

## **WS01 - Continuous Higher-Order Sliding-Mode Controllers**

### **Organizers:**

**Leonid Fridman (Universidad Nacional Autónoma de México)**

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### **Speakers:**

**Leonid Fridman (Universidad Nacional Autónoma de México)**

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**Vadim Utkin (Ohio State University)**

### **TIMETABLE**

9.00-10.00 Higher Order Sliding Mode Controllers: Stages of Development  
Leonid Fridman

The history and evolution of higher order sliding mode control(HOSMC) will be discussed. The second order sliding mode control algorithms and their specific features will be presented. The principal arbitrary order sliding mode controllers will be presented. Videos with the experimental illustration of the properties of the main sliding mode algorithms will be presented.

10.00-10.30 Main notions Definitions of solutions. Types of convergence  
Leonid Fridman

The lecture surveys elements of Filippov theory of differential equations with discontinuous right-hand sides and its recent extensions are discussed. Stability notions (from Lyapunov stability(1982)to fixed-time stability (2012))are observed.

10.30-10.45 Cafe Break

10.45- 13.00  
Lyapunov Based Design for Continuous Sliding Mode controllers  
Jaime Moreno

- Motivation and basic idea of the continuous sliding mode controllers
- Lyapunov-Based Design of State Feedback Continuous SMC for:
  - First order plants

- Second Order Plants:
  - Continuous Terminal Sliding Mode Controller
  - Continuous Twisting Controller
  - Discontinuous Integral Controller
- Higher Order Plants
- Lyapunov-Based Design of Arbitrary-Order Exact Differentiators
- Output Feedback Continuous SMC

13.00-14.00 Lunch

14.00 -15.30

Continuous Sliding Mode Controllers gains redesign and adaptation  
Jaime Moreno

Gain Design of Continuous Sliding Mode Controllers and Adaptation.  
Jaime A. Moreno

- Gain Design for continuous sliding mode controllers: Alternatives
- An Introduction to Generalized Polynomials and Generalized Polynomial Systems:
  - Generalized Polynomials and Generalized Forms (GF)
  - Generalized Polynomial Systems
  - Positive (Semi-) Definiteness of Generalized Forms
    - Polya's Theorem
    - Sum of Squares Decomposition for GF
- Gain Design of CSM Controllers for Generalized Form Systems
- Gain Adaptation

15.30-15.45 Cafe Break

15.45-16.15

Sliding surface design for arbitrary order sliding modes  
Leonid Fridman

Two main concepts for sliding surfaces design procedure: pole placement and optimal stabilization are generalized for the case of arbitrary order sliding modes. For the pole placement case, the formula of Ackermann-Utkin is extended allowing the design of sliding surfaces with arbitrary relative degree. The natural connection between order of singularity for singular optimal stabilization problem and order of sliding mode controller is shown and used in the design the sliding surface and the sliding mode controller of corresponding order.

16.45-17.15

Super-twisting algorithm for the systems with general uncertainties  
Leonid Fridman

In the lecture it will be shown that the presence of the state uncertainties in control generates algebraic loops in Super-Twisting Algorithm (STA) design, for the case when the uncertainties depends on the states a Generalized Super-Twisting Algorithm (GSTA) is needed.

A global finite-time stability analysis for the GSTA based on a strict non-smooth Lyapunov function for three different scenarios is performed:

- (1) time dependent uncertain control gain and perturbation,
- (2) known control gain with state and time dependent perturbations,
- (3) state and time dependent uncertain control gain and perturbations.

17.15- 18.00 Concluding remark and discussion

V. Utkin, L.Fridman, J.Moreno

Is it reasonable to use the discontinuous controller instead of continuous ones?

## CONCLUDING REMARKS

### References

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