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A Data Mining Approach to Discover Critical Events for Event-Driven Optimization in Building Air Conditioning Systems

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Abstract

While online optimal control is regarded as an efficient tool to improve the operating efficiency of air conditioning, traditional optimal control strategies utilize the so-called time-driven optimization (TDO) scheme which triggers actions by "time". Although it works well for simple air conditioning systems, several limitations are encountered when systems become more and more complex. Since TDO is a periodic scheme, it may not be suitable or efficient to react to stochastic operational changes. Recently, in order to solve those limitations, the event-driven optimization (EDO) scheme has been proposed, in which actions are triggered by "event". However, previous studies only used prior knowledge to discover important events, which could only find events for general systems, and might not comprehensive because human prior knowledge is limited after all. Moreover, prior-knowledge-based method is able to discover new knowledge. Thus, this paper presents an effective data mining approach to discover the hidden knowledge in massive data set for EDO in building air conditioning systems. Results shown that data-mining-based EDO achieves a higher energy saving with reduced computation load, in comparison with the traditional TDO. Since the data mining approach can help to automate the process of finding critical events and event threshold, it also improves the practicability of EDO.

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Keywords: data mining; variable importance; building efficiency; event-driven optimization; air conditioning systems;

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1. Introduction

Event-driven optimization (EDO) has found to be effective in achieving energy efficient operation with greatly reduced computation load, which makes it applicable for online optimal control of air conditioning systems. In EDO, "event" plays an important role since it drives the timing and action of the optimization, which is a key factor affecting the energy and computation efficiencies of online optimal control.

The majority of the existing operation strategies for building services systems is developed by domain expertise or heuristic rules [1,2]. Thus, in our previous studies [3,4], prior knowledge was utilized and important events were successfully identified. However, considering human prior knowledge is limited and the system is not static (also evolving), prior understandings may be insufficient when pursuing further improvement, and additional ways are needed to discover more critical events for EDO. With the widespread penetration of building automation systems (BASs), huge amount BAS data is available. Effective understanding of these data can help to find important events. Data mining is believed to be a powerful tool to learn the hidden knowledge inside large dataset [5]. The major data mining practices in building field are as follows: finding patterns, associations, or relationships [6], building prediction models [7,8], diagnostics [9] and tuning controllers [10].

However, most of the previous attempts stop at identifying critical factors on energy performance or system faults. For building optimal control, only guidelines were provided, while the direct benefit of applying the discovered knowledge has rarely been demonstrated. Therefore, this study presents a more complete data mining practice on BAS data, which investigates the dataset, interprets the dataset, and utilizes the discovered knowledge to formulate the optimal control strategy (under the EDO framework), where the benefits obtained from the formulated strategy are directly revealed through simulation. Following contributions are made in this paper: (1) variable importance is directly output by the data mining algorithm, and users can select events based on the relative importance instead of domain knowledge; (2) Euclidean distance of decision variables is proposed to estimate the optimization reward; (3) event threshold is directly computed with the help of Euclidean distance of decision variables, which avoids the tedious trial-and-error method previously used [4].

2. Method

2.1. Brief overview of EDO and event space establishment

EDO is a new RTO framework in which optimization actions are triggered by event [3,4]. An event describes a set of *state transitions* that physically happen in a system [11,12]. In daily operation of air conditioning systems, state transitions are numerous and may come from environment (e.g. weather changes), system itself (e.g. operation mode changes) and occupants (e.g. occupancy changes). As not all of the state transitions should be used to define events in EDO, only those important state transitions that could cause a significant influence on concerned objectives will be selected. The selection criteria is developed using the notion of *optimization reward* as follows.

- If the predicted *optimization reward* associated with the state transition is "large", then we select it;
- If the predicted *optimization reward* associated with the state transition is "small", then we will not use it (considering that it would also consume resources like computation).

To establish the event space (the set of events), a three-step method is developed as shown in Figure 1. Step 1 is state transition identification that is used to identify possible critical state transitions. Step 2 is to define the candidate event space. Step 3 is to optimize the candidate event space by event performance analysis. Finally, the EDO design will be validated. Please note that although a state transition could be important, it may be a suitable event. Therefore, the Step 3 is necessary, which performs the analysis of event performance in terms of three key indices, i.e. energy performance, computational performance and performance score. Performance score is a index that both considers energy and computational performances (shown in eqn. (1)).

$$PS = a \times score_{EC} + b \times score_{CC} \tag{1}$$

where $score_{EC} = ES\%_{ei} / ES\%_{BC}$ and $score_{CC} = CS\%_{ei}$; a and b are the weighting factors; *ES%* is energy saving and *CS%* is computation saving; *EC* is energy consumption and *CC* is computation consumption; *BC* is the base case; ei is the event i;