13th International Workshop on VARIABLE STRUCTURE SYSTEMS
June 29 - July 2nd, 2014 NANTES

The 13th International Workshop on Variable Structure Systems is from June 29 to July 2nd, 2014, on the campus of *Ecole Centrale de Nantes*, in the IRCCyN building, in Nantes, France. The objective is to bring together the international community of researchers and practitioners in the area of Variable Structure Systems and Sliding Mode Control. The VSS 2014 consists of 3 plenary sessions, regular and interactive sessions and panel discussions on the most recent results obtained in the field of sliding mode control and variable structure systems.

### Sunday June 29, 2014

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<th>Time</th>
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<tr>
<td>17:00 – 19:30</td>
<td>Registration (in Nantes downtown – <em>Le Lieu Unique</em> - <a href="http://www.lelieuunique.com">www.lelieuunique.com</a>)</td>
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All the sessions and opening/closure ceremonies will be held in Amphitheater S, IRCCyN Building, campus of Ecole Centrale. The lunches will be taken in L Building.

### Monday June 30, 2014

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<tr>
<td>8:00 – 8:30</td>
<td>Registration</td>
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<td>8:30 – 9:00</td>
<td>Opening ceremony</td>
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### Tuesday July 1, 2014

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<tr>
<td>20:00</td>
<td>Banquet (in a boat on Erdre river - <a href="http://bateaux-nantais.fr">http://bateaux-nantais.fr</a>)</td>
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### Wednesday July 2, 2014

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<th>Time</th>
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<tr>
<td>17:30 – 18:00</td>
<td>Closure ceremony</td>
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### Program at a Glance

<table>
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<tr>
<th>Day</th>
<th>9:00 – 10:00</th>
<th>10:15 – 12:35</th>
<th>14:15 – 15:00</th>
<th>15:25 – 17:45</th>
<th>18:00 – 19:00</th>
<th>Panel discussion I</th>
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<tr>
<td>June 30</td>
<td>Plenary session I</td>
<td>Prof. A. Levant</td>
<td>Session 1</td>
<td>Interactive session</td>
<td>Break</td>
<td>Organiser L. Fridman, UNAM, Mexico</td>
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<td>Univ. of Tel-Aviv, Israel</td>
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<tr>
<td>July 1</td>
<td>Plenary session II</td>
<td>Prof. C. Edwards</td>
<td>Session 3</td>
<td>Session 4.1</td>
<td>Break</td>
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<td>Univ. of Exeter, UK</td>
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<tr>
<td>July 2</td>
<td>Plenary session III</td>
<td>Dr.Ing. J. Komsta</td>
<td>Session 5</td>
<td>Session 6.1</td>
<td>Break</td>
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<td>Bosch Rexroth, USA</td>
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1 Institut de Recherche en Communications et Cybernétique de Nantes
PLENARY SESSION I. June 30, 9:00-10:00 – Chair : S. Spurgeon
Prof. A. Levant, University of Tel-Aviv, Israel

« Some prospects of the modern sliding-mode control »

Abstract. The standard sliding-mode control (SMC) approach is usually described as a specific method of controlling heavily uncertain systems. Its well-known idea is to choose a proper constraint to be established in finite time and to be kept afterwards by high-frequency switching. The solution notably includes the search of a suitable constraint and overcoming the chattering effect. Today, after a long evolution history, the SMC technique is capable to solve the most difficult problems of the contemporary control theory.

The modern SMC method often produces the straight-forward solution of the original control problem. Indeed, the finite-time establishment of a constraint with arbitrary relative degree is now optional. Also the SM-based observation has been shown to provide for the exact robust output derivatives in finite time. Thus, one can practically ideally solve most black-box control problems, provided the input and the output are scalars. The control can be chosen as smooth as needed, excluding any high-energy system vibrations. The results are currently extended to the multi-input multi-output case. The developed methods are proved to be effective also in control of hybrid or switched systems, systems with variable delays, systems with distributed parameters, stabilization of continuous systems, etc.

What happens when the parameters of the system uncertainty are themselves uncertain? These uncertainty-iteration problems require tuning of previously constant parameters, i.e. the SM adaptation. The Lyapunov function development is carried out for complicated systems featuring high-relative degrees and finite-time stability. The convergence rate regulation is now feasible, which includes the fixed-time convergence option as the extremal case. SMC optimization, including SMC system accuracy optimization and comparison with high-gain methods, has been recently performed.

While discrete SMs have been already studied for a long time, practical discretization methods for high-order SMC systems draw the attention only now. The author also believes that the practical-relative-degree approach opens a lot of new application possibilities.

The practical SMC theory implementation issues produce new challenging theoretical SMC problems. The approximability problems and stochastic analysis of high-order SMC systems still wait for their time.
PLENARY SESSION II. July 1st, 9:00-10:00 – Chair : Y. Shtessel
Prof. C. Edwards, University of Exeter, UK.

« Sliding mode fault detection and fault tolerant control: perspectives and applications »

Abstract. Over the last decade, sliding mode ideas have been applied to problems of both fault detection and fault tolerant control. The latter can be viewed as exploiting the well known insensitivity properties of sliding mode controllers to matched uncertainty, whilst the former (typically) exploits knowledge of the equivalent injection signals necessary to retain a sliding motion in an observer formulation, and which therefore contains information about faults which may be present in the systems. This talk will attempt to explain this surge in interest and argue why sliding mode schemes are indeed well suited to tackle such problems. It will also explore the limitations and trade-offs inherent in the sliding mode approach and its connections to other methods. The talk will describe the application of sliding mode controllers and observers to several real engineering problems from the aerospace domain, and will show the results obtained from implementing them on test rigs to demonstrate the feasibility of these schemes.

PLENARY SESSION III. July 2nd, 9:00-10:00 – Chair : E. Usai
Dr.Ing. J. Komsta, Bosch Rexroth Corporation, Bethlehem, PA, USA

« Theory and Practice of Sliding Mode Control for Industrial Electro-Hydraulic Systems »

Abstract. In modern production machinery, fluid power is the muscle for the most demanding processes and applications, such as industrial presses, rolling mills, molding machines, flight simulators, industrial robots etc. In the last two decades, technical and economic forces have dynamically changed the requirements of hydraulic drive technology. Demands for efficiency, dynamics and quality of production processes, have forced the hydraulic drive industry to search for new and more advanced nonlinear control methods. Standard linear algorithms cannot assure optimal behavior in the presence of dominant system nonlinearities and strong system variations in hydraulic systems. Therefore, since the early 1990’s, many innovative linear and nonlinear control algorithms designed for hydraulic drives have been proposed. Of the many different algorithms available for industrial motion systems, one of the most promising is Sliding Mode Control (SMC). SMC is well known for its robustness against modeling uncertainties and external disturbances, as well as possessing a simple structure and a manageable design process. This makes it ideal in many industrial applications.

The presentation discusses integral sliding mode control methods, and higher order SMC disturbance compensators suitable for electro-hydraulic drives. The controllers presented, and the tuning rules developed, fulfill the demands of industry for suitability and handling during system commissioning. The controller performance was empirically verified and the results show that dynamic behavior, accuracy and robustness of electro-hydraulic drives can be significantly improved using nonlinear Sliding Mode Control.
Panel Discussions

Organizer: Prof. L. Fridman, UNAM, Mexico City, Mexico

PANEL DISCUSSION I – June 30, 18:00-19:00

Pros and Cons of High Order Sliding Mode Control
Speakers. Utkin.
All “Pros&Cons” of high-order sliding mode control are discussed in the context of the basic concepts of this control methodology: relative degree, continuous control, chattering suppression. The objective of the presentation is to establish a bridge between “conventional” or 1st order and “new” high-order sliding mode controllers and evaluate the potential of each of them. The attempt to compare two methodologies raises open questions, which can serve as a starting point for further research.

How to generalize super-twisting for arbitrary relative degree?
Speakers. Kamal, Moreno, Fridman, Levant.
Generalization of the Super-Twisting Algorithm (STA) is discussed. Proposed algorithm called \((r+1)\)-th order STA provides for relative degree \(r\) systems with respect to output
- finite-time convergence to the \((r+1)\)-th order sliding mode set;
- absolutely continuous control signal;
- using the information about the output, it is differentiated till the order \((r-1)\).
The convergence conditions for the 3-STA algorithm are proposed. The formula for algorithms of arbitrary order is suggested. The possibilities to prove their convergence will be discussed.

Discrete realization of fixed time convergence.
Speakers. Levant, Efimov, Polyakov, Moreno.

Recently, a new type of convergence for SM controllers and differentiators has been considered. For example, it has been shown that fixed time convergence is not feasible via Euler discretization. The possibilities of the discrete realization of fixed time convergence will be discussed.

PANEL DISCUSSION II – July 1st, 17:00-18:00

Practical relative degree: frequency domain approach
Speakers. Fridman, Shtessel, Levant, Boiko.

The exact output tracking in controllable minimum-phase perturbed SISO systems, which mathematical model has well-defined known relative degree \(r\), can be achieved via HOSM controller with an HOSM observer/differentiator of \(r-1\) order. However, relative degree of the principal mathematical model that is used for the HOSM controller/observer design inevitably is reduced with respect to relative degree of the real system. It has been shown that the unmodeled dynamics has a fractal nature that increases system’s relative degree up to infinity. This yields chattering. Since it is impossible to design the HOSM control for system with relative degree \(r \to \infty\), a new notion of Practical Relative Degree (PRD) has been introduced using the time-domain techniques. A novel approach to defining the PRD using the frequency domain technique will be discussed. This approach is based on the following new concepts:
• the Level of Tolerance that includes the definitions of the acceptable amplitude and the acceptable frequency of the oscillation in the real sliding mode ;
• the Performance Margins, specifically Performance Gain Margins (PGM) and Performance Phase Margins (PPM) that characterize the additional gain and the additional phase shift that the system can tolerate until the Level of Tolerance is violated.

Two approaches to defining the PRD will be discussed

• if the model of the system is unknown, the PRD of the system is the smallest order of SM controller that generates the oscillations in the system satisfying the Level of Tolerance;
• the Performance Phase Margin (PPM) and the Performance Gain Margin (PGM) could be found for each tested sliding mode controller. The smallest order of controller that satisfies the Level of Tolerance with the desired/given PGM and PPM could be also considered as PRD.

When the adaptation of SM controllers is needed ?
Speakers: Y. Shtessel, L. Fridman, L. Hsu, G. Bartolini

Recently two important approaches to SM adaptation were published. SM adaptation when the upper bound of perturbations and their derivatives are known. In this case, 2 approaches can be used

• classical adaptation of SM gain to equivalent control;
• reconstruction of the perturbations basing on HOSM differentiators, and use of the perturbations estimation for direct compensation or as SM control gain.

Although, there are papers published on adapting the SMC for perturbed systems with unknown bounds of perturbations (these algorithms usually yield the gain overestimation), we suggest discussing several recent results on adaptive SMC/HOSM for such systems. The proposed concept consists in dynamically increasing the SMC/HOSM gains until the sliding mode is established. Then, the gains can be dynamically reduced so that the sliding mode is still retained. The proposed questions for the discussion are

• Adapt the control gains or reconstruct the perturbation and compensate ?
• Does the adaptation make sense in systems with known bounds of the perturbations ?
• Adaptation in systems with unknown bounds of the perturbations :
  o gain overestimation ?
  o how to guarantee the ability to retain the sliding mode with minimal gains ?
  o the best concepts for the adaptation algorithms ?
  o Lyapunov approach versus the “minoring- majoring” and other techniques ?

How to implement output Super-Twisting Controllers (STC) based on HOSM observers correctly?
Speakers. Fridman, Kamal, Levant.

Recently, a lot of papers devoted to output based Super-Twisting controllers (STC) using HOSM differentiators have been published. Implementation of the STC requires that the first time derivative of the sliding surface must be Lipschitz in time. STC based on the absolutely continuous estimation of the surface cannot be implemented. That is why the order of differentiators is important there. Different methodologies for output based implementations of STC will be discussed.
Oral and Interactive sessions
Abstracts
### June 30th

**Session 1 (10:15-12:35) – Theory and methodology 1 - Chair : A. Polyakov**

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<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
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<tr>
<td>10:15 – 10:35</td>
<td>High Order Integral Nested Sliding Mode Control</td>
<td>Juan Diego Sánchez-Torres, Antonio Navarrete-Guzman, Guillermo Rubio-Astorga and Alexander G. Loukianov</td>
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<td></td>
<td><strong>Abstract</strong>: This paper exposes a controller for the nonlinear systems in the block controllable form. This proposal guarantees exponential exact tracking in the presence of unknown matched and unmatched disturbances by means a combination of the block control method and integral terms designed with high-order sliding-modes algorithms. Both, matched and unmatched, disturbances are compensated by those integral continuous terms and the tracking is achieved with the design of a nominal control law.</td>
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<td>10:35 – 10:55</td>
<td>Accelerated High-Order MIMO Sliding Mode Control</td>
<td>Arie Levant, Yaniv Dvir</td>
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<td><strong>Abstract</strong>: Multi-Input Multi-Output High-Order Sliding-Mode (HOSM) control is designed, provided the system features well-defined vector relative degree, and the corresponding matrix of the high-order output partial derivatives with respect to controls is approximately proportional to a known nominal matrix. A finite-time-stable HOSM with predefined convergence rate is obtained. Asymptotic accuracies are calculated in the presence of noises and discrete sampling.</td>
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<td>10:55 – 11:15</td>
<td>On Output-based Sliding Mode Control Design Using Minimax Observer</td>
<td>Sergiy Zhuk and Andrey Polyakov</td>
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<td><strong>Abstract</strong>: The classical problem of the sliding mode control design, which guarantees finite-time reaching and further system motion on a linear hyperplane, is considered for the linear time-invariant disturbed system with the noised measurements of the output. The control law, which provides to the closed-loop system the optimal reaching (as close as possible) of the selected sliding surface, is designed using minimax state observer. The case of discontinuous and continuous admissible feedbacks are studied. The theoretical results are supported by numerical simulations.</td>
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<td>11:15 – 11:35</td>
<td>A New Class of Fast Finite-Time Discontinuous Controllers</td>
<td>Emmanuel Cruz-Zavala and Jaime A. Moreno</td>
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<td><strong>Abstract</strong>: We introduce a new class of high-order sliding mode (HOSM) controllers with improved convergence rate for a single-input uncertain system. The controllers are designed by means of Control Lyapunov Functions (CLF's) and properties of homogeneous systems in the bi-limit. Therefore, the proposed controllers in feedback with the system make the close-loop system homogeneous in the bi-limit. Robustness and convergence rate are improved in comparison with the reported HOSM.</td>
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<td><strong>Abstract</strong>: For the problem of providing invariance in outputs of the system with external perturbations not belonging to the control space, a solution was proposed based on the effect of vibrolinearization of the relay elements. The developed relay vortex algorithms of control were used in the closedloop system for generation of damping oscillating modes with unlimited growth in oscillation frequency which enabled relay vibrolinearization. At that, realized was the theoretically infinite coefficient of linearization enabling asymptotic invariance of the output to a wide class of external perturbations.</td>
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<td><strong>Abstract</strong>: In this work, Unity Vector Control is revisited based on the results by V. Utkin and co-workers. The approach here presented extends the one reported by V. Utkin and co-workers so that independent feedback gains may be specified for each input channel. Simulation results illustrate the advantages of the proposed technique for a holonomic model of a two-link manipulator.</td>
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Harshal B. Oza, Yury V. Orlov and Sarah K. Spurgeon  
**Abstract:** The aim of this paper is to provide a survey of the tools for analysis and synthesis of finite time stable controllers. The paper analyses the literature in continuous and discontinuous finite time stabilisation in a unified way covering both the fundamentals as well as the latest techniques available in this non-linear control paradigm. The contribution of the paper lies in its exposition of the robustness properties that continuous and discontinuous controllers guarantee. Some open problems are identified which are relevant to both the theory and practice of finite time stabilisation. |
Adaptive control with asymptotical sliding mode of uncertain plants with input and state delays
Mirkin Boris, Gutman Per-Olof and Shtessel Yuri

Abstract: Asymptotical sliding mode design of direct model reference adaptive control (MRAC) for a class of systems with input and state delays based only on the lumped-delays is developed. To overcome the difficulty to directly predict the plant state, a control design is proposed based on a new approach. The approach relies on a decomposition of the adaptive control design procedure where a `generalized error'' in conjunction with auxiliary linear filters with adjustable gains are introduced and the sliding variable is formed on the basis of this error. The effect of such a decomposition is to pull the input delay out of first step of the design procedure.

Application of Super-Twisting-Like Observers for Bioprocesses
Moreno Jaime A. and Mendoza Ismael

Abstract: State and reaction rate estimation in highly uncertain bioprocess models is an important topic for a successful control of these processes. Discontinuous observers, as for example the super-twisting estimator, offer unique properties as convergence in finite time and insensitivity with respect to non-vanishing perturbations. We present a generalization of the classical super-twisting observer and illustrate its use in the estimation of variables in a bioprocess.

Backstepping Sliding Mode Controller for a Co-ordinated Links (COOL) Robot Arm
Adhikary Nabanita and Mahanta Chitralekha

Abstract: In this paper, a modified backstepping sliding mode controller (BSMC) is proposed for trajectory tracking of a robotic arm. The controller gain is adaptively tuned to tackle unknown uncertainties and a dynamic surface controller logic is used in the final stage to get rid of the explosion of terms problem inherent in backstepping design. Also, the relative degree of the system is increased by one so that the control law is finally obtained as an integral of a discontinuous signal thereby reducing the chattering prevalent in the sliding mode. The combination of the backstepping and sliding mode control methods makes the controller robust against both matched and mismatched uncertainties. Simulation studies conducted on a 3 degrees of freedom co-ordinated links (COOL) robot arm shows effectiveness of the proposed controller.

Chaos Synchronization Applied to Secure Communication via Sliding Mode Control and Norm State Observers
Rodrigues Victor Hugo and Roux Oliveira Tiago

Abstract: In this paper, we have assumed that the parameters of a unified chaotic system are time-varying, uncertain and only the output variable is available for feedback. Due to its robustness to parametric uncertainties and fast transient responses, a sliding mode control strategy is introduced to globally synchronize two of these chaotic systems, i.e., the initial conditions of master (transmitter) and slave (receiver) systems are arbitrary. This result also allow us to solve the problem of secure communications by using the chaotic nature of the unified attractors, where the proposed formulation based on norm observers and time-varying cryptographic keys increases the security level of the approach. Simulation results illustrate fast synchronization and less vulnerability properties of the new communication scheme.

DC motor control on the base of vortex algorithm
Kochetkov Sergey and Utkin Victor

Abstract: The new control algorithms for wide class of electromechanical systems are proposed on the base of discontinuous control in the paper. The designed vortex algorithms provide full invariance of the closed loop system with respect to unmeasured unmatched disturbances. The efficiency of the proposed algorithms is demonstrated on the base of DC motor control.

Design of Guidance Law Based on Nonsingular Terminal Sliding Mode Control and Finite-time Disturbance Observer
Jin Shi, Zhang Zhenxing and Li Shihua

Abstract: The terminal guidance problem for missile intercepting maneuvering targets is investigated in this paper. To guarantee the disturbance rejection performance and alleviate the chattering problem, nonsingular terminal sliding mode control(NTSMC) and finite-time disturbance observer(FTDO) are introduced to design the composite guidance
law considering the first-order autopilot dynamics. In this paper, the target acceleration and some state variables are regarded as unknown bounded disturbances. Finite-time disturbance observer (FTDO) is employed to estimate the disturbances and estimations of disturbances are employed as feedforward compensation to weaken the influence of disturbances. The proposed guidance law can guarantee that the line of sight (LOS) angular rate converges to zero in finite time. Simulation comparisons show the effectiveness of the proposed method.

**Direct Power Control with Disturbance Compensation for Grid Connected Power Converters - A Discrete-Time Sliding Mode Approach**
Huseinbegovic Senad and Drazenovic Branislava

**Abstract:** This paper presents a design of a direct power control using the discrete-time sliding mode control. The design is intended for a grid-connected inverter or a doubly fed induction generator. The constant switching frequency is implemented by the space vector modulation, having the modulation period equal to the sample period. The effects of the discretization and external disturbances are analyzed. To solve this problem, a power based disturbance compensator is proposed. Its digital hardware implementation is simple. The simulation results show that the designed control system has a better steady state performance and robustness than a non-compensated control system.

**Estimation of Tire Parameters via Second-Order Sliding Mode Observers with Unknown Inputs**
Tafner Robert, Reichhartinger Markus and Horn Martin

**Abstract:** This paper considers the identification of unknown parameters related to a vehicle tire model using second-order sliding mode techniques. In a tailored two-stage procedure unknown input state observers recover the characteristic tire parameters. One of them is based on a modified super-twisting algorithm that extends the class of feasible uncertainties. In contrast to other methods for identification of tire parameters, typically requiring extensive sensor equipment, the proposed mechanisms only rely on standard measurement sensors. Furthermore, the algorithms are employable in-vehicle for online identification of model parameters. The overall concept is evaluated by the use of a complex vehicle dynamics simulation environment.

**Experimental Evaluation of a Cascade Sliding Mode-PI Controller for a Coupled-Inductor Boost Converter**
Carrero Niliana, Batlle Carles and Fossas Enric

**Abstract:** This paper describes the experimental results obtained for a cascade sliding mode PI control in a coupled-inductor Boost converter. A non-linear control strategy similar to sliding mode control was designed for the inner loop, while for the secondary control loop an experimentally tuned PI controller is proposed. The main goal of the closed loop system is to regulate the output voltage of the converter. The control was designed starting with a piece-wise complementarity model of the converter. The complementarity framework allows to model uni-directional switches, with the idealized current and voltage of the diodes as complementary variables, i.e. variables that are non-negative and such that their product is zero at any time. The experimental results show the robustness of the control strategy under step changes in the input voltage and load.

**Graph-based Field Automata for Modeling of Sliding Mode Systems**
Kryachkov Mikhail and Polyakov Andrey

**Abstract:** A novel hybrid automaton admitting the modeling of both conventional and modern sliding mode systems is presented. A scheme for defining hybrid-automaton executions beyond Zeno points is proposed. Conventional and Filippov-like executions of the hybrid automaton are introduced and studied.

**Higher Order Integral Nested Sliding Mode Control of Internal Combustion Engine**
Meza-Aguilar Marco, Loukianov Alexander, Sánchez-Torres Juan, Navarrete-Guzmán Antonio and Rivera Jorge

**Abstract:** In this paper, a controller for internal combustion engine is presented. This controller is based on the combination of high order sliding mode, integral sliding mode and globally linearizing strategies. The globally linearizing technique is used to find a control law such that output is related linearly to the input, i.e. to find a suitable equation eliminating the nonlinearity between output and input. The integral sliding mode control is used to guarantee the robustness of the closed-loop system, and the high order sliding mode control is applied to track the reference signal, to reject perturbations and to estimate a certain unknown value of the system by means of the equivalent control method.

**Higher order sliding mode air-to-fuel ratio in SI engines**
Rivera Jorge, Espinosa Javier and Loukianov Alexander

**Abstract:** In this work one presents a novel nonlinear control strategy for the normalized air to fuel ratio (represented by $\lambda$ variable) for spark ignition engines. The control method is based on the high order sliding mode
methodology that results to be robust to matched perturbations and alleviates the chattering problem. The dynamics for $\lambda$ depends on the time derivative of the input control, i.e., the injected fuel mass flow $\dot{m}_{fi}$. This term is estimated by means of a well known robust sliding mode differentiator. Then, based on time delayed measurements given by an UEGO sensor, a high order sliding mode observer is proposed where the equivalent injected signal contains actual values. Finally, simulations based on a mean value engine model demonstrate the good performance of the proposed control method.

**Linear-Quadratic Optimal Sliding Plane Design for Networked Control of Dynamical Systems**

Iganciuk Przemyslaw

**Abstract:** The paper addresses the problem of remote plant control in networked environment with the use of sliding-mode control. While introducing numerous benefits, networked control of dynamic systems brings the challenges of finite rate of information exchange and delay. In order to account for finite sampling, the study is conducted directly in discrete time domain. The main emphasis is placed on the design of sliding hyperplane for the systems involving information transfer delay. It is formally shown that the design of linear-quadratic (LQ) optimal plane for a discrete time-delay system may be reduced to plane selection for a delay-free system represented in delay compensator dynamics. The obtained solution relieves complexity of the optimization problem while maintaining robustness to mismatched disturbances of LQ optimal planes.

**Mismatched Disturbance Estimation and Compensation for Seeker System using Higher Order Sliding Mode Control**

Tamhane Bhagyashri, Mujumdar Amruta and Kurode Shailaja

**Abstract:** This paper develops a higher order sliding mode control approach for system with non vanishing mismatched uncertainties through a nonlinear disturbance observer. A novel, stable sliding surface is designed by augmenting the state vector with the estimated disturbance as an extra state. The super twisting algorithm is applied to obtain a continuous, robust control for this extended state system. Convergence of the states ensures convergence of the mismatched disturbance via higher order sliding mode technique. Efficacy of the scheme is proved by MATLAB simulation on seeker system of a missile. This estimation compensation approach is tried for various kinds of mismatched disturbances.

**MRFT-Based Robust and Adaptive Controller Design for Gas Loop of Liquid-Gas Separator**

Al Shehhi Hamdati, Boiko Igor

**Abstract:** The Modified Relay Feedback Test (MRFT) was recently proposed as a continuous oscillation method for identification of process parameters and controller tuning. In this research, the MRFT is used for the design of a robust and an adaptive PI controllers for a gas loop in the two-phase separator. The gas normally uncounted in the separator is the natural gas (mostly methane) which is contained in crude oil coming from the reservoir. In this paper, the PI controller is developed based on sixty four modes of operation corresponding to certain ranges of gas inflow and liquid level values – the two parameters that characterize the operating modes. It is shown through the developed model and simulations that these operating modes affect the dynamics of the gas loop. Dynamic properties of the process in each mode are studied through MRFT. A robust and an adaptive PI controllers are designed in order to maintain the pressure during the change of the operating conditions. Performance of the designed control system is studied by simulations.

**Periodic Behaviors of A Discretized Twisting Algorithm Based Sliding Mode Control System**

Yan Yan, Yu Xinghuo and Changyin Sun

**Abstract:** In this paper, we show that Euler discretization of the sliding mode control system with twisting algorithm can lead to periodic behaviors. Bounds for periodic orbits are derived, which allow one to estimate the maximum chattering amplitude for a given value of the time step. It is shown that for certain parameter values, there exist arbitrarily long periodic orbits. Theoretical results are illustrated with simulation examples.

**Robust Control of Pneumatic Actuators Based on a Simplified Model With Delayed Input**

Edjekouane Essaid, Riacky Samer, Ghanes Malek and Barbot Jean-Pierre

**Abstract:** Due to frictions and air compressibility, the dynamics of pneumatic actuators is often described by a complex fourth-order non linear model. Therefore, simplifying the model of pneumatic actuators is of prime interest to design a controller. In this paper a simple second order model is proposed by modeling the pressure dynamics with a pure time delay on the control input. The Artstein transformation is applied to this model to get a delay-free second order system. Then the delay-free system is stabilized using a robust nonlinear controller. The relevance of the proposed approach is demonstrated through experimental tests.
### Robust output regulation of variable structure systems with multivalued controls
Miranda Felix and Castanos Fernando

**Abstract:** We consider the problem of robust output regulation for a class of passive linear systems. We take a 'control by interconnection of systems' approach, where the controller is defined by means of a multivalued function. The resulting closed-loop system can be cast into the form of a variable structure system with interesting properties: output feedback (perfect knowledge of the plant state is not required) and perfect regulation despite parametric uncertainty and unmatched disturbances. The methodology is illustrated through a physical and an abstract example.

### Sliding Control Variation for Ball-Plate System Stabilization
Valadez Rangel Humberto, Loukianov Alexander, Toledo Bernardino and Corrochano Eduardo

**Abstract:** The fundamental purpose of this paper is to present a stabilizing control for rolling ball (ball-plate system), which is developed using the framework of the theory of high order control variation in combination with integrator backstepping and sliding mode control. Under this scheme, control laws are proposed to solve the complex and general problem of stabilization for this system.

### Sliding Mode Control of Electric Power System Comprised of Fuel Cell and Multiple-Modular DC-DC Boost Converters
Ashok Kumar Roshini Sukanya

**Abstract:** The paper deals with controlling an electric power system comprised of a Proton Exchange Membrane Fuel Cell (PEMFC) as a Primary Source of Electric power Supply (PSES) and multiple-modular boost DC-DC power converter as a Secondary Sources of Electric Power Supply (SSES). System's PEMFC/multiple-modular DC-DC boost power converter zero dynamics are analyzed and appeared to be stable. Relative degree approach is applied for direct control of the output load voltage as well as the PEMFC current in the presence of the model uncertainties. The adaptive gain super-twisting sliding mode controller controls the current in PEMFC. The decoupled Sliding Mode Controllers (SMC) are designed for controlling the output voltages of the multiple modular converters. The efficacy and robustness of the proposed two-fold SMC and 2-SM adaptive-gain controllers are confirmed via computer simulations. Key words: electric power systems, sliding mode control

### The Block Design of Invariant Tracking System for MIMO Nonlinear Control Plant
Krasnova Svetlana, Utkin Victor

**Abstract:** The paper deals with tracking problem for multiple-input multiple-output nonlinear systems under mismatched external disturbances. The existence conditions of the input-output block form (IOBF) with regard for the external disturbances are obtained. This form is the basis for the decentralized control design in a narrow formulation, without entering a dynamic compensator generating derivatives of control actions. Sliding mode observers used to estimate the unmeasured variables of the new coordinate basis and external influences. These observers are not required expansion of the state space due to dynamic models of the external disturbances and the reference signals.
June 30th

Session 2 (15:25-17:45) – Sliding mode applications in transport and energy domains - Chair: I. Boiko and C. Kunusch

15:25 – 15:45

**Feasibility Study of Variable Gain Super-Twisting Control in Fuel Cells Based Systems**
Carolina Evangelista, Paul Puleston and Cristian Kunusch

*Abstract:* This work presents a controller based on a Super-Twisting (ST) algorithm with variable gains, designed to maximize the efficiency of a fuel cell (FC). The strategy consists on regulating the oxygen excess ratio, maintaining it at an optimum value in spite of external disturbances and model uncertainties. The tested algorithm has the well-known advantages of the original ST with fixed gains, such as simplicity, robustness against uncertainty and disturbances, reduced chattering and finite time convergence. In addition, the variability of its gains allows expanding the range of operation, without a significant increase in the complexity of the control law. The adjustment of the gains is based on certain variable bounding functions, which have to be determined analysing the system and its characteristics. This process is laborious for a non-linear system like the FC, but is performed off-line during the design stage. Promising results have been obtained through exhausting simulation tests, considering model uncertainties and highly variable load regimes.

15:45 – 16:05

**Air Breathing Hypersonic Missile Continuous Higher Order Sliding Mode Control for Maximum Target Penetration**
P. Yu, Y. Shtessel, S. S. Mehta, and C. L. Pasiliao

*Abstract:* The hypersonic missile control in the terminal phase is considered and addressed using higher order sliding mode control techniques. The third order sliding mode controller that comprises the continuous finite reaching time controller driven by the continuous higher order sliding mode disturbance observers have been proposed, designed and studied. The proposed higher order sliding mode controller has been validated via simulations of a hypersonic missile in the terminal phase. The controllers demonstrated robustness and high accuracy of the output tracking in the presence of matched and unmatched external disturbances and missile model uncertainties.

16:05 – 16:25

**Design of Gain Scheduling Control Strategy for Artificial Gas Lift in Oil Production through Modified Relay Feedback Test**
Huda Hussein, Ahmed Al Durra and Igor Boiko

*Abstract:* One of the major problems encountered in artificial gas lifting is the stability of production from wells were gas lift may show a highly oscillatory behavior, and hence production varies greatly with time. This paper presents methodology of design of a gain scheduling strategy based on a new physical model of artificial gas lift in oil wells. The model was preliminarily validated by comparing the states dynamics with other models from the literature which have been replicated. The Modified Relay Feedback Test (MRFT) method was used to calculate the PI controller parameters, and the model reached steady state for different operating points. Gain scheduling was then performed following the MRFT results to provide a simple PI controller tuning parameters for the automatic control and optimization of the production from the oil well, and to compensate for the casing-heading instability in the system.

16:25 – 16:45

**Non-Smooth Missiles Guidance: Interceptor-Defender Scenario with Uncertainties**
Alexander Poznyak

*Abstract:* Here the dynamic scenario with two participants (an interceptor interpreted as an anti-missile and a defender treated as an anti-anti-missile) is considered. The first one (an interceptor) is intended to reach a capture zone, associated with a given nominal trajectory of a missile which is assumed to be non-maneuvered. But in the same time it should maintain a large enough distance from the second player (a defender) whose individual aim is to protect the nominal plant (a missile). The second participant realizes its behavior in such a way that its position would be as close as possible to an interceptor and far enough from a missile which it protects. Individual cost functions related with
non-smooth feedback control strategies for each participant are introduced. The gain parameters of
the non-smooth feedbacks are selected in an "optimal manner" providing the biggest rate of
convergence to the desired regime. The effective zones in the state space, where the designed control
decreases the cost functions, are obtained. Illustrative numerical simulations confirm the workability
of the suggested approach.

**Flight Control System Design with High Order Sliding Modes for Nonlinear Aircraft Model**
Erkan Abdulhamitbilal

*Abstract:* In this paper, an aircraft robust flight control system design is studied via high order sliding
mode techniques with parameter uncertainties in flight speed, altitude, aerodynamic coefficients
without any reconfiguration of control parameters. Complete nonlinear six degree of freedom flight
dynamics model is built for a conventional aircraft in state space. Control commands are assumed to
be aileron deflection of wings, elevator deflections of horizontal stabilizers, rudder deflection of
vertical fin, trust input of jet-engine/propeller. Twisting and super-twisting algorithms are considered
and compared to illustrate effectiveness of each control system on nonlinear aircraft dynamics for
different flight conditions.

**Robust Flight Sliding Modes Control System Design for Nonlinear Aircraft with Parameter
Uncertainties**
Erkan Abdulhamitbilal

*Abstract:* In this paper, an aircraft robust flight control system design is studied via sliding mode
techniques with parameter uncertainties in flight speed, altitude, aerodynamic coefficients without any
reconfiguration of control parameters. Complete nonlinear six degree of freedom flight dynamics
model is built for a conventional aircraft in state space. Control commands are assumed to be aileron
deflection of wings, elevator deflections of horizontal stabilizers, rudder deflection of vertical fin,
trust input of jet-engine/propeller. Also, actuator dynamics are considered. A design example is given
to illustrate effectiveness of proposed control system with and without actuator dynamics for three
different flight conditions.

**MRFT Based Identification of Process Dynamics**
Muhammad Haekal and Igor Boiko

*Abstract:* The Modified relay feedback test (MRFT) was recently proposed for non-parametric tuning
of PID controllers. In the present research, the use of the MRFT for identification of process
dynamics is investigated. It is shown that the use of the MRFT allows one to ensure identification in
the frequency domain, with frequencies generated automatically in the frequency range most
important for a considered process. In fact, the range of generated frequencies can always be
produced in such a way as to include and be in vicinity of the gain and phase cross-over frequencies.
It is proposed that identification is done through minimization of a specific cost function that
characterizes matching of the Nyquist plot of the model to the experimentally obtained points of the
process Nyquist plot. The proposed methodology is illustrated by an example of identification of
dynamics of an experimental level control setup.
### July 1st

**Session 3 (10:15 – 12:35) – High order sliding mode (SM) control – Chair: T. Roux-Oliveira**

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<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
<th>Abstract</th>
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<tr>
<td>10:15 – 10:35</td>
<td>Multivariable BMRAC Extension to Arbitrary Relative Degree Using Global Robust Exact Differentiators</td>
<td>Andrei Battistel, Eduardo V. L. Nunes, Liu Hsu</td>
<td>This paper presents the non-uniform arbitrary relative degree extension to the Multivariable Binary Model Reference Adaptive Control (BMRAC). Global exact output tracking for uncertain linear plants is obtained without requiring stringent symmetry assumptions on the High Frequency Gain with good transient performance and robustness. To overcome the relative degree obstacle, we employ the multivariable version of the Global Robust Exact Differentiator (GRED) scheme, which achieves uniform global practical stability and exact tracking by switching a linear lead filter with a nonlinear one based on robust exact differentiators.</td>
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<td>10:35 – 10:55</td>
<td>Extremum Seeking Control via Monitoring Function and Time-Scaling for Plants of Arbitrary Relative Degree</td>
<td>Liu Hsu, Tiago Roux Oliveira and José Paulo V. S. Cunha</td>
<td>An output-feedback variable-structure based extremum seeking controller was recently introduced for nonlinear uncertain systems by using a monitoring function. The class of systems considered was restricted to the relative degree one case. In this paper, generalization is achieved to include more general dynamics with arbitrary relative degree, uncertain parameters and order. Global stability properties of the closed-loop system and exponential convergence to a neighborhood of the desired extremum are proved. The main contribution of this paper is to develop a time-scaling procedure to essentially reduce the analysis and control design to that of a relative degree one case. Simulation results illustrate the performance of the proposed extremum seeking control algorithm in different time scales.</td>
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<td>10:55 – 11:15</td>
<td>An Application of Computer Aided Parameter Tuning of a Super-Twisting Sliding Mode Controller</td>
<td>M. Kleindienst, M. Reichhartinger, M. Horn and E. Usai</td>
<td>A tuning procedure of the super-twisting algorithm is exploited in order to operate a thermal plant within predefined specifications. The configuration consisting of the chosen control algorithm and the thermal plant results in a limit cycle, i.e. the solutions of the closed-loop system are periodic functions of time. The tuning algorithm is based on the pre-specified amplitude and frequency of the variable to be controlled. The computation of the constant controller gains is based on the equation of harmonic balance. A possibly needed dynamical filter is introduced to guarantee that every desired amplitude and frequency of the limit cycle can be adjusted. The tuning procedure is extended such that the controller parameters can be calculated directly without using any graphical aids. Real world experiments demonstrate the achieved accuracy of the tuning algorithm.</td>
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<td>11:15 – 11:35</td>
<td>On the Boundary Control of Distributed Parameter Systems by Second-Order Sliding-Mode Technique. Recent Advances and New Results</td>
<td>Antonello Baccoli, Yury Orlov, Alessandro Pisano and Elio Usai</td>
<td>The primary concern of the present paper is to give an overview of the available results and methods in the field of second-order sliding mode based boundary control synthesis for uncertain and perturbed distributed parameter systems. We particularly aim at showing how the same basic algorithm (the combined Twisting/PD algorithm) can be applied to solve different problems involving parabolic and hyperbolic-type equations. Then, we deal with a reaction-diffusion process by also providing some novelty in that a destabilizing mixed-type boundary condition, which was not considered in the previous work [14], is taken into account. The effectiveness of the developed controller is supported...</td>
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<td>11:35 – 11:55</td>
<td>A Modified Super-Twisting Algorithm for Systems of Relative Degree More Than One</td>
<td>Michael Basin, Pablo Rodriguez-Ramirez</td>
<td>This paper presents a homogeneous continuous super-twisting algorithm for systems of relative degree more than one. The conditions of finite-time convergence to the origin are obtained and the robustness of the designed algorithm is discussed. The paper concludes with numerical simulations illustrating performance of the designed algorithms.</td>
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<td>11:55 – 12:15</td>
<td>Robust Output-Feedback Control for Container-Slosh System using Variable Gain Super-Twisting Algorithm</td>
<td>Jyoti Prakash Mishra, Shailaja R. Kurode</td>
<td>This paper presents robust control of containerslosh coupled dynamical system. Variable Gain Super-twisting Algorithm (VGSTA) is used to synthesize an output-feedback control. The surface used is finite time converging. The detailed stability proof is presented. The proposed controller is compared with classical PID. The proposed method is verified via rigorous simulations. The robustness analysis is also validated in simulations.</td>
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<td>12:15 – 12:35</td>
<td>Lyapunov functions for Twisting and Terminal controllers</td>
<td>Tonámetl Sánchez, Jaime A. Moreno</td>
<td>In this work, homogeneous Lyapunov functions for the Second Order Sliding Mode algorithms “Twisting” and “Terminal” are designed. Such functions are obtained using asystematic and constructive method. The designing method and the Lyapunov functions provide sets of gains that guarantee finite time stability of the system’s origin in the disturbed case. It is also proved that the conditions for the controller’s gains are even necessary and sufficient.</td>
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### July 1\textsuperscript{st}

**Session 4 (14:15-16:50) – Sliding mode applications in power energy and mechanics – Chair : D. Biel**

<table>
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<th>Time</th>
<th>Presentation</th>
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| 14:15 – 14:35 | A Fixed-Time Second Order Sliding Mode Observer for a Class of Nonlinear Systems  
|             | Juan Diego Sánchez-Torres and Alexander G. Loukianov  
|             | **Abstract:** This paper presents a second order fixed time sliding mode observer based on an extension of the super-twisting algorithm. This observer can be applied to a class of nonlinear system with a block-wise representation. The block structure provides a straightforward form to the application of the proposed second order sliding mode algorithm, yielding to finite-time convergence with a settling time independent to the system initial conditions. Finally, as numerical simulation example, the case of a linear induction motor is studied, exposing the efficiency and feasibility of the proposal. |
| 14:35 – 14:55 | Sliding Mode Control of Three-Phase, Boost-Type and Three-Wire, Single-Phase AC/DC Power Converters  
|             | Yazan Alsmadi, Vadim Utkin, Longya Xu Aimeng Wang  
|             | **Abstract:** This paper presents a novel control strategy of three-phase, boost-type and, three-Wire, single-phase AC/DC Power Converters AC/DC power converters. The proposed control algorithm is based on Sliding Mode Control methodology. The basic idea is to apply a feedback implementation of pulse-width modulation (PWM). The method exhibits low sensitivity to disturbances and fast dynamic performance in addition to the main converter properties. The proposed sliding mode control method ensures that the power converter has the following properties: pure sinusoidal input currents at unity power factor from the ac line and low level of DC output voltage ripple. Discussion starts with the circuit model and design methodology of three-phase, boost-type and single-phase, three-wire AC/DC Power Converters. Then, a sliding mode current control tracking system is designed for both converters. Finally, output voltage control is developed. The effectiveness of the proposed control strategy has been demonstrated through various simulation cases. |
| 14:55 – 15:15 | Sliding Mode Control Of A Three-Phase Four-Wire LCL Rectifier  
|             | Domingo Biel, Arnau Dòria-Cerezo and Enric Fossas  
|             | **Abstract:** In this paper a control algorithm for a three-phase four-wire rectifier with an inductive-capacitive-inductive filter is presented. The control scheme consists in an inner current loop designed using the Sliding Mode Control technique, and an two external loops that regulates the DC bus voltage and also keeps the split bus balanced. Numerical simulations are also provided to show the performance of the closed loop. |
| 15:15 – 15:35 | Combined Estimation of State-of-Charge and State-of-Health of Li-ion Battery Cells Using SMO on Electrochemical Model  
|             | Satadru Dey, Beshah Ayalew and Pierluigi Pisu  
<p>|             | <strong>Abstract:</strong> Advanced battery management systems require accurate information of battery State-of-Charge (SOC) and State-of-Health (SOH) for diagnostics and prognostics as well as for efficient capacity utilization. In this paper, an integrated SOC and SOH estimation scheme is presented that applies sliding modes on an electrochemical model for Li-ion Battery Cell. The electrochemical model is selected and progressively reduced to sufficiently describe the relevant temporal and spatial evolution of Li-ion concentration in each electrode. The proposed estimation scheme is comprised of three sub-estimators which work jointly: two separate adaptive sliding mode observers (SMO) for estimation of Li-ion concentration and film resistance, and a separate parameter estimator for the solid state diffusion coefficient of negative electrode. Convergence of the observers has been proven using Lyapunov’s stability theory. Simulation results are included to demonstrate the effectiveness of the overall scheme. |
| 15:35 – 15:50 | Coffee break |</p>
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<th>Time</th>
<th>Session Title</th>
<th>Authors</th>
<th>Abstract</th>
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<tr>
<td>15:50 – 16:10</td>
<td>Hybrid Sliding Mode Control for Two Cells Converter</td>
<td>M. Bennmiloud, A. Benalia, And M. Djemai</td>
<td>This paper deals with the switching design for two cells converter. With a systematic manner and a geometric analysis, we developed a novel switching surfaces using the sliding mode control theory. The limit cycle of the converter is taken in consideration in the control design phase. The proposed control scheme combines the performances of PWM control techniques (optimal steady state) and the advantages of the direct control strategies (control of the transitory state). This is validated through simulation under fast variations of the input voltage.</td>
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<td>16:10 – 16:30</td>
<td>Distributed Tracking For Mechanical Systems Using Second-Order Sliding-Modes</td>
<td>Jorge Dávila</td>
<td>In this paper, the second-order sliding-mode super-twisting controller is modified to provide distributed tracking for mechanical systems. The distributed tracking is ensured by the proposed controller after a finite-time transient. The controller ensures the exact tracking of leader's position in spite of bounded external disturbances and uncertainties. The corresponding conditions for the distributed tracking and for the simultaneous consensus are studied. The convergence of the tracking error to zero is proven by Lyapunov methods. Simulations show the workability of the proposed method.</td>
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<td>16:30 – 16:50</td>
<td>Sliding Mode Control of a Forestry-Standard Mobile Hydraulic System</td>
<td>Carlos Vázquez, Stanislav Aranovskiy and Leonid Freidovich</td>
<td>In this paper, a sliding mode control design for a forestry-standard mobile hydraulic system, including bounded model uncertainties and external disturbances, is proposed. The approach includes inverse of a dead-zone-like nonlinearity and a feedforward compensation. Besides, two strategies for chattering attenuation are implemented, improving the overall performance. Experimental results performed over an industrial setup confirm efficacy of the proposed methodology. Additionally, a comparison with a PID controller is presented.</td>
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<td>10:15 – 10:35</td>
<td><strong>Fixed Switching Frequency Sliding Mode Control using an Hysteresis Band Controller</strong></td>
<td>Repecho Víctor, Biel Domingo and Fossas Enric</td>
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<td>Abstract:</td>
<td>This paper presents a hysteresis band controller in charge of fixing the switching frequency of a sliding mode controller. The proposed control measures the switching period of the control signal and modifies the hysteresis band of the comparator to regulate the switching frequency of the sliding motion. The switching frequency control system is modelled and a design criterion of the control parameters is derived to guarantee the closed loop stability.</td>
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<td>10:35 – 10:55</td>
<td><strong>Continuous Higher Order Sliding Mode Control Based on Adaptive Disturbance Compensation</strong></td>
<td>Edwards Christopher and Shtessel Yuri</td>
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<td>Abstract:</td>
<td>The hypersonic missile control in the terminal phase is considered and addressed using higher order sliding mode control techniques. The third order sliding mode controller that comprises the continuous finite reaching time controller driven by the continuous higher order sliding mode disturbance observers have been proposed, designed and studied. The proposed higher order sliding mode controller has been validated via simulations of a hypersonic missile in the terminal phase. The controllers demonstrated robustness and high accuracy of the output tracking in the presence of matched and unmatched external disturbances and missile model uncertainties.</td>
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<td>10:55 – 11:15</td>
<td><strong>Accuracy of Disturbed Homogeneous Sliding Modes</strong></td>
<td>Livne Miki and Levant Arie</td>
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<td>Abstract:</td>
<td>The asymptotic accuracy of disturbed homogeneous systems is studied. The results are applied to estimate the accuracy of homogeneous output-feedback high-order sliding-mode controllers in the presence of disturbances changing or eliminating the system relative degree. Two academic examples demonstrate the accuracy calculation.</td>
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<td>11:15 – 11:35</td>
<td><strong>Discrete-Time Chattering-Free Integral Sliding Mode Control of Continuous-Time Descriptor Systems</strong></td>
<td>Drazenovic Branislava, Milosavljevic Cedomir and Veselic Boban</td>
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<td>Abstract:</td>
<td>This paper considers a hybrid approach to control of linear dynamic and impulse controllable continuous-time disturbed linear descriptor systems. The first step in control is a design of continuous state feedback that makes system impulse-free. The obtained system is represented as a state space system of relative order zero. Based on this model, a full order discrete-time sliding mode control providing given pole placement is designed. The reaching control is completely decentralized and chattering-free. Simulations show a very good suppression of slow disturbances. All design steps and simulations require only standard MATLAB Toolbox.</td>
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<td>11:35 – 11:55</td>
<td><strong>A New Reaching Law Based Sliding Mode Flow Controller for Connection-Oriented Data Transmission Networks</strong></td>
<td>Bartoszewicz Andrzej and Lesniewski Piotr</td>
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<td>Abstract:</td>
<td>In this paper we first propose a new reaching law for discrete time sliding mode control of linear time-invariant systems subject to disturbance and modelling uncertainty. The reaching law makes the sliding variable rate of change proportional to the inverse tangent of this variable, which results in bounded state and control effort. Then we apply the proposed reaching law to design an efficient flow control strategy for multi-source connection oriented (for example ATM or MPLS) data transmission networks. The strategy ensures full exploitation of the available bandwidth and eliminates the risk of data loss in the network. Moreover, the strategy proposed in this paper generates bounded data transmission rates which are limited by design parameters and do not depend</td>
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on the initial state of the network.

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| 11:55 – 12:15 | **Output Integral Sliding Mode based Robustified LQ control for Switched Uncertain Systems**  
Galvan-Guerra Rosalba and Fridman Leonid  
*Abstract:* This paper presents observation and control methodologies for a class of switched uncertain linear time invariant systems with autonomous location transitions. A switched algebraic hierarchical observer is designed using an output integral sliding mode technique in order to reconstruct the state in every location, based only on the available output information. The sequence of locations is identified using the information given by the switching surfaces and the nominal trajectory generated by a hybrid LQ optimal control. The hybrid LQ control problem is robustified using an integral sliding mode control, allowing to eliminate the perturbations/uncertainties dynamics from the switched uncertain system, theoretically exactly, right after the first moment, using only output information. Simulations illustrate the effectiveness of the proposed approach. |
| 12:15 – 12:35 | **L2-gain analysis of sliding mode controllers**  
Osuna Topacio and Orlov Yury  
*Abstract:* The present work extends the L2-gain analysis towards sliding mode dynamic systems. The developed analysis is then applied to a first order sliding mode algorithm to illustrate that the resulting closed loop system is capable not only of rejecting matched uniformly bounded disturbances, but also of attenuating unbounded ones, including mismatched disturbances. |
### Sliding mode control for a class of underactuated systems using feedforward normal form: A slosh-container system
Thakar Parth, Bandyopadhyay Bijnan and Gandhi Prasanna

**Abstract:** This paper deals with the design of stable sliding mode control (SMC) for the underactuated slosh-container system using feedforward normal form. A nonlinear coordinate transformation is used to convert the system into so-called feedforward normal like form to decouple the control input appearing in one of the degree of freedom (DOF). This results in the design simplicity for the sliding mode control as well as the equivalent control and reduced order system derivation and its stability analysis. The range of surface parameters to provide the stable sliding motion for the system using proposed scheme, is also large compared to our earlier results. Simulation results are also presented to illustrate the proposed method.

### Experimental comparisons between implicit and explicit implementations of discrete-time sliding mode controllers: towards chattering suppression in output and input signals
Bin Wang, Brogliato Bernard, Acary Vincent, Boubakir Aheine and Plestan Franck

**Abstract:** This paper presents a set of experimental results concerning the sliding mode control of an electro-pneumatic system. Two discrete-time control strategies are considered for the implementation of the discontinuous part of the sliding mode controller: explicit and implicit discretizations. While the explicit implementation is known to generate numerical chattering, the implicit one is expected to significantly reduce chattering while keeping the accuracy. The experimental results reported in this work remarkably confirm that the implicit discrete-time sliding mode supersedes the explicit ones, with several important features: chattering in the control input is almost eliminated (while the explicit and saturated controllers behave like high-frequency bang-bang inputs), the input magnitude depends only on the perturbation size and is largely independent of the controller gain and sampling time.

### Recent advances in sliding-mode based consensus strategies
Pilloni Alessandro, Franceschelli Mauro, Pisano Alessandro and Usai Elio

**Abstract:** In this paper we present a review of our recent advancements in consensus-based cooperative control by using sliding-mode concepts for networked systems. In particular, strategies for achieving consensus in networks of persistently perturbed agents with static and switching network topologies, which can be disconnected for intervals of time, are discussed. We consider both first and second order agent models. Convergence proofs are carried out by means of nonsmooth Lyapunov analysis and simulative results are presented to corroborate the theoretical results.

### An Integral Sliding Mode Fault Tolerant Control Scheme for an Octorotor Using Fixed Control Allocation
Alwi Halim, Hamayun Mirza Tariq and Edwards Christopher

**Abstract:** This paper presents a fault tolerant control scheme which uses integral sliding mode and fixed control allocation. Traditional integral sliding mode control can only handle actuator faults, but when combined with control allocation, the resulting scheme can also handle total actuator failures directly without reconfiguring the baseline integral sliding mode controller. In comparison to most of the existing literature on integral sliding mode fault tolerant control, the control allocation component proposed in this paper uses a fixed structure and therefore does not require any information about the actuator faults/failures i.e. it does not require any fault detection or isolation information. This allows further simplification as the proposed scheme also does not need the baseline controller to be reconfigured. To demonstrate the efficacy of the proposed scheme, a highly redundant multi-rotor UAV (specifically an octorotor model) is considered in the simulations.
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<td>15:35 – 15:50</td>
<td>Coffee break</td>
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| 15:50 – 16:10 | Fault Detection for Nonlinear Non-affine Systems via Sliding-Mode Output-Feedback and HOSM Differentiator  
Rios Hector, Punta Elisabetta and Fridman Leonid  
**Abstract:** This paper deals with the fault detection problem for nonlinear uncertain non-affine systems. The variable-structure output-feedback stabilization based on observer is required. Depending on the type of uncertainties, conditions are given under which convergence to the unique solution of both the system and the observer, and fault detection are achieved. Simulation results illustrate the feasibility of the proposed approach. |
| 16:10 – 16:30 | Study on Short Periodic Solutions of a Discretized Second-Order Sliding-Mode Control System  
Wang Xiangyu and Li Shihua  
**Abstract:** In this paper, short periodic solutions of a discretized second-order sliding-mode control system are investigated. Specifically, the existence and stability of short periodic solutions are analyzed. Moreover, the explicit descriptions of short periodic solutions are also presented. |
| 16:50 – 17:10 | Output Feedback Hybrid-Impulsive Second Order Sliding Mode Control: Lyapunov Approach  
Shtessel Yuri, Glumineau Alain, Plestan Franck and Weiss Martin  
**Abstract:** A perturbed nonlinear system of relative degree two controlled by output feedbacks discontinuous-hybrid-impulsive control is studied. The output hybrid-impulsive terms serve to drive instantaneously the system's trajectory to the origin or to its small vicinity, when the practical impulsive action is approximated. The output feedback impulsive action combined with the output relay feedback control guarantees a uniform exact convergence with zero convergence time of system's trajectory to a real 2-SMC in the presence of bounded perturbations. The stability of the considered hybrid-impulsive system is studied using Lyapunov approach. |
| 17:10 – 17:30 | Adaptive Extremum Seeking Scheme for ABS Control  
Dincmen Erkin  
**Abstract:** A sliding mode based extremum seeking algorithm is applied to the ABS control problem where the optimum slip ratio is searched online for maximum braking force in unknown road conditions. By making the parameter of the search algorithm adaptive, an adaptive extremum seeking scheme is proposed to improve the behavior of the controlled system around the optimum operating point. Simulation study is presented to illustrate the effectiveness of the methodology. |
General Informations

wireless NAME  Invites
wireless login  20vss14
wireless password  QhF25iGe

Phone contact

Franck PLESTAN : +33 (0)2 40 37 69 14, +33 (0)6 49 22 41 62

Alain GLUMINEAU : +33 (0)2 40 37 69 13, +33 (0)6 22 76 00 43

Emily THUREAU : +33 (0)2 40 37 69 95
TRANSPORTATION INFORMATION

A pass ticket is supplied for a free transportation on the TAN network from June 29 to July 2.

Partial map of Lines 1 (Bold Green) and 2 (Bold Red) of Nantes streetcar

(for the complete map, go to Public Transportation website www.tan.fr)

Station “Ecole Centrale – Audencia” – Line 2 – VSS 2014 place

Station “Motte Rouge” – Line 2 - Banquet

Stations “Duchesse Anne – Chateau” – Line 1 – Sunday’s registration // Railway Station (Gare SNCF in French)
To reach the campus, from Downtown, the most convenient way is to use the **Line 2 of streetcar** (tramway in French) **direction “Orvault-Grand Val”** and stop at the station “Ecole Centrale – Audencia”. The station is near the campus entrance. The duration between Downtown and Campus by streetcar is less than 20 minutes.
How to reach « Les Bateaux Nantais » for the Banquet

From the streetcar stop (Motte Rouge, line 2), follow the steps below:

• Take the north-east on Quai de Versailles to Boulevard Amiral Courbet: 100 m

• Turn right onto Boulevard Amiral Courbet: 29 m

• Continue to Pont de la Motte Rouge (Bridge): 120 m. **Take care! there are roadworks on the bridge, but pedestrian access is maintained.**

• At the roundabout, take the 1st exit left onto Place Waldeck Rousseau

Destination will be on the left.

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**Bateaux Nantais**

**Quai de la Motte Rouge**

**44008 NANTES CEDEX 1**

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