Model Predictive Control for Intelligent Building Energy Management

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Abstract

The building sector consumes over 30%, with an annual growth rate of 1.3%, of global final energy and is responsible for nearly 40% of global carbon emissions. Building energy efficiency harbours enormous potential as a major contributor to global carbon footprint reduction and urban sustainability. In this context, World Green Building Council announced the Net Zero Carbon Buildings Commitment of achieving net zero carbon operation for buildings under their control by 2030 and all buildings by 2050. Advances in building energy management systems (BEMS) offer significant potential to improve building energy efficiency and occupant well-being. Current BEMS are mostly based on reactive control (e.g., proportional–integral–derivative control), which lacks the level of intelligence needed to handle challenges such as increasing demand for occupant's well-being and the proliferous adoption of multiple energy systems (e.g., renewable energy and energy storage) in buildings. Empowered by the increased connectivity and access to diverse data in buildings brought by emerging digital technologies (e.g., internet of things (IoT), wireless communication network and cloud/edge computing), adopting more sophisticated building energy management solutions is expected to be a major path to achieve building energy efficiency and carbon footprint reduction goals. Model predictive control (MPC) and data-driven approaches (e.g., machine learning (ML)) are widely identified as key technology enablers e.g., International Energy Agency (IEA) through its global initiatives of IEA-EBC Annex 67 Energy Flexible Buildings and Annex 81 Data-Driven Smart Buildings. This talk presents our research work on the development and application of MPC as well as ML-based MPC for building energy management. The key feature of MPC is that it exploits a predictive building model for predicting future building states and, subsequently, performing optimal controls based on the predictions. We proposed a multi-objective MPC scheme for coordinated control of multiple building services (air-conditioning, dimmable lighting and automated shading). The multi-objective MPC can optimize these multiple building services simultaneously and achieve the overall optimum of energy efficiency and human comfort in buildings. To further enhance the adaptability of MPC for building energy management applications, we proposed two novel MPC schemes incorporating ML, i.e., adaptive ML-based MPC and ML-based approximate MPC. The key feature of adaptive ML-based MPC is that it employs an adaptive ML-based model as the predictive building model. The ML-based approximate MPC employs a ML model to approximate the control laws of MPC, then, uses the ML model to replace MPC for building control. The control-oriented building modelling, optimization formulation, control implementation in real buildings (a lecture theatre, an office and laboratory test facility) as well as experimental results of the three proposed MPC schemes will be presented and discussed. Finally, open problems and our ongoing/future research efforts are discussed.

Keywords: *Model Predictive Control, Building Energy Management, Machine Learning, Energy Efficiency*

Short biography

Dr. Wan is currently an Associate Professor in the School of Mechanical & Aerospace Engineering at Nanyang Technological University. Prior to joining NTU, he was an Assistant Professor of Mechanical Engineering at Kyungpook National University, Korea. His research interests cover aerosol sciences, building energy, smart buildings, indoor environmental quality, catalytic oxidation systems and numerical simulations. Dr. Wan led numerous government- and industry-funded research projects ranging from fundamental studies of fundamental thermos-fluids sciences, aerosol sciences and impacts of indoor environmental quality on occupant cognitive function. He has also been working on development of novel green building technologies such as high-performance Cool materials for buildings and pavements, advanced building control and automation systems, integrated dimmable lighting and dynamic shading system, chilled ceiling system and other technologies for energy efficiency and occupant well-being. Dr. Wan has published over 100 international refereed journal and conference articles and is inventor of 3 patents. He is a member of American Society of Mechanical Engineers (ASME), American Chemical Society (ACS) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

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