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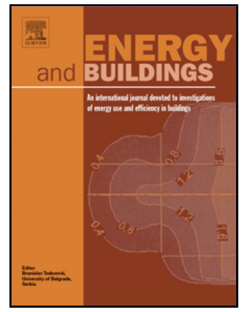

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A New Data-Driven Controllability Measure with Application in Intelligent Buildings

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Abstract

Buildings account for ca. 40% of the total energy consumption and ca. 20% of the total CO2 emissions. More effective and advanced control integrated into Building Management Systems (BMS) represents an opportunity to improve energy efficiency. The ease of availability of sensors technology and instrumentation within today's intelligent buildings enable collecting high quality data which could be used directly in data-based analysis and control methods. The area of data-based systems analysis and control is concentrating on developing analysis and control methods that rely on data collected from meters and sensors, and information obtained by data processing. This differs from the traditional model-based approaches that are based on mathematical models of systems. We propose and describe a data-driven controllability measure for discrete-time linear systems. The concept is developed within a data-based system analysis and control framework. Therefore, only measured data is used to obtain the proposed controllability measure. The proposed controllability measure not only shows if the system is controllable or not, but also reveals the level of controllability, which is the information its previous counterparts failed to provide. We use two illustrative examples to demonstrate the method, which also include an intelligent building.

Keywords: `Data-based analysis and control, Gramian, Controllability, Dynamic Systems, Measured data, Intelligent Buildings.`

1. Introduction

Worldwide and regionally, in European Union, and United States , buildings are responsible for ca. 40% of the total energy consumption and ca. 20% of the total CO2 emissions. To improve these figures, the energy-efficiency of buildings has to be improved. One way to address this issue is through more effective advanced control integrated into Building Management Systems (BMS) e. g. [1, 2, 3]. The area of control engineering has achieved significant results in solving a long list of challenging problems, many of which have had tremendous impact in our daily lives. The increasing advances in the area of information and communication technologies (ICT), as well as convenience of availability of data need to be put in service of the area of control engineering. To fulfil this task, however, a new paradigm for system analysis and control is needed. The currently developing area of data-based system analysis and control is focused on developing analysis and control methods that utilize data collected from meters and sensors, and information obtained by data processing, rather than mathematical models of systems [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14]. Two of the more significant key measures in modern control theory are controllability and observability [15, 16, 17, 18, 19]. This implies that data-based analysis of controllability and observability has been found to be of added interest [8], [4], [11]. Kalman controllability and observability matrices represent the basis for the existing methods that are described in literature that are focused on data-based analysis of controllability and observability. Kalman matrices, however, do not provide any information about the degree of controllability and observability, only barely designate if a system is controllable/observable. The information on the degree of controllability and observability is important is used in applications such as system reduction, and control configuration selection and control design [18, 19, 17, 20]. In this paper we introduce a data-based controllability measure. The suggested data-based controllability measure is generated using only data collected from meters. The advanted of the suggested controllability measure is that it reveals the degree of controllability, besides the usual outcome of whether a system is controllable or not. While our presented results are applied to controllability, they can be straightforwardly be extended to apply to observability analysis by duality. The method is illustrated with the help of two illustrative examples, including an intelligent building.

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