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DESIGN OF FINITE-TIME ALGORITHMS OF ADAPTIVE COMPENSATION OF MULTISINUSOIDAL DISTURBANCES IN LINEAR SYSTEMS WITH UNKNOWN PARAMETERS

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Abstract

This work studies adaptive output-feedback compensation of unmatched multisinusoidal disturbances in LTI plants with unknown parameters and unmeasurable state. The disturbance affects both input and output and has unknown harmonic components. A disturbance observer based on a modified of the model reference adaptive control (MRAC) parametrization lemma enables a direct output-feedback design without backstepping. Controller parameters are tuned via finite-time convergence (FTC). To avoid ill-conditioning and underflow of determinant-based FTC in high dimensions, QR decomposition is used for numerically reliable matrix operations. Simulations validate closed-loop performance.

Keywords

adaptive output-feedback; multisinusoidal disturbances; finite-time convergence; MRAC parametrization; QR decomposition

СИНТЕЗ ФИНИТНЫХ АЛГОРИТМОВ АДАПТИВНОЙ КОМПЕНСАЦИИ МУЛЬТИСИНУСОИДАЛЬНЫХ ВОЗМУЩЕНИЙ В ЛИНЕЙНЫХ СИСТЕМАХ С НЕИЗВЕСТНЫМИ ПАРАМЕТРАМИ

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Аннотация

В работе рассматривается адаптивная компенсация несогласованных мультисинусоидальных возмущений в ЛТИ-объектах с неизвестными параметрами и неизмеримым состоянием на основе выходной обратной связи. Возмущение воздействует как на вход, так и на выход объекта и содержит неизвестные гармонические составляющие. Наблюдатель возмущения, построенный на модифицированной лемме параметризации модельно-эталонного адаптивного управления (MRAC), обеспечивает прямой выходной синтез без применения бэкстеппинга. Настройка параметров регулятора выполняется по алгоритму конечноременной сходимости (FTC). Для предотвращения плохой обусловленности и численного переполнения вниз (underflow), характерных для детерминантных условий FTC в высокоразмерных задачах, используется QR-разложение, обеспечивающее численно устойчивые матричные операции. Моделирование подтверждает работоспособность замкнутой системы.

Ключевые слова

адаптивная выходная обратная связь; мультисинусоидальные возмущения; сходимость с конечным временем; параметризация MRAC; QR-разложение

Introduction. This work concerns the problem of adaptive compensation of multisinusoidal (multiharmonic) disturbances in linear time-invariant (LTI) plants with unknown parameters. The external disturbance simultaneously affects both the input and output of the plant

and can be represented as a multiharmonic signal with unknown frequencies, phases, and amplitudes. The state of the plant is assumed unmeasurable. A special observer based on the MRAC parametrization lemma is employed to handle unknown plant and disturbance parameters. Unlike existing direct output-feedback methods, the proposed design does not require a backstepping procedure. For controller parameters tuning, the finite-time convergence (FTC) algorithm is applied. In order to overcome the problem of high dimensions, the QR-decomposition is employed to ensure numerically reliable matrix inversion.

Main text. We address adaptive compensation of unmatched and a priori unknown multisinusoidal disturbances affecting a LTI plant with unknown parameters and unmeasurable state. The problem of direct adaptive compensation of unmatched external disturbances has been solved for linear systems [1] and nonlinear systems [2] with unknown parameters by applying the backstepping approach. Thus, the first contribution of this work is the design of a new disturbance observer based on the MRAC parametrization lemma, which enables direct adaptive disturbance compensation without the backstepping procedure. Regarding controller parameter tuning, FTC methods have previously been applied to low-dimensional parameter systems [3], where determinant-based conditions were used to overcome matrix inversion. However, in adaptive compensation of multisinusoidal disturbances, the parameter vector is high-dimensional. In this case, determinant-based criteria become ill-conditioned and may suffer from numerical underflow. Therefore, the second contribution of this work is the development of an FTC algorithm based on QR-decomposition, which ensures numerically reliable matrix inversion in high-dimensional settings.

Conclusions. This work provides a solution to the problem of finite-time tuning for the adaptive output-feedback compensation of multisinusoidal disturbances in LTI plants with unknown parameters. The proposed algorithm is analytically investigated, and the closed-loop system is validated through numerical simulations. Future research will focus on robust control extensions and sensitivity analysis with respect to measurement noise.

Literature

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