MR8500 - PhD Topics in Marine Control Systems (2020)

Backstepping designs on complex nonlinear systems

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An intensive lecture is given showing how thousands of theoretical papers on backstepping designs can be understood in 2+2 hours. The highlights are as follows.

Lecture 1 (2 hours)

- Backstepping design on complex nonlinear systems is similar to cooking (or the street food – wok box). Choose the favorite noodle, vegetable, meat, and sauce, then wok.
- The development of backstepping, from simple systems to complex uncertain systems.
- Review the basic backstepping design approaches. Point out the challenges and show methods to overcome them.
- Give a few title pages of journal papers. Tell the students that they can easily understand and apply these results after this intensive lecture.
- Introduce a significant semi-global stability criteria $\dot{V} = -\gamma V + \delta$ which is crucial to the backstepping designs on complex nonlinear systems.
- Introduce 6 elegant methods:
    1. Dynamic surface control and commanded filters,
    2. Finite-time control,
    3. Neural network and fuzzy logic system,
    4. Nussbaum function,
    5. Barrier Lyapunov function,
    6. Hyperbolic tangent function.

  These methods could be modularized design approaches.
    - Highlight the assumptions of each method. (The core idea of backstepping is cancellation based on a series of assumptions.)
    - Introduce the corresponding inequality used in each method.
    - Deduct the key steps by hand.
    - Show the benefits and shortcomings of each method.

Lecture 2 (2 hours)

- All types of system uncertainties and complexities can be transferred into specific forms in which the abovementioned elegant methods are appliable. The methodologies can be categorized into robustness-based and estimation-based.
- Begin from the problems of a class of systems, including state constraints, input nonlinearities (input saturation/deadzone/time-varying control coefficient), unknown disturbance, time-delay effects, pure-feedback system, event-triggered systems, stochastic systems.
- Complex systems are discussed, including the underactuated system, switched system, and multi-agent consensus system.
    - Introduce the corresponding Lyapunov-based stability theorem to the abovementioned systems.
- Understand the robustness-based method and the approximation-based method (funny GIFs).
- Call back: Briefly explain how to solve the nonlinear problems proposed in the titles from Lecture 1 in a modularized way.
- Call back: Compare backstepping design and cooking.