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Active disturbance rejection control: Methodology and theoretical analysis

Volume 53, Issue 4, January 2014, Pages 963-976

Yi Huang | Wenchao Xue

The methodology of ADRC and the progress of its theoretical analysis are reviewed in the paper. Several breakthroughs for control of nonlinear uncertain systems, made possible by ADRC, are discussed. The key in employing ADRC, which is to accurately determine the "total disturbance" that affects the output of the system, is illuminated. The latest results in theoretical analysis of the ADRC-based control systems are introduced. © 2014 ISA.

A robust PID controller based on imperialist competitive algorithm for load-frequency control of power systems

Volume 52, Issue 1, January 2013, Pages 88-95

Hamed Shabani | Behrooz Vahidi | Majid Ebrahimpour

A new PID controller for resistant differential control against load disturbance is introduced that can be used for load frequency control (LFC) application. Parameters of the controller have been specified by using imperialist competitive algorithm (ICA). Load disturbance, which is due to continuous and rapid changes of small loads, is always a problem for load frequency control of power systems. This paper introduces a new method to overcome this problem that is based on filtering technique which eliminates the effect of this kind of disturbance. The object is frequency regulation in each area of the power system and decreasing of power transfer between control areas, so the parameters of the proposed controller have been specified in a wide range of load

changes by means of ICA to achieve the best dynamic response of frequency. To evaluate the effectiveness of the proposed controller, a three-area power system is simulated in MATLAB/SIMULINK. Each area has different generation units, so utilizes controllers with different parameters. Finally a comparison between the proposed controller and two other prevalent PI controllers, optimized by GA and Neural Networks, has been done which represents advantages of this controller over others. © 2012 ISA.

SEARCH MENU

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Finite-time H∞ control for a class of Markovian jump systems with mode-dependent time-varying delays via new Lyapunov functionals

Volume 52, Issue 6, November 2013, Pages 768-774

Jun Cheng | Hong Zhu | Shouming Zhong | Yong Zeng | Xiucheng Dong

This paper is concerned with the problem of finite-time H∞ control for a class of Markovian jump systems with mode-dependent time-varying delays via new Lyapunov functionals. In order to reduce conservatism, a new Lyapunov-Krasovskii functional is constructed. Based on the derived condition, the reliable H∞ control problem is solved, and the system trajectory stays within a prescribed bound during a specified time interval. Finally, numerical examples are given to demonstrate the proposed approach is more effective than some existing ones.© 2013 Published by Elsevier Ltd. All rights reserved.

Terminal sliding mode tracking control for a class of SISO uncertain nonlinear systems

Volume 52, Issue 2, March 2013, Pages 198-206

Mou Chen | Qing-Xian Wu | Rong Xin Cui

In this paper, the terminal sliding mode tracking control is proposed for the uncertain single-input and single-output (SISO) nonlinear system with unknown external disturbance. For the unknown external disturbance of nonlinear systems, terminal sliding mode disturbance observer is presented. The developed disturbance observer can guarantee the disturbance approximation error to converge to zero in the finite time. Based on the output of designed disturbance observer, the terminal sliding mode tracking control is presented for uncertain SISO nonlinear systems. Subsequently, terminal sliding mode tracking control is developed using disturbance observer technique for the uncertain SISO nonlinear system with control singularity and unknown non-symmetric input saturation. The effects of the control singularity and unknown input saturation

are combined with the external disturbance which is approximated using the disturbance observer. Under the proposed terminal sliding mode tracking control techniques, the finite time convergence of all closed-loop signals are guaranteed via Lyapunov analysis. Numerical simulation results are given to illustrate the effectiveness of the proposed terminal sliding mode tracking control. © 2012 ISA.

Interior search algorithm (ISA): A novel approach for global optimization

Volume 53, Issue 4, January 2014, Pages 1168-1183

Amir H. Gandomi

This paper presents the interior search algorithm (ISA) as a novel method for solving optimization tasks. The proposed ISA is inspired by interior design and decoration. The algorithm is different from other metaheuristic algorithms and provides new insight for global optimization. The proposed method is verified using some benchmark mathematical and engineering problems commonly used in the area of optimization. ISA results are further compared with well-known optimization algorithms. The results show that the ISA is efficiently capable of solving optimization problems. The proposed algorithm can outperform the other well-known algorithms. Further, the proposed algorithm is very simple and it only has one parameter to tune. © 2014 ISA.

Second order sliding mode control for a quadrotor UAV

Volume 53, Issue 4, January 2014, Pages 1350-1356

Bin Xiong | Ji Liang Luo

A method based on second order sliding mode control (2-SMC) is proposed to design controllers for a quadrotor UAV. For the switching sliding manifold design, the selection of the coefficients of the switching sliding manifold is in general a sophisticated issue because the coefficients are nonlinear. In this work, in order to perform the position and attitude tracking control of the quadrotor perfectly, the dynamical model of the quadrotor is divided into two subsystems, i.e., a fully actuated subsystem and an underactuated subsystem. For the former, a sliding manifold is defined by combining the position and velocity tracking errors of one state variable, i.e., the sliding manifold has two coefficients. For the latter, a sliding manifold is constructed with a linear combination of position and velocity tracking errors of two state variables, i.e., this sliding manifold has four coefficients. In order to further obtain the nonlinear coefficients of the sliding manifold, Hurwitz stability analysis is used to the solving process. In addition, the

flight controllers are derived by using Lyapunov theory, which guarantees that all system state trajectories reach and stay on the sliding surfaces. Extensive simulation results are given to illustrate the effectiveness of the proposed control method. © 2014 ISA.

Position and attitude tracking control for a quadrotor UAV

Volume 53, Issue 3, January 2014, Pages 725-731

Ling Jing Xiong | En Hui Zheng

A synthesis control method is proposed to perform the position and attitude tracking control of the dynamical model of a small quadrotor unmanned aerial vehicle (UAV), where the dynamical model is underactuated, highly-coupled and nonlinear. Firstly, the dynamical model is divided into a fully actuated subsystem and an underactuated subsystem. Secondly, a controller of the fully actuated subsystem is designed through a novel robust terminal sliding mode control (TSMC) algorithm, which is utilized to guarantee all state variables converge to their desired values in short time, the convergence time is so small that the state variables are acted as time invariants in the underactuated subsystem, and, a controller of the underactuated subsystem is designed via sliding mode control (SMC), in addition, the stabilities of the subsystems are demonstrated by Lyapunov theory, respectively. Lastly, in order to demonstrate the robustness of the proposed control method, the aerodynamic forces and moments and air drag taken as external disturbances are taken into account, the obtained simulation results show that the synthesis control method has good performance in terms of position and attitude tracking when faced with external disturbances. © 2014 ISA.

On the centrality of disturbance rejection in automatic control

Volume 53, Issue 4, July 2014, Pages 850-857

Zhiqiang Gao

It is shown that the problem of automatic control is, in essence, that of disturbance rejection, with the notion of disturbance generalized to symbolize the uncertainties, both internal and external to the plant. A novel, unifying concept of disturbance rejector is proposed to complement the traditional notion of controller. The new controller-rejector pair is shown to be a powerful organizing principle in the realm of automatic control, leading to a Copernican moment where the model-centric design philosophy is replaced by the one that is control-centric in the following sense: the controller is designed for a canonical model and is fixed; the difference

between the plant and the canonical model is deemed as disturbance and rejected. © 2013 ISA.

Cat Swarm Optimization algorithm for optimal linear phase FIR filter design

Volume 52, Issue 6, November 2013, Pages 781-794

Suman Kumar Saha | Sakti Prasad Ghoshal | Rajib Kar | Durbadal Mandal

In this paper a new meta-heuristic search method, called Cat Swarm Optimization (CSO) algorithm is applied to determine the best optimal impulse response coefficients of FIR low pass, high pass, band pass and band stop filters, trying to meet the respective ideal frequency response characteristics. CSO is generated by observing the behaviour of cats and composed of two sub-models. In CSO, one can decide how many cats are used in the iteration. Every cat has its' own position composed of M dimensions, velocities for each dimension, a fitness value which represents the accommodation of the cat to the fitness function, and a flag to identify whether the cat is in seeking mode or tracing mode. The final solution would be the best position of one of the cats. CSO keeps the best solution until it reaches the end of the iteration. The results of the proposed CSO based approach have been compared to those of other well-known optimization methods such as Real Coded Genetic Algorithm (RGA), standard Particle Swarm Optimization (PSO) and Differential Evolution (DE). The CSO based results confirm the superiority of the proposed CSO for solving FIR filter design problems. The performances of the CSO based designed FIR filters have proven to be superior as compared to those obtained by RGA, conventional PSO and DE. The simulation results also demonstrate that the CSO is the best optimizer among other relevant techniques, not only in the convergence speed but also in the optimal performances of the designed filters. © 2013 ISA. Published by Elsevier Ltd. All rights reserved.

Finite-time control for nonlinear spacecraft attitude based on terminal sliding mode technique

Volume 53, Issue 1, January 2014, Pages 117-124

Zhankui Song | Hongxing Li | Kaibiao Sun

In this paper, a fast terminal sliding mode control (FTSMC) scheme with double closed loops is proposed for the spacecraft attitude control. The FTSMC laws are included both in an inner control loop and an outer control loop. Firstly, a fast terminal sliding surface (FTSS) is constructed, which can drive the inner loop tracking-error and the outer loop tracking-error on the FTSS to

converge to zero in finite time. Secondly, FTSMC strategy is designed by using Lyaponov's method for ensuring the occurrence of the sliding motion in finite time, which can hold the character of fast transient response and improve the tracking accuracy. It is proved that FTSMC can guarantee the convergence of tracking-error in both approaching and sliding mode surface. Finally, simulation results demonstrate the effectiveness of the proposed control scheme. © 2013 ISA.

SEARCH MENU

Anti-disturbance control theory for systems with multiple disturbances: A survey

Volume 53, Issue 4, January 2014, Pages 846-849

Lei Guo | Songyin Cao

The problem of anti-disturbance control has been an eternal topic along with the development of the control theory. However, most methodologies can only deal with systems subject to a single equivalent disturbance which was merged by various types of uncertainties. In this paper, a review on anti-disturbance control is presented for systems with multiple disturbances. First, the classical control methods are briefly reviewed for disturbance attenuation or rejection problems. Then, recent advances in disturbance observer based control (DOBC) theory are introduced and especially, the composite hierarchical anti-disturbance control (CHADC) is firstly addressed. A comparison of different approaches is briefly carried out. Finally, focuses in the field on the current research are also addressed with emphasis on the practical application of the techniques. © 2013 ISA.

Modified active disturbance rejection control for time-delay systems

Volume 53, Issue 4, January 2014, Pages 882-888

Zhiqiang Gao

Industrial processes are typically nonlinear, time-varying and uncertain, to which active disturbance rejection control (ADRC) has been shown to be an effective solution. The control design becomes even more challenging in the presence of time delay. In this paper, a novel modification of ADRC is proposed so that good disturbance rejection is achieved while maintaining system stability. The proposed design is shown to be more effective than the standard ADRC design for time-delay systems and is also a unified solution for stable, critical stable and unstable systems with time delay. Simulation and test results show the effectiveness and practicality of the proposed design. Linear matrix inequality (LMI) based stability analysis is

provided as well. © 2013 ISA.

SEARCH MENU

Active disturbance rejection based trajectory linearization control for hypersonic reentry vehicle with bounded uncertainties

Volume 54, Issue , January 2015, Pages 27-38

Xingling Shao | Honglun Wang

This paper investigates a novel compound control scheme combined with the advantages of trajectory linearization control (TLC) and alternative active disturbance rejection control (ADRC) for hypersonic reentry vehicle (HRV) attitude tracking system with bounded uncertainties. Firstly, in order to overcome actuator saturation problem, nonlinear tracking differentiator (TD) is applied in the attitude loop to achieve fewer control consumption. Then, linear extended state observers (LESO) are constructed to estimate the uncertainties acting on the LTV system in the attitude and angular rate loop. In addition, feedback linearization (FL) based controllers are designed using estimates of uncertainties generated by LESO in each loop, which enable the tracking error for closed-loop system in the presence of large uncertainties to converge to the residual set of the origin asymptotically. Finally, the compound controllers are derived by integrating with the nominal controller for open-loop nonlinear system and FL based controller. Also, comparisons and simulation results are presented to illustrate the effectiveness of the control strategy.

Survey on methods of increasing the efficiency of extended state disturbance observers

Volume 56, Issue , January 2015, Pages 18-27

R. Madoński | P. Herman

This survey presents various methods of improving the overall estimation quality in the class of extended state observers (ESO), which estimate not only the conventional states of the system, but the acting disturbance as well. This type of observers is crucial in forming the active disturbance rejection control structure (ADRC), where the precision of online perturbation reconstruction and cancellation directly influences the robustness of the closed-loop control system. Various aspects of the observer-based disturbance estimation/rejection loop are covered by this work and divided into three categories, related with observer: structure, tuning, and working conditions. The survey is dedicated to researchers and practitioners who are interested in

increasing the efficiency of their ADRC-based governing schemes.

Active disturbance rejection control for fractional-order system

(https://www.elsevier.com/journals/isa-transactions/0019-0578/guide-for-authors)
Volume 52, Issue 3, May 2013, Pages 365-374

Mingda Li | Donghai Li | Jing Wang | Chunzhe Zhao

Fractional-order proportional-integral (PI) and proportional-integral- derivative (PID) controllers are the most commonly used controllers in fractional-order systems. However, this paper proposes a simple integer-order control scheme for fractional-order system based on active disturbance rejection method. By treating the fractional-order dynamics as a common disturbance and a ctively rejecting it, active disturbance rejection control (ADRC) can achieve the desired response. External disturbance, sensor noise, and parameter disturbance are also estimated using extended state observer. The ADRC stability of rational-order model is analyzed. Simulation results on three typical fractional-order systems are provided to demonstrate the effectiveness of the proposed method. © 2013 ISA.

Robust attitude control design for spacecraft under assigned velocity and control constraints

(https://www.elsevier.com/journals/isa-transactions/0019-0578/guide-for-authors)
Volume 52, Issue 4, July 2013, Pages 480-493

Qinglei Hu | Bo Li | Youmin Zhang

A novel nonlinear control design under the constraints of assigned velocity and actuator torques is investigated for attitude stabilization of a rigid spacecraft. More specifically, a nonlinear feedback control is firstly developed by explicitly taking into account the constraints on individual angular velocity components as well as external disturbances. Considering further the actuator misalignments and magnitude deviation, a modified robust least-squares based control allocator is employed to deal with the problem of distributing the previously designed three-axis moments over the available actuators, in which the focus of this control allocation is to find the optimal control vector of actuators by minimizing the worst-case residual error using programming algorithms. The attitude control performance using the controller structure is evaluated through a numerical example.

Second-order sliding mode control for DFIG-based wind turbines fault ride-through capability enhancement

Volume 53, Issue 3, January 2014, Pages 827-833

Mohamed Benbouzid | Brice Beltran | Yassine Amirat | Gang Yao | Jingang Han | Hervé Mangel

This paper deals with the fault ride-through capability assessment of a doubly fed induction generator-based wind turbine using a high-order sliding mode control. Indeed, it has been recently suggested that sliding mode control is a solution of choice to the fault ride-through problem. In this context, this paper proposes a second-order sliding mode as an improved solution that handle the classical sliding mode chattering problem. Indeed, the main and attractive features of high-order sliding modes are robustness against external disturbances, the grids faults in particular, and chattering-free behavior (no extra mechanical stress on the wind turbine drive train). Simulations using the NREL FAST code on a 1.5-MW wind turbine are carried out to evaluate ride-through performance of the proposed high-order sliding mode control strategy in case of grid frequency variations and unbalanced voltage sags. © 2014 ISA.

Continuous high order sliding mode controller design for a flexible air-breathing hypersonic vehicle

Volume 53, Issue 3, January 2014, Pages 690-698

Jie Wang | Qun Zong | Rui Su | Bailing Tian

This paper investigates the problem of tracking control with uncertainties for a flexible air-breathing hypersonic vehicle (FAHV). In order to overcome the analytical intractability of this model, an Input-Output linearization model is constructed for the purpose of feedback control design. Then, the continuous finite time convergence high order sliding mode controller is designed for the Input-Output linearization model without uncertainties. In addition, a nonlinear disturbance observer is applied to estimate the uncertainties in order to compensate the controller and disturbance suppression, where disturbance observer and controller synthesis design is obtained. Finally, the synthesis of controller and disturbance observer is used to achieve the tracking for the velocity and altitude of the FAHV and simulations are presented to illustrate the effectiveness of the control strategies. © 2014 ISA.

Practical sliding mode control for robust tracking of higher order delay time

systems with experimental application

Volume 52, Issue 1, January 2013, Pages 36-44

A. A. Khandekar | G. M. Malwatkar | B. M. Patre

In this paper, a discrete time sliding mode controller (DSMC) is proposed for higher order plus delay time (HOPDT) processes. A sliding mode surface is selected as a function of system states and error and the tuning parameters of sliding mode controller are determined using dominant pole placement strategy. The condition for the existence of stable sliding mode is obtained by using Lyapunov function. The proposed method is applicable to HOPDT processes with oscillatory and integrating behavior, open loop instability or non-minimum phase characteristics and works satisfactory under the effect of parametric uncertainty. The method does not require reduced order model and provides simple way to design the controllers. The simulation and experimentation results show that the proposed method ensures desired tracking dynamics. © 2012 ISA.

Diagnosis of broken-bars fault in induction machines using higher order spectral analysis

Volume 52, Issue 1, January 2013, Pages 140-148

I. Said | T. Ghanes | H. Henao | G. A. Capolino | G. Cirrincione

Detection and identification of induction machine faults through the stator current signal using higher order spectra analysis is presented. This technique is known as motor current signature analysis (MCSA). This paper proposes two higher order spectra techniques, namely the power spectrum and the slices of bi-spectrum used for the analysis of induction machine stator current leading to the detection of electrical failures within the rotor cage. The method has been tested by using both healthy and broken rotor bars cases for an 18.5 kW-220 V/380 V-50 Hz-2 pair of poles induction motor under different load conditions. Experimental signals have been analyzed highlighting that bi-spectrum results show their superiority in the accurate detection of rotor broken bars. Even when the induction machine is rotating at a low level of shaft load (no-load condition), the rotor fault detection is efficient. We will also demonstrate through the analysis and experimental verification, that our proposed proposed-method has better detection performance in terms of receiver operation characteristics (ROC) curves and precision-recall graph. © 2012 ISA.

fractional adaptive control for an automatic voltage regulator

Volume 52, Issue 6, November 2013, Pages 807-815

Norelys Aguila-Camacho | Manuel A. Duarte-Mermoud

This paper presents the application of a direct Fractional Order Model Reference Adaptive Controller (FOMRAC) to an Automatic Voltage Regulator (AVR). A direct FOMRAC is a direct Model Reference Adaptive Control (MRAC), whose controller parameters are adjusted using fractional order differential equations. Four realizations of the FOMRAC were designed in this work, each one considering different orders for the plant model. The design procedure consisted of determining the optimal values of the fractional order and the adaptive gains for each adaptive law, using Genetic algorithm optimization. Comparisons were made among the four FOMRAC designs, a fractional order PID (FOPID), a classical PID, and four Integer Order Model Reference Adaptive Controllers (IOMRAC), showing that the FOMRAC can improve the controlled system behavior and its robustness with respect to model uncertainties. Finally, some performance indices are presented here for the controlled schemes, in order to show the advantages and disadvantages of the FOMRAC.

IMC-PID-fractional-order-filter controllers design for integer order systems

Volume 53, Issue 5, January 2014, Pages 1620-1628

Bettayeb Maâmar | Mansouri Rachid

 One of the reasons of the great success of standard PID controllers is the presence of simple tuning rules, of the automatic tuning feature and of tables that simplify significantly their design. For the fractional order case, some tuning rules have been proposed in the literature. However, they are not general because they are valid only for some model cases. In this paper, a new approach is investigated. The fractional property is not especially imposed by the controller structure but by the closed loop reference model. The resulting controller is fractional but it has a very interesting structure for its implementation. Indeed, the controller can be decomposed into two transfer functions: an integer transfer function which is generally an integer PID controller and a simple fractional filter.

Chattering-free adaptive multivariable sliding mode controller for systems with matched and mismatched uncertainty

Volume 52, Issue 3, May 2013, Pages 335-341

Sanjoy Mondal | Chitralekha Mahanta

In this paper, a chattering free adaptive sliding mode controller (SMC) is proposed for stabilizing a class of multi-input multi-output (MIMO) systems affected by both matched and mismatched types of uncertainties. The proposed controller uses a proportional plus integral sliding surface whose gain is adaptively tuned to prevent overestimation. A vertical take-off and landing (VTOL) aircraft system is simulated to demonstrate the effectiveness of the proposed control scheme. © 2013 ISA.

Linear active disturbance rejection control of underactuated systems: The case of the Furuta pendulum

Volume 53, Issue 4, January 2014, Pages 920-928

A. Ramírez-Neria | H. Sira-Ramírez | R. Garrido-Moctezuma | A. Luviano-Juárez

An Active Disturbance Rejection Control (ADRC) scheme is proposed for a trajectory tracking problem defined on a nonfeedback linearizable Furuta Pendulum example. A desired rest to rest angular position reference trajectory is to be tracked by the horizontal arm while the unactuated vertical pendulum arm stays around its unstable vertical position without falling down during the entire maneuver and long after it concludes. A linear observer-based linear controller of the ADRC type is designed on the basis of the flat tangent linearization of the system around an arbitrary equilibrium. The advantageous combination of flatness and the ADRC method makes it possible to online estimate and cancels the undesirable effects of the higher order nonlinearities disregarded by the linearization. These effects are triggered by fast horizontal arm tracking maneuvers driving the pendulum substantially away from the initial equilibrium point. Convincing experimental results, including a comparative test with a sliding mode controller, are presented. © 2013 ISA.

Modified active disturbance rejection control for processes with time delay

Volume 53, Issue 4, January 2014, Pages 873-881

Qiming Zheng | Zhiqiang Gao

Active disturbance rejection control (ADRC) has been shown to be an effective tool in dealing with real world problems of dynamic uncertainties, disturbances, nonlinearities, etc. This paper addresses existing limitations with plants that have a large transport delay. In particular, to

overcome the delay, the extended state observer (ESO) in ADRC is modified to form a predictive ADRC, leading to significant improvements in the transient response and stability characteristics, as shown in extensive simulation studies and hardware-in-the-loop tests, as well as in the frequency response analysis. In this research, it is assumed that the amount of delay is approximately known, as is the approximated model of the plant. Even with such uncharacteristic assumptions for ADRC, the proposed method still exhibits significant improvements in both performance and robustness over the existing methods such as the dead-time compensator based on disturbance observer and the Filtered Smith Predictor, in the context of some well-known problems of chemical reactor and boiler control problems. © 2013 ISA.

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