Automatic control of mechatronic systems

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We present different concepts of nonlinear control for mechatronic systems, with special emphasis on the practical implementation in an industrial environment. Differential geometry and differential algebra will serve as a common mathematical basis for the controller design problem and the concepts of passivity and dissipativity are used to take the physical nature of the to-be-controlled plants into account.

It turns out that in industrial applications a large potential for improving the product quality and increasing the efficiency lies in the automation system and the used control techniques. Since most of the physical systems are nonlinear in nature, it is quite obvious that an improvement in the performance of the closed loop can often only be achieved by means of control techniques that take the essential nonlinearities into consideration. Nevertheless, it can be observed that industry often hesitates to implement these nonlinear controllers, despite all advantages from the theoretical point of view. The reasons for this are manifold, but are mainly due to the fact that a straight forward application of the nonlinear control methods only shows satisfying results in an idealized simulation environment. However, in the industrial reality one has to cope with several restrictions, like e.g. not all state variables are available by measurement, the signals are corrupted by non negligible transducer and quantization noise, the sensors and actuators have a limited accuracy, e.g. aging processes, and last but not least the controllers can only be implemented on a hardware platform with limited sampling time. To our knowledge, a systematic approach for solving all these problems is not available and, of course, we do not intend to present a general solution. But on the basis of some applications like the position/force control of a four-high mill stand in a cold rolling mill with the hydraulic adjustment system and a PWM-controlled dc-to-dc converter, namely the Ćuk-converter, we will demonstrate how these restrictions can be considered.

Apart from the demands on the controller design due to the implementation in an industrial environment a second feature, mainly stimulated by the philosophy of mechatronics, will be presented. Here, we propose to leave the classical way of a separation between the constructional and the controller design. We will rather regard the design of the actuators and sensors as a part of the control loop synthesis. By means of two applications, on the one hand piezoelectric smart structures and on the other hand micro-machined electrostatic transducers we will demonstrate the potential and the feasibility of this proposed integrated design.