Towards a Big Data-enabled Virtual Experimentation Framework for Sustainability-Oriented, Large-scale Infrastructure Planning

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ABSTRACT

Big data and data analytics have been prominent methods for addressing key technical challenges in real time monitoring, operations planning and lifecycle design of large scale systems. Sensor technology and flexible data acquisition and storage have offered unprecedented levels of (often time-stamped) data availability. Besides use of Big Data analytics in finance, sales and marketing, engineering applications such as large scale infrastructure, energy and environmental planning have been leveraging Big Data solutions to the fullest. Big Data applications in infrastructure planning are targeting key objectives, such as system-level energy efficiency, continuity and quality of service, flexible resource allocation, to allow for better energy management and eventually inform and drive the development of more sustainable, energy-conscious, reliable, flexible and resilient environments.

In this work, use of Big Data and data analytics techniques is presented for a university campus use case. The primary mission is to leverage large amounts and varieties of data in order to support situational awareness through real-time campus operations monitoring and energy usage. However, building instrumentation, as well as sensor operability and measurement accuracy is not uniform across campus, hence source data must undergo through additional cleaning, filtering, sorting and overall validation processing. Data non-availability, or total lack of, is another major obstacle, which has led to exploration of physics-based modeling techniques to support simulation of system behavior during intervals of unknown performance. Eventually, this study has proven successful in yielding a multi-scale integrated campus-level environment, thus extending beyond standard data-driven performance monitoring towards a virtual experimentation framework, with simulation-based predictive capabilities for System-of-Systems (SoS) level, sustainability-oriented infrastructure planning.

FORESIGHT, is a substantiation of this framework in the form of an interactive campus data browser for both real-time data stream visual analytics, and predictive analytics for campus energy performance forecasting. Predictive modeling functions are implemented through a combination of parametric data-driven and physic-based modeling and simulation approaches. Models of buildings, plants, modes of transportation, and energy delivery networks have been implemented and can respond to parametric variation of internal and external factors, e.g. weather change, shift in consumer behavior, or unexpected ruptures and service discontinuities. Data availability, both historic and real-time has allowed for a more accurate modeling of consumer behavior such as demand for electricity or cooling loads, through use of State-of-the-Art machine learning techniques. Experience and lessons learned from recent Big Data initiatives in large-scale manufacturing applications, has allowed for further extending the current capabilities in data filtering, machine learning and data-driven forecasting. With development and demonstration of Big Data-driven methods for the implementation of a virtual energy campus, the outlook is to extend the boundaries of the energy infrastructure, both horizontally to the district or city levels, and vertically to further include additional energy and resource layers, such as water and waste management, EV support networks and cybersecurity.

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