Applied Nonlinear Control Workshop

Saarbrücken
Friday, May 28, 2010

Hosted by Prof. J. Rudolph
Chair of Systems Theory and Control Engineering
(Lehrstuhl für Systemtheorie und Regelungstechnik)
Universität des Saarlandes

Purpose

The Applied Nonlinear Control Workshop aims to assemble experts and colleagues in the nonlinear control field to present and discuss current research activities. This informal event aims to further promote the national and international collaboration that exists among the attendees. The workshop is timed to benefit from Prof. Alan Lynch's visit to Germany.

Workshop Overview

The event begins at 10:00 on Friday, May 28 with a welcome address by Prof. J. Rudolph. He will also introduce the research activities of the Chair of Systems Theory and Control Engineering.

Talks will be held throughout the day in **Building A5 1** on the University of Saarland campus. Sessions are in room −1.22 (basement) before lunch and in room −1.03 (basement) after lunch. Coffee and lunch will be provided.

Tentative Schedule

Room −1.22	
10:00 – 10:30	Welcome and Introduction (J. Rudolph)
10:30 – 11:00	T.M.P. Nguyen
11:00 – 11:15	Coffee
11:15 – 11:45	H. Fehr
11:45 – 12:15	S. K. Nguang
12:15 – 12:45	A. Lynch
12:45 – 14:00	Lunch and Discussions
Room −1.03	
14:00 – 14:30	M. Zeitz
14:30 – 15:00	J. Raisch
15:00 – 15:30	K. Listmann
15:30 – 16:00	Break/Discussions
16:00 – 16:30	A. Gensior
16:30 – 17:00	M. Barczyk
17:00 – 17:30	D. Kastelan

Abstracts

Magnetometer-plus-GPS-aided Inertial Navigation System Design for a Helicopter UAV

M.Sc. Martin Barczyk (University of Alberta)

We consider the Extended Kalman Filter (EKF)-based aided navigation system design used on the University of Alberta's ANCL Helicopter UAV. We review the mathematics of coordinate frame transformations, attitude parametrization and rigid-body kinematics. We cover the modeling and identification of the on-board inertial sensors corrupted by time-varying bias and white noise terms. We focus on the magnetometer and describe a novel calibration procedure applied to this sensor, experimentally evaluating its performance versus a conventional calibration and the uncalibrated case. We describe the topology of the aided navigation system and cover the details of the high-rate integration of the navigation dynamics, the low-rate correction of the estimates using an EKF observer, and the initialization stage of the system. The INS performance in experiment is demonstrated for the cases of ground and flight testing, focusing on the issues of heading angle observability and the importance of calibration.

Flatness Based Switching Frequency Estimation of Sliding Mode Controllers for Single-Input Systems

Dipl.-Ing. Hendrik Fehr (TU Dresden)

A method is presented that allows an estimation of the switching frequency when sliding mode controllers are used for the control of single-input flat systems. The estimation of the switching frequency is done with respect to nominal trajectories for the flat output. That means, no simulation is required - even for non stationary trajectories - which is considered an outstanding feature of the proposed method. In order to illustrate the efficiency of the method a sliding mode controller for a boost converter is considered as an example. Finally the switching frequency estimation is compared to simulation and measurement results.

Flatness Based Energy Optimal Control of a Doubly Fed Induction Generator System

Dr.-Ing. Albrecht Gensior (TU Dresden)

A system consisting of a doubly fed induction generator is considered where the stator windings are connected to the grid and the rotor windings are fed by a converter. The latter shares the same DC-link with a second converter connected to the grid. Using this conguration it is possible to provide reactive power to the grid by both, the doubly fed machine and the grid connected converter. Using a flatness based approach this freedom is exploited to minimize the total power loss in the system. The findings are supported by an example.

Inertial Sensor Model Identification Using Allan Variance

M.Sc. David Kastelan (Universität des Saarlandes)

The Allan variance may be used to identify and characterize non-deterministic processes that affect the stability of a signal. This talk applies this analysis technique to drift test data from a Microstrain 3DM-GX1 inertial measurement unit (IMU). Allan variance expressions are outlined for processes known to corrupt inertial sensor output. The root-Allan variances of drift test data are computed and analysed to demonstrate that the IMU's measurement noise and bias variation may be described by Gaussian white noise and exponentially-correlated processes, respectively. The parameters of these processes are identified and the corresponding sensor models are presented.

Output Synchronization of Dynamical Systems

Dipl.-Ing. Kim Listmann (TU Darmstadt)

Recently, synchronization of multi-agent systems is a very active field of research. So far, only simple dynamical systems were considered and the influence of the network connecting them was examined. Moreover, the agents were allowed to exchange their full state information with the group. In this talk, we will extend this to more complex dynamical systems that exchange only parts of their state information, i.e. their outputs. To this end, we regard synchronization as a structural constraint control problem. Then, by applying standard techniques of systems and control theory synchronization controllers for general linear systems can be designed. Synchronization is achieved even in the case of packet-switched and delayed networks. Finally, we highlight some major differences when nonlinear systems are considered.

Globally Stabilizing Output Feedback Method for MIMO Systems in a Restricted Nonlinear Observer Form

Prof. Alan Lynch (University of Alberta)

In this talk we present a constructive method for globally asymptotically stabilizing a MIMO nonlinear system by output feedback. The class of systems considered is a generalization of the output feedback form, in which the subsystems are allowed to be dynamically coupled through the output-dependent nonlinearities. The result relies on the use of filtered transformations and backstepping, and can be viewed as a direct extension of an existing method. The method is demonstrated via simulation on an example and several interesting features that distinguish the SISO case from its MIMO generalization are observed.

Robust Static Output Feedback Controller Design for Polynomial Systems

Prof. Sing Kiong Nguang (University of Auckland)

Many control systems can be modelled or approximated by polynomial systems. This talk examines the problem of designing a static output feedback controller for uncertain polynomial systems using an iterative algorithm based on the sum of squares (SOS) decomposition. Numerical examples are provided at the end of the talk to demonstrate the effectiveness of the proposed design technique.

A Flatness Based Backstepping Controller Design with Sliding Mode for Asynchronous Machines

M.Sc. Thi Mai Phuong Nguyen (TU Dresden)

Two nonlinear controllers for voltage inverter-fed induction machines are presented in order to ensure flatness based trajectory tracking. The first one is a sliding mode controller and for the design of the second one a backstepping approach is used, where also a sliding mode regime arises. Simulation results illustrate the value of the presented methods.

Distibuted Set-Valued State Estimation for Switched Systems with Quantised Measurements

Prof. Jörg Raisch (TU Berlin; Max-Planck-Institut, Magdeburg)

The topic of this talk is distributed state estimation for time-invariant systems with finite input and output spaces. We assume that the system under investigation can be realised by a hybrid I/S/O-machine. Our approach is based on the concept of l-complete approximations, which, in the described framework, can be interpreted as discrete event abstractions for hybrid dynamical systems. In particular, it has been shown that l-complete approximations can be used to provide set-valued estimates for the unknown system state. Estimates are conservative in the sense that the true state can be guaranteed to be contained in the set-valued estimate. In this talk, we show that for a class of hybrid systems the same estimate can be obtained via a distributed, or decentralised, approach involving several less complex approximations, which are run in parallel. For a larger class of systems, it can be shown that this approach provides an outer approximation of the estimate provided by a monolithic l-complete estimator. The proposed procedure implies significant computational savings during estimator synthesis, with an only modest increase in on-line effort. The latter is a result of "assembling" the global estimate from the available local estimates. The resulting computational trade-off is explicitly discussed.

Flat Inputs in the MIMO Case

Prof. Michael Zeitz (Universität Stuttgart)

The notion of flat inputs to an autonomous system with given outputs can be seen as dual to the search for flat outputs of a controlled system with given inputs. In contrast to a fictitious flat output, a flat input must be realized as a physical actuator such that the considered system becomes differentially flat. The determination of a flat input is of practical relevance if the actuators are not yet fixed and flatness-based analysis and design methods have to be applied. In the SISO case, a flat input exists if and only if the system is locally observable. Then, the vector field associated to the flat input is given by the last column of the inverse observability matrix scaled by an arbitrary function. In the talk, the notion of flat inputs is extended towards nonlinear MIMO systems. Thereby, the two different cases of differential flatness of MIMO systems corresponding to linearizability either by static or by quasi-static feedback have to be distinguished. In addition, the problem of realizing flat inputs as physical actuators is discussed for mechanical systems.