Attestation
Forms of Media	Powerpoint, whiteboard, computer laboratory
Literature	Evolutionary algorithms: • S. Nolfi, D. Floreano Evolutionary Robotics: The Biology, Intelligence and Technology of Self-Organizing Machines. MIT Press, 2004. ISBN: 978-0-262-64056-5 Emergent Effects: • Xie M, Xiang M, Xiang C, Liu H, Hu Z (eds) Intelligent Robotics and Applications. Springer, 2009

Module “Communication and Information”

Module name	Communication and Information
Module code.	M_BB_E_5
Courses (where applicable)	Biomimetic Communication Ontology in Biomimetics
Semester	Summer Semester
Module Coordinator	Prof. Dr. William Megill
Lecturer(s)	Prof. Dr. William Megill Prof. Dr. Julian Vincent
Timetabled Hours	Biomimetic Communication Lectures 1 HPW Practical: 1 HPW Ontology in Biomimetics Lectures 1 HPW
Workload	45 h Attendance 75 h Self-study 30 h Exam preparation
Credit Points	5
Module Objectives	Students will have a solid understanding of information processing and communication, in the human, computer and animal worlds. They will be able to apply biomimetic examples and principles to communications engineering challenges. They will be able to use TRIZ and ontology methods to discover and develop more general solutions to technical problems.
Course content	Biomimetic Communication Information reception, emission, and transfer; Sensor systems; Signal propagation in the environment; Tuning of communication systems to purpose; frequency vs amplitude modulation; Spectral analysis and voiceprints; Information packaging and handshake protocols; signal in noise; bioinspired communication strategies Ontology in Biomimetics

	The Engineer and the Biologist – communication impossible?; developing a theory for biomimetics; TRIZ, BioTRIZ; Ontology as a tool for R&D; Information harvesting; Innovation from information
Assessment	Oral or written exam
Forms of Media	Presentation (Board, PowerPoint, Flipchart, Whiteboard), Practical Work at PC (Computerlab)
Literature	Hauser MD, Konishi M (2003) The design of animal communication. MIT Press Online resources