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ADAPTIVE CONTROL FOR UNSTABLE MULTIVARIABLE LINEAR SYSTEMS UNDER UNKNOWN EXTERNAL DISTURBANCES

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Abstract
In this work, a new method for the direct compensation of unknown external disturbances in a class of unstable multivariable linear systems is proposed, where both the reference signal and the external disturbances are unknown and have a harmonic form, and are therefore considered as unknown disturbances acting on the control system. The proposed method begins with the design of a linear decoupling controller based on state feedback to eliminate undesirable cross-couplings between inputs and outputs. Next, special observers are constructed. Finally, the control law and the adaptive algorithm are designed using the estimated states from these observers, ensuring that the system output accurately tracks the reference signal. In this paper, an adaptive algorithm with memory regressor extension is applied to improve the quality of parameter convergence. The proposed method enables the design of independent adaptive control laws for each control channel, thereby making the adaptive algorithm easier to tune and reducing its computational complexity, while eliminating interactions between control channels.

Keywords
adaptive control, harmonic disturbance, disturbances compensation, decoupling, Falb-Wolovich method, MIMO system.

АДАПТИВНОЕ УПРАВЛЕНИЕ НЕУСТОЙЧИВЫМИ МНОГОКАНАЛЬНЫМИ ЛИНЕЙНЫМИ СИСТЕМАМИ ПРИ НЕИЗВЕСТНЫХ ВНЕШНИХ ВОЗМУЩЕНИЯХ

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Аннотация
В данной работе предлагается новый метод прямой компенсации неизвестных внешних возмущений для класса неустойчивых многоканальных линейных систем, в которых как задающий сигнал, так и внешние возмущения являются неизвестными и имеют гармоническую форму, вследствие чего рассматриваются как неизвестные возмущения, воздействующие на систему управления. Предлагаемый метод начинается с синтеза линейного развязывающего регулятора на основе обратной связи по состоянию для устранения нежелательных перекрёстных связей между входами и выходами. Далее строятся специальные наблюдатели. На заключительном этапе формируются закон управления и адаптивный алгоритм с использованием оценённых состояний, полученных от этих наблюдателей, что обеспечивает точное слежение выходной переменной системы за задающим сигналом. В работе применяется адаптивный алгоритм с расширением регрессора памяти для повышения качества сходимости параметров. Предложенный метод позволяет синтезировать независимые адаптивные законы управления для каждого канала управления, что упрощает настройку адаптивного алгоритма, снижает его вычислительную сложность и устраняет взаимодействие между каналами управления.

Ключевые слова

адаптивное управление, гармонические возмущения, компенсация возмущений, развязка каналов, метод Фальба-Воловича, многоканальная система.

Introduction. A highly effective disturbance compensation method is based on the internal model principle, in which the disturbance is treated as the output of a linear autonomous system. The problem of adaptive disturbance compensation based on the internal model principle has been extensively studied, particularly in cases where the disturbance is modeled as the output of an exosystem with unknown parameters (see Section 1.4 in [1]). This paper presents a new approach to the disturbance compensation problem, based on the results on adaptive output regulation (see Section 4.2.3 in [1]). As in the approach presented in [1], a single adaptive controller is designed for the entire system; therefore, only one adaptation gain is available to adjust the overall convergence rate of all control channels. Therefore, this paper proposes to further develop the direct disturbance compensation method [1] by designing independent adaptive controllers for each control channel when applying the adaptive algorithm with memory regressor extension. This approach simplifies the tuning of the adaptive algorithm, reduces its computational complexity, and eliminates the adverse effects arising from interactions between control channels.

Main Part. In this work, we propose a new method for the direct compensation of unknown external disturbances in a class of unstable linear MIMO systems, where both the reference signal and external disturbances analyzed in this study are unknown and take a harmonic form, thus being considered as unknown disturbances influencing the control system. The proposed method begins with the design of a linear decoupling controller based on state feedback [2] to eliminate undesirable cross-couplings between inputs and outputs. Next, special observers are constructed. Finally, the control law and adaptive algorithm are designed using the estimated states from these observers, ensuring that the system output accurately tracks the reference signal.

Conclusions. This paper presents the development of the adaptive disturbance compensation method for linear multivariable systems subjected to unknown multi-harmonic disturbances introduced in [1]. The application of a system decoupling strategy based on the Falb–Wolovich approach [2] makes the adaptive law easier to tune while reducing the computational complexity of the algorithm and eliminating interactions between control channels. In future work, the proposed method will be extended to address the disturbance compensation problem for systems with unmeasured states.

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