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IEEE Transactions on Automatic Control publication information

Scanning The Issue

Identification of Fault Estimation Filter From I/O Data for Systems With Stable Inversion

Classical methods for estimating additive faults are based on state-space models, e.g., moving horizon estimation (MHE) and unknown input observers (UIOs). This paper contributes new direct design methods from closed-loop I/O data for systems with stable inversion, which do not require building a state-space model by first principles, nor require identifying it. Inspired by subspace identification, we use the input and

output (I/O) relationship of a plant in a Vector ARX (VARX) form to parameterize least-squares (LS) problems for estimating faults. We prove that with the order of the VARX descriptions tending to infinity, the fault estimates are unbiased. Under lower relative degrees, we prove that our new methods are equivalent to system-inversion-based estimation for both LTI and LTV systems. We will show more general unbiased estimation conditions for higher relative degrees. These require that the underlying inverted system from faults to outputs is stable. Algorithms of identifying unbiased fault estimation filters from data will be developed in this paper based on single LS. Moreover, covariance of the fault estimates can also be extracted from data.

Output-Based Event-Triggered Control With Guaranteed -Gain and Improved and Decentralized Event-Triggering

Most event-triggered controllers available nowadays are based on static state-feedback controllers. As in many control applications full state measurements are not available for feedback, it is the objective of this paper to propose event-triggered dynamical output-based controllers. The fact that the controller is based on output feedback instead of state feedback does not allow for straightforward extensions of existing event-triggering mechanisms if a minimum time between two subsequent events has to be guaranteed. Furthermore, since sensor and actuator nodes can be physically distributed, centralized event-triggering mechanisms are often prohibitive and, therefore, we will propose a decentralized event-triggering mechanism. This event-triggering mechanism invokes transmission of the outputs in a node when the difference between the current values of the outputs in the node and their previously transmitted values becomes “large” compared to the current values and an additional threshold. For such event-triggering mechanisms, we will study closed-loop stability and -performance and provide bounds on the minimum time between two subsequent events generated by each node, the so-called inter-event time of a node. This enables us to make tradeoffs between closed-loop performance on the one hand and communication load on the other hand, or even between the communication load of individual nodes. In addition, we will model the event-triggered control system using an impulsive model, which truly describes the behavior of the event-triggered control system. As a result, we will be able to guarantee stability and performance for event-triggered controllers with larger minimum inter-event times than the existing results in the literature. We illustrate the developed theory using three numerical examples.

Combining Convex&x2013;Concave Decompositions and Linearization Approaches for Solving BMIs, With Application to Static Output Feedback

A novel optimization method is proposed to minimize a convex function subject to bilinear matrix inequality (BMI) constraints. The key idea is to decompose the bilinear mapping as a difference between two positive semidefinite convex

mappings. At each iteration of the algorithm the concave part is linearized, leading to a convex subproblem. Applications to various output feedback controller synthesis problems are presented. In these applications, the subproblem in each iteration step can be turned into a convex optimization problem with linear matrix inequality (LMI) constraints. The performance of the algorithm has been benchmarked on the data from the library.

Computational Complexity Certification for Real-Time MPC With Input Constraints Based on the Fast Gradient Method

This paper proposes to use Nesterov's fast gradient method for the solution of linear quadratic model predictive control (MPC) problems with input constraints. The main focus is on the method's a priori computational complexity certification which consists of deriving lower iteration bounds such that a solution of pre-specified suboptimality is obtained for any possible state of the system. We investigate cold- and warm-starting strategies and provide an easily computable lower iteration bound for cold-starting and an asymptotic characterization of the bounds for warm-starting. Moreover, we characterize the set of MPC problems for which small iteration bounds and thus short solution times are expected. The theoretical findings and the practical relevance of the obtained lower iteration bounds are underpinned by various numerical examples and compared to certification results for a primal-dual interior point method.

Adaptive Information Collection by Robotic Sensor Networks for Spatial Estimation

This work deals with trajectory optimization for a robotic sensor network sampling a spatio-temporal random field. We examine the optimal sampling problem of minimizing the maximum predictive variance of the estimator over the space of network trajectories. This is a high-dimensional, multi-modal, nonsmooth optimization problem, known to be NP-hard even for static fields and discrete design spaces. Under

an asymptotic regime of near-independence between distinct sample locations, we show that the solutions to a novel generalized disk-covering problem are solutions to the optimal sampling problem. This result effectively transforms the search for the optimal trajectories into a geometric optimization problem. Constrained versions of the latter are also of interest as they can accommodate trajectories that satisfy a maximum velocity restriction on the robots. We characterize the solution for the unconstrained and constrained versions of the geometric optimization problem as generalized multicircumcenter trajectories, and provide algorithms which enable the network to find them in a distributed fashion. Several simulations illustrate our results.

Stability of a Class of Linear Switching Systems with Applications to Two Consensus Problems

In this paper, we first establish a stability result for a class of linear switched systems involving Kronecker product. The problem is interesting in that the system matrix does not have to be Hurwitz at any time instant. This class of linear switched systems arises in the control of multi-agent systems under switching network topology. As applications of this stability result, we give the solvability conditions for

both the leaderless consensus problem and the leader-following consensus problem for general marginally stable linear multi-agent systems under switching network topology. In contrast with some existing results, our results only assume that the dynamic graph is uniformly connected.

Quantized Control for Nonlinear Stochastic Time-Delay Systems With Missing Measurements

In this paper, the quantized control problem is investigated for a class of nonlinear stochastic time-delay network-based systems with probabilistic data missing. A nonlinear stochastic system with state delays is employed to model the networked control systems where the measured output and the input signals are quantized by two logarithmic quantizers, respectively. Moreover, the data missing phenomena

are modeled by introducing a diagonal matrix composed of Bernoulli distributed stochastic variables taking values of 1 and 0, which describes that the data from different sensors may be lost with different missing probabilities. Subsequently, a sufficient condition is first derived in virtue of the method of sector-bounded uncertainties, which guarantees that the closed-loop system is stochastically stable and the controlled output satisfies performance constraint for all nonzero exogenous disturbances under the zero-initial condition. Then, the sufficient condition is decoupled into some inequalities for the convenience of practical verification. Based on that, quantized controllers are designed successfully for some special classes of nonlinear stochastic time-delay systems by using Matlab linear matrix inequality toolbox. Finally, a numerical simulation example is exploited to show the effectiveness and applicability of the results derived.

Verification of Bounded Discrete Horizon Hybrid Automata

We consider the class of o-minimally definable hybrid automata with a bounded discrete-transition horizon. We show that for every hybrid automata in this class, there exists a bisimulation of finite index, and that the bisimulation quotient can be effectively constructed when the underlying o-minimal theory is decidable. More importantly, we give natural specifications for hybrid automata which ensure the boundedness of discrete-transition horizons. In addition, we show that these specifications are reasonably tight with respect to the decidability of the models and that they can model modern day real-time and embedded systems. As a result, the analysis of several problems for these systems admit effective algorithms. We provide a representative example of a hybrid automaton in this class. Unlike previously examined subclasses of o-minimally defined hybrid automata with decidable verification properties and extended o-minimal hybrid automata, we do not impose re-initialization of the continuous variables in a memoryless fashion when a discrete transition is taken. Our class of hybrid systems has both rich continuous dynamics and strong discrete-continuous coupling, showing that it is not necessary to either simplify the continuous dynamics or restrict the discrete dynamics to achieve decidability.

Inner Approximations for Polynomial Matrix Inequalities and Robust Stability Regions

Following a polynomial approach, many robust fixed-order controller design problems can be formulated as optimization problems whose set of feasible solutions is modeled by parametrized polynomial matrix inequalities (PMIs). These feasibility sets are typically nonconvex. Given a parametrized PMI set, we provide a hierarchy of linear matrix inequality (LMI) problems whose optimal solutions generate inner approx-

imations modeled by a single polynomial superlevel set. Those inner approximations converge in a well-defined analytic sense to the nonconvex original feasible set, with asymptotically vanishing conservatism. One may also impose the hierarchy of inner approximations to be nested or convex. In the latter case, they do not converge any more to the feasible set, but they can be used in a convex optimization framework at the price of some conservatism. Finally, we show that the specific geometry of nonconvex polynomial stability regions can be exploited to improve convergence of the hierarchy of inner approximations.

Stabilizing Model Predictive Control of Stochastic Constrained Linear Systems

This paper investigates stochastic stabilization procedures based on quadratic and piecewise linear Lyapunov functions for discrete-time linear systems affected by multiplicative disturbances and subject to linear constraints on inputs and states. A stochastic model predictive control (SMPC) design approach is proposed to optimize closed-loop performance while enforcing constraints. Conditions for stochastic convergence and robust constraints fulfillment of the closed-loop system are enforced by solving

linear matrix inequality problems off line. Performance is optimized on line using multistage stochastic optimization based on enumeration of scenarios, that amounts to solving a quadratic program subject to either quadratic or linear constraints. In the latter case, an explicit form is computable to ease the implementation of the proposed SMPC law. The approach can deal with a very general class of stochastic disturbance processes with discrete probability distribution. The effectiveness of the proposed SMPC formulation is shown on a numerical example and compared to traditional MPC schemes.

Recursive Update Filtering for Nonlinear Estimation

Nonlinear filters are often very computationally expensive and usually not suitable for real-time applications. Real-time navigation algorithms are typically based on linear estimators, such as the extended Kalman filter (EKF) and, to a much lesser extent, the unscented Kalman filter. This work proposes a novel nonlinear estimator whose additional computational cost is comparable to EKF updates, where is the number of recursions, a tuning parameter. The higher the less the filter relies on the linearization assumption. A second algorithm is proposed with a differential update, which is equivalent to the recursive update as tends to infinity.

Temporal Logic Control of Discrete-Time Piecewise Affine Systems

We present a computational framework for automatic synthesis of a feedback control strategy for a discrete-time piecewise affine (PWA) system from a specification given as a linear temporal logic (LTL) formula over an arbitrary set of linear predicates in the system's state variables. Our approach consists of two main steps. First, by defining appropriate partitions for its state and input spaces, we construct a finite abstraction of the PWA system in the form of a control transition system. Second,

by leveraging ideas and techniques from LTL model checking and Rabin games, we develop an algorithm to generate a control strategy for the finite abstraction. While provably correct and robust to state measurements and small perturbations in the applied inputs, the overall procedure is conservative and expensive. The proposed algorithms have been implemented as a software package and made available for download. Illustrative examples are included.

System Theoretic Aspects of Influenced Consensus: Single Input Case

This technical note examines the dynamics of networked multi-agent systems operating with a consensus-type algorithm, under the influence of an attached node or external agent. Depending on the specific scenario, the attached node can be viewed as a network intruder or an administrator. We introduce an influence scheme, naive of the network topology, involving predictable excitation of the network with the objective of manipulating, disrupting, or

steering its evolution. The spectrum of the corresponding Dirichlet matrix provides bounds on the system-theoretic properties of the resulting influenced network, quantifying its security—or viewed differently—its manageability. Finally, the controllability gramian for influenced consensus is examined, providing insights into its -norm and controllability properties.

Fourier-Hermite Kalman Filter

In this note, we shall present a new class of Gaussian filters called Fourier-Hermite Kalman filters. Fourier-Hermite Kalman filters are based on expansion of nonlinear functions with the Fourier-Hermite series in same way as the traditional extended Kalman filter is based on the Taylor series. The first order truncation of the Fourier-Hermite series gives the previously known statistically linearized filter.

A Decomposition Technique for Nonlinear Dynamical System Analysis

A method for analyzing large-scale nonlinear dynamical systems by decomposing them into coupled lower order subsystems that are sufficiently simple for computational analysis is presented. It is shown that the decomposition approach can be used to scale the Sum of Squares programming framework for nonlinear systems analysis. The method constructs subsystem Lyapunov functions which are used to form a composite Lyapunov function for the whole system. Further computational savings

are achieved if a method based on sparsity maximization is used to obtain the subsystem Lyapunov functions.

Robustness and Safe Sampling of Distributed-Delay Control Laws for Unstable Delayed Systems

In the control of delayed systems by a finite spectrum assignment (FSA) , in the control law, the integral over the time delay of a function of past control appears. This assignment is in fact available for continuous delayed process independently of the stability of the latter, which is very interesting since Smith predictor is usually only used with stable processes. Nevertheless, in case of FSA control implementation, this integral control should be sampled so that spectrum assignment is not necessarily preserved and an unstable discrete closed loop can be obtained , . In this technical note, FSA integral control robustness with respect to prediction time uncertainty is analyzed for an unstable continuous linear system. A transformation approach is also proposed to understand the effects of different ways of sampling control laws. In a last part, a case study shows how Simpson approximation of integral control law leads to an unstable digital closed loop.

A Supervised Switching Control Policy for LPV Systems With Inaccurate Parameter Knowledge

This technical note deals with the switched supervised control of linear parameter varying systems whose parameters values are online acquirable only with an arbitrarily large degree of uncertainty. The purpose is to define a switching policy inside a family of predesigned controllers so that the switched closed-loop system result to be exponentially stable. The proposed switching logic is based on a performance-evaluation criterion which uses a measurable Lyapunov-like functional of the output. The exponential stability condition is derived imposing a sufficient long time interval over which the functional is decreasing. An interesting feature of the technical note is that no particular structure on the kind of uncertainty affecting the parameter values is assumed.

LMI Relaxations for Reduced-Order Robust Control of Continuous-Time Uncertain Linear Systems

This technical note is concerned with the problem of reduced order robust dynamic output feedback control design for uncertain continuous-time linear systems. The uncertain time-invariant parameters belong to a polytopic domain and affect all the system matrices. The search for a reduced-order controller is converted in a problem of static output feedback control design for an augmented system. To

solve the problem, a two-stage linear matrix inequality (LMI) procedure is proposed. At the first step, a stabilizing state feedback scheduled controller with polynomial or rational dependence on the parameters is determined. This parameter-dependent state feedback controller is used at the second stage, which synthesizes the robust (parameter-independent) output feedback dynamic controller. A homogeneous polynomially parameter-dependent Lyapunov function of arbitrary degree is used to assess closed-loop stability with a prescribed attenuation level. As illustrated by numerical examples, the proposed method provides better results than other LMI based conditions from the literature.

Stochastic Barbalat's Lemma and Its Applications

In the deterministic case, a significant improvement on stability analysis of nonlinear systems is caused by introducing Barbalat's lemma into control area after Lyapunov's second method and LaSalle's theorem were established. This note considers the extension of Barbalat's lemma to the stochastic case. To this end, the uniform continuity and the absolute integrability are firstly described in stochastic forms. It is nevertheless a small generalization upon the existing references since our result can be used to adapted processes which are not necessarily Itô diffusions. When it is applied to Itô diffusion processes, many classical results on stochastic stability are covered as special cases.

Discrete-Time Observer Error Linearizability via Restricted Dynamic Systems

In this technical note, we define the observer error linearization problem of a discrete-time autonomous nonlinear system via a restricted dynamic system. This is the dual to restricted dynamic feedback linearization in a loose sense. Necessary and sufficient conditions for this problem are obtained in terms of the index.

Robust Finite-Horizon Kalman Filtering for Uncertain Discrete-Time Systems

In this note, we propose a design for a robust finite-horizon Kalman filtering for discrete-time systems suffering from uncertainties in the modeling parameters and uncertainties in the observations process (missing measurements). The system parameter uncertainties are expected in the state, output and white noise covariance matrices. We find the upper-bound on the estimation error covariance and we minimize the proposed upper-bound.

Distributed Containment Control with Multiple Dynamic Leaders for Double-Integrator Dynamics Using Only Position Measurements

This note studies the distributed containment control problem for a group of autonomous vehicles modeled by double-integrator dynamics with multiple dynamic leaders. The objective is to drive the followers into the convex hull spanned by the dynamic leaders under the constraints that the velocities and the accelerations of both the leaders and the followers are not available, the leaders are neighbors of only a subset of the followers, and the followers have only local interaction. Two containment control algorithms via only position measurements of the agents are proposed. Theoretical analysis shows that the followers will move into the convex hull spanned by the dynamic leaders if the network topology among the followers is undirected, for each follower there exists at least one leader that has a directed path to the follower, and the parameters in the algorithm are properly chosen. Numerical results are provided to illustrate the theoretical results.

Extended Controller Synthesis for Continuous Descriptor Systems

This technical note presents a complete solution to the nonstandard output feedback control problem for continuous descriptor systems where unstable and nonproper weighting functions are used. In such a problem, the desired controller has to satisfy two conditions simultaneously: (i) the closed-loop is admissible and has a minimum norm, (ii) only the internal stability of a part of the closed-loop is sought. The condition of the existence of such a controller is deduced. An explicit characterization of the optimal solution is also formulated, based on two generalized algebraic Riccati equations (GAREs) and two generalized Sylvester equations. A numerical example is included to illustrate the validity of the proposed results.

Characterization of Stability Region for General Autonomous Nonlinear Dynamical Systems

The existing characterization of stability regions was developed under the assumption that limit sets on the stability boundary are exclusively composed of hyperbolic equilibrium points and closed orbits. The characterizations derived in this technical note are a generalization of existing results in the theory of stability regions. A characterization of the stability boundary of general autonomous nonlinear dynamical systems is developed under the assumption that limit sets on the stability boundary are composed of a countable number of disjoint and indecomposable components, which can be equilibrium points, closed orbits, quasi-periodic solutions and even chaotic invariant sets.

EKF-Like Observer With Stability for a Class of Nonlinear Systems

An Extended-Kalman-Filter (EKF)-like observer is derived from a former observer result for a class of nonlinear systems, which can be written as a linear part in the unmeasured states on the one hand, and some additive nonlinearity with a triangular Jacobian on the other hand. It is shown how the previously presented excitation condition for exponential stability of the observer, extends to this EKF version. The observer is illustrated in simulation with two

challenging examples, the first one in leak detection, and the second one in chaos synchronization.

Synchronization of Dynamical Networks by Network Control

In this note, we study locally controlled synchronization of a dynamical network by introducing a distributed controller which has a different network structure from the original network. We refer to this configuration as a feedback network. To reflect practical reality, a cost function is considered to constrain the controller, and then the constrained controller design problem is transformed into a mixed-integer nonlinear optimization problem. In addition, when a single controller cannot be found under the con-

straint, a switching controller is designed by a Lyapunov function method. The convex combination technique is used to design the synchronizing switching signal between the candidate controllers, and its coefficients are given by the solution of a convex optimization problem. We also provide a feasible way to construct the candidate controllers, and give a numerical example which demonstrates the effectiveness of the proposed results.

Robust Inversion Based Fault Estimation for Discrete-Time LPV Systems

The article presents a state-space based Fault Diagnosis (FD) method for discrete-time, affine Linear Parameter Varying (LPV) systems. The goal of the technical note is to develop a robust and dynamic inversion based technique for systems with parameter varying representations when an additive, exogenous disturbance signal perturbs the system. After applying geometric concepts for explicit fault inversion, a robust strategy is proposed to attenuate the effect of the unknown disturbance input signal on the fault estimation error. The proposed robust observer is derived as a solution of off-line Linear Matrix Inequality (LMI) conditions. The technical note demonstrates the viability of the novel methodology through a numerical example.

Adaptive Output Feedback Design Using Asymptotic Properties of LQG/LTR Controllers

This technical note introduces an observer-based adaptive output feedback tracking control design for multi-input-multi-output dynamical systems with matched uncertainties. The reported methodology exploits asymptotic behavior of LQG/LTR regulators. Sufficient conditions for closed-loop stability and uniform ultimate boundedness of the corresponding tracking error dynamics are formulated. This method is valid for systems whose nominal linearized dynamics are controllable and observable. We assume that the number of the system measured outputs (sensors) is greater than the number of the control inputs (actuators) and that the system output-to-input matrix product has full column rank. In this case, the system can be "squared-up" (i.e., augmented) using pseudo-control signals to yield relative degree one minimum-phase dynamics. Since it is known that the "squaring-up" problem is solvable for any controllable observable triplet (A, B, C), the proposed design is applicable to systems whose regulated output dynamics may be non-minimum phase or have a high relative degree. A simulation example is presented to demonstrate key design features.

Single Integration Optimization of Linear Time-Varying Switched Systems

This technical note considers the switching time optimization of time-varying linear switched systems subject to quadratic cost—also potentially time-varying. The problem is formulated so that only a single set of differential equations need to be solved prior to optimization. Once these differential equations have been solved, the cost may be minimized over an arbitrary number of modes and mode sequences without requiring additional simulation. The differential equations that need to be simulated are as smooth as the system's vector fields, despite the fact that the optimization itself is nonsmooth. The technique is illustrated in examples from the literature.

Delay Robustness in Non-Identical Multi-Agent Systems

We investigate the robustness of consensus protocols on sensor networks to different types of feedback delays. We provide set-valued conditions for consensus of linear Multi-Agent Systems (MAS) with nonidentical agent dynamics and heterogeneous delays. These conditions consider different feedback delay configurations and are robust and scalable to unknown, arbitrary large topologies and unknown but bounded self-delays and communication delays. Moreover, we provide consensus conditions for relative degree two MAS with different feedback delays in order to illustrate the applicability of these set-valued conditions.

Fault Tolerance in Asynchronous Sequential Machines Using Output Feedback Control

This note presents a control scheme for fault diagnosis and tolerance in asynchronous sequential machines. The considered asynchronous machine is subject to permanent faults, so the system remains in the faulty condition indefinitely after the occurrence of fault inputs. When the machine has a certain structural redundancy, we can design a corrective controller and observer that diagnose faults and compensate the closed-loop system so that it can maintain the normal input/output behavior. The proposed framework is based on the output feedback control scheme and asynchronous techniques.

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