1:30 p.m.	C. Knoll, K. Röbenack (DE-Dresden)

Analysis and Control of an Underactuated Pendulum

Underactuated mechanical systems, i. e., systems whose dimension of configuration space exceeds that of the input space, represent an interesting and challenging class from the viewpoint of control theory and pose an highly active research field. Underactuated systems arise from different fields of motivation: academic demonstration examples like the inverted pendulum on a cart, originally fully actuated mechanisms with a lack of actuators due to weight saving or actuator failure and systems where full actuation is not possible or not desired for technical reasons. Our work is inspired from the problem of damping load oscillations on a container crane without moving the crab for the sake of operator comfort. As a model of such a crane we consider a mathematical planar pendulum with variable length, i.e. we assume the rope to be massless and inelastic and the load to be a mass point. This forms a simple underactuated system: The load mass has two translational degrees of freedom but there is only one control input, namely the force applied to rope. The equilibrium points of the system form a one-dimensional manifold. As the linearization about any equilibrium point is not controllable the system has to be addressed by means of nonlinear control theory. Our contribution now consists in the following: First it is shown that the system is not input-state linearizable and has a maximum relative degree of three. Then a collocated exact input-output-linearization is performed which results in a Byrnes-Isidori normal form representation of the system equations. As next step the time derivative of the total energy of the pendulum is expressed as Lie derivative along the vector fields of the normal form. Based on this a simple rule can be deduced to appropriately influence the total energy whilst keeping the rope length controlled. Subsequently, the system dynamics is projected into a subspace of the state space where the properties of the normal form can easily be exploited. This allows the design of a sliding mode control algorithm which implements the aforementioned rule. Finally, simulation results are presented and this control approach is compared to the common solution based on a control-Lyapunov function.

1:50 p.m.	H. Bönicke, Ch. Ament (DE-Ilmenau)

Use of the Mechatronics Development System EasyKit for Didactical Purposes

In today's industry an increasing amount of customer-adapted mechatronical systems is needed. For this purpose, employees with expert knowledge about the design of electronics and microcontroller software are searched for. Especially, for small companies it is difficult to find such employees. One of the main reasons can be found in the fact that young people usually get in contact with this topic just after they started to study, which is very late. It would be better, if electronics and microcontroller programming could be taught already in school, which probably would bring more students to the according degree courses. It is understandable that at normal schools such education cannot be done easily. On the one hand, this is, because at most schools the infrastructure does not exist. On the other hand, this is, because the subject of electronics and microcontroller programming is very difficult, because both has to be learned about at the same time. The EasyKit system, which was actually created for assisting during the development process of mechatronical systems of small and medium complexity, contains a complete didactical strategy for teaching electronics and software to young people starting already at the age of 15 and 16. For people of this age a beginner's package with an electronics board was designed, containing a microcontroller and a variety of standard peripherals and interfaces. The microcontroller can be programmed by the graphical software development tool EasyLab. Besides the electronics board, an application board with a small motor, a fork light barrier and a light sensor is included. To get the basic information of microcontrollers, a web based training is delivered with the beginner's package. Besides, a teach-ware and examples of test applications are also delivered. Like this, a complete mechatronical system can be put into operation easily. Later, the development software EasyLab can be replaced by other tools like MPLAB or AVRStudio and the electronics can be replaced by own electronics. Like this it is not necessary to learn everything about electronics and microcontroller software at the same time. The beginner's package gives the schools the possibility to build up the necessary infrastructure to teach about this topic.

2:10 p.m.	U. Kreutzer, D. Gerling, J. Schwara, D. Kahl (DE-München)

A Model Reference Based Sliding Mode Approach for Parameter-Varying Systems

The proposed paper presents a Model Reference-based Sliding Mode Control in order to deal with the control of parameter varying systems. The examined system is a Permanent Magnet DC-drive, which is nominally a linear, time-invariant first order system. By dependence of the parameters of the states it turns into a linear, time-variant system of first order. Sliding-Mode Control (SMC) is known for certain robustness properties, which comes along with the drawback of high switching amplitudes and switching action. Model Reference Adaptive Control (MRAC) is used to adapt control parameters to unknown dynamics via Lyapunov-stability criteria. The SMC consists of a continuous part and a discontinuous part. While the continuous part is a feedforward control, the discontinuous part is a pure switching control. The adaptation scheme works as a load observer, so it can not distinguish between an external load or the change of a parameter. So the feedforward and switching control are both adapted to load changes and parameter variations. The switching amplitude may be weighted by the error between reference and measurement as well as by the adapted parameters. The proposed paper will first state the problem, in order to show how both named control techniques may be combined for the resulting closed-loop equations. The effectiveness of the proposed control-scheme is proven by both simulations and measurements. A proof of stability via Lyapunov-technique is given. Closing the proposed control-schemes will be judged.

2:30 p.m.	K. Meissner (DE-Wernigerode)

Design of Mechatronic Systems with High Availability in very harsh Operating Conditions

The use of mechatronic systems in very harsh environments requires a strengthened and seamless interlocking of the individual components. This paper presents the methods and approaches that were developed during a research project for the stabilization and increase in the reliability of such systems. This includes a catalogue of measures for the mechanical and electronic design of such intensely-used systems as well as a software framework. Using the example of an inline marking system for castings, it is shown how mechatronic systems installed in harsh operating environments can be protected both constructively as well as through the use of modern control, regulation, and monitoring systems. The developed catalogue of measures is based in the first step on a questionnaire, in order to investigate the primary features of the system. Based on this questionnaire, in the second step the mechanical and electrotechnical loads were determined. Harsh operating environments can be understood as high loads with metallic and non-metallic dust, high and very high temperatures (>500°C), high electromagnetic interference, and high mechanical loads. In the third step, corresponding countermeasures can then be selected from the catalogue of measures and combined as appropriate. Similar to these measures, in a fourth step – after the initial mechanical and electrotechnical design has been completed – the necessary software components for the controlling, monitoring, and protection of the system can be selected. In the final step of the design, the overall system is examined and – through any necessary iterations of steps two to four – the interfaces between and the requirements of the individual mechatronic components are adjusted.

2:50 – 3:10 p.m. Coffee break

3:10 p.m.	R. Suzuki, N. Kobayashi (JP-Kamazawa), E. P. Hofer (DE-Ulm)

Sensorless Force Control via Internal Model Control Based Controller and Its Applications to Myoelectric Hand

The scope of this paper focuses on internal model control (IMC) based controller for sensorless force control. We develop a prototype of a myoelectric robotic hand that can hold an object with suitable grasping force. The optimal force distribution of the robotic hand when grasping an object is discussed by using a new IMC based controller. Generally force sensors, pressure sensors or additional sensors are required for detecting external force. However, this complicates mechanical structures and controller schemes for such robotic hands. To solve the problem, the disturbance estimation property of the IMC controller is pointed out. The IMC based controller has the required robustness, especially, disturbance compensation, decoupling property for the closed-loop system, and disturbance estimation for parameter perturbations. The proposed controller is applied to grasping control of a myoelectric robotic hand. The prototype of the robotic hand and bio-feedback system are also proposed. The robotic hand has no force sensor for detecting grasping objects. The operator is able to feel reflection force from objects by using the bio-feedback system. The experimental results is shown in this paper on sensorless grasping control by using the proposed controller. The robotic hand grasps a sponge as a grasping object via myoelectric signals. The operator changes level of signals “gain” or “loss” for grasping. From information of the bio-feedback system the operator controls grasping force. The results shows that the proposed controller estimates reflection force from the grasping object. The controller generates appropriate torque to the motor for grasping the sponge. The proposed research specifically emphasizes that from theoretical and experimental findings the disturbance estimation property of the proposed controller is useful for detecting reflection force without additional sensors, e.g. force sensors or pressure sensors. The results are a further step in life supports to contribute towards the development of equipment interacting with humans.

3:30 p.m.	I. Mozgova, H.-P. Brückner, F.-W. Bach, H. Blume, T. Hassel, S.-M. Kussike, M. Bierbaum, P. Büggenam, M. Piszczek (DE-Hannover)

Development of a Therapeutic Device Supporting Real-Time Dynamic Vertical Force Unload

One of the priority directions of motion rehabilitation process optimization and analysis is the simultaneous application of different physical therapeutic methodologies. The regular training using therapeutic devices promotes stimulation and improvement of the muscular tonus. The general goal of the present work was the development and the evaluation of efficiency and safety performance of a designed therapeutic device, which is aimed at a patient's dynamic unloading during walking, combined with a plantar pressure storage system. The proposed devices overcomes the lack of a dynamic vertical unload force enabling the patients to walk at random speed. The suggested equipment has been developed on the base of a MintDrive-II (Baldor Electric Company) versatile intelligent drive with an integrated motion controller. Appropriate software has been created using the structured multitasking BASIC-like programming language Mint. The plantar pressure registration was realized with a computerized insole sensor system F-scan (Tekscan Inc.). The actual force measured by an external sensor is feed back to the MintDrive-II in order to assure to stay below a predefined maximal weight bearing. The developed rehabilitation system ensures: operational safety, positional adjustment, choice of unload level, automatic load control in a real-time operation mode and provides a visual feedback of the current walking process. The software interface allows downloading a patient's data for archiving, reporting or exporting as an ASCII-file for additional analysis. As part of a rehabilitation technology for the purpose of miscellaneous training conditions and of a variety of training intensity a treadmill and mechanical steps are used.

End of Lecture Session