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A Digital Twin Approach to Support Real-time Situational Awareness and Intelligent Cyber-physical Control in Energy Smart Buildings

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Abstract : Emerging smart buildings often employ cyberinfrastructure, cyber-physical systems, and Internet of Things (IoT) technologies to increase the automation and responsiveness of building operations for better energy efficiency and lower carbon emission. These operations include the control of Heating, Ventilation, and Air Conditioning (HVAC) and lighting systems, which are often considered a major source of energy consumption in both commercial and residential buildings. Developing energy-saving control models for optimizing HVAC operations usually requires the collection of high-quality instrumental data from iterations of in-situ building experiments, which can be time-consuming and labor-intensive. This abstract describes a digital twin approach to automate building energy experiments for optimizing HVAC operations through the design and development of an adaptive web-based platform. The platform is created to enable (a) automated data acquisition from a variety of IoT-connected HVAC instruments, (b) real-time situational awareness through domain-based visualizations, (c) adaption of HVAC optimization algorithms based on experimental data, (d) sharing of experimental data and model predictive controls through web services, and (e) cyber-physical control of individual instruments in the HVAC system using outputs from different optimization algorithms. Through the digital twin approach, we aim to replicate a real-world building and its HVAC systems in an online computing environment to automate the development of building-specific model predictive controls and collaborative experiments in buildings located in different climate zones in the United States. We present two case studies to demonstrate our platform's capability for real-time situational awareness and cyber-physical control of the HVAC in the flexible research platforms within the Oak Ridge National Laboratory (ORNL) main campus. Our platform is developed using adaptive and flexible architecture design, rendering the platform generalizable and extendable to support HVAC optimization experiments in different types of buildings across the nation.

Keywords : energy-saving buildings, digital twins, HVAC, cyber-physical system, BIM
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