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Editorial

Sensing and Data-Driven Control for Smart Building and Smart City Systems

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The emergence of dense networked embedded sensor systems in monitoring and control applications has enabled the collection of data, information processing, decision, and actuation at previously unseen temporal and spatial resolution and scale. The built environment offers significant opportunities and challenges for the application of such intelligent sensor systems with tangible economic, environmental, and social benefits. Buildings in particular, as hallmark of global urbanisation tendencies, have great potential to leverage modern technologies to operate more efficiently and provide better living and working conditions. This addresses, among others, aspects related to energy management, occupancy detection and prediction, safety, and security. At a larger scale, smart city infrastructures are able to implement these advances towards wider benefits in environmental monitoring, traffic management, improved utilities networks, and social services. Design of human-in-the-loop approaches offers citizens valuable direct feedback mechanisms towards the intelligent systems and administrators for real-time adaptation and responsiveness with medium term impact on suitable policy development.

The special issue aimed to collect contributions covering the state of the art and recent advances in this area, addressing both theoretical and applied implemented approaches for both scientific and technical impact. Potential topics that were initially defined include but were not limited to the following: intelligent sensors in smart building applications, for example, environmental, occupancy detection and activity tracking, air quality, safety, and energy efficiency, adaptive and distributed sensing strategies including virtual sensors, large scale monitoring systems for data collection through wireless sensor networks, data management and computational intelligence approaches for knowledge extraction from raw sensor streams, data-driven methods for modelling, simulation, and control of smart building and smart city systems, open hardware and software architectures to support complex sensor systems integration, bridging heterogeneity, and proprietary systems through standardisation. New sensing, computing, and control paradigms were also accounted for, such as cyberphysical systems (CPS), Industry 4.0, and multiagent systems (MAS).

Ten articles were finally accepted after a thorough review process out of 25 submissions. In total, 38 authors from eight countries contributed to the successful outcome of the special issue. The accepted articles can be broadly grouped in clusters, which identify key current areas of research in line with the special issue topics:

(i) Wireless sensor networks, including communication aspects

(ii) Smart building modelling through sensor systems

(iii) Machine learning algorithms for knowledge extraction from data

(iv) IT infrastructure to efficiently support intensive and persistent sensing data flows.

The accepted papers are briefly introduced next.

In the article titled "Design of a Smart Sensor Network System for Real-Time Air Quality Monitoring on Green Roof" by Z. Zhao et al., the authors present the design and evaluation of an embedded sensor node for PM2.5, wind speed, temperature, and relative humidity monitoring in urban environments. The device provides Wi-Fi radio connectivity and supports the cloud-ready MQTT protocol for relaying the collected information to a dedicated server application. The low-power and low-cost design shows promise for ubiquitous deployment to mitigate air pollution hotspots through increased awareness.

The paper titled "A Novel Non-Line-of-Sight Indoor Localization Method for Wireless Sensor Networks" by Y. Wang et al. approaches the important challenge of non-line-of-sight (NLOS) localization in harsh radio environments such as indoor spaces, where channel attenuation due to various obstacles and persons, multipath propagation, and other radio effects can occur. For positioning a node in relation to a set of known anchors, the time of arrival (ToA) is used along with residual analysis method in order to carry out NLOS localization. For unknown node positioning, an optimisation problem is defined based on the LOS measurements and solved by means of the particle swarm optimisation with a constriction factor (PSO-C) method. The technique yields an improvement between 20 and 33% over other literature techniques on a custom testbed.

A low-energy-consumption distributed fault detection mechanism (LEFD) is introduced in "Fault Detection Modelling and Analysis in a Wireless Sensor Network" by S. Jia et al. The authors argue that through a two-stage algorithm network congestion and energy consumption are reduced. This exploits the time correlation information in the first stage to detect faulty nodes and spatial correlation in the second stage. Performance evaluation is defined in terms of detection accuracy (DA) and false-positive ratio (FPR), illustrated over various simulation scenarios in the NS2 software.

An in-depth scalability test of low-power and long-range radio technology for future sensor networks is performed in "LoRa (Long-Range) High-Density Sensors for Internet of Things" by A. Lavric. LoRa/LoRaWAN technology represents a key technology for enabling high-density distributed sensing for various smart city functions, whether environmental monitoring, traffic management, or security applications. The presented simulation results lead to a maximisation of the total number of nodes in a network with proper selection of the network and communication parameters in terms of packet payload size, the duty circle parameter, and the spreading factor.

The paper titled "Measuring Occupants' Behaviour for Buildings' Dynamic Cosimulation" by F. Naspi et al. carries out an in-depth experimental study for measurement and modelling of human behaviour in buildings, important for improving the control strategies of the building HVAC and lighting subsystems. Two stochastic and data-driven behavioural models, one for predicting light switching and one for window opening, are developed and deployed to the IESVE simulation software. The main results point to a reduction of the discrepancy with respect to real profiles up to 58% and 26% when simulating light switching and ventilation, respectively, in comparison to standard profiles by means of the adoption of behavioural profiles.

A method for data fusion between direct sensor readings and contextual information and domain knowledge is presented in the paper titled "Estimating Occupancy from Measurements and Knowledge Using Bayesian Network for Energy Management" by M. Amayri et al. The application for improved HVAC control of unoccupied or underoccupied smart buildings is developed through an unsupervised learning method with Bayesian Networks. The reported results highlight that the energy efficiency can be increased by roughly 5% over known optimal control techniques and more than 25% over rule-based control while maintaining the same occupant comfort.

The paper titled "Data-Driven Modelling of Smart Building Ventilation Subsystem" by G. Stamatescu et al. focuses on illustrating a black-box data-driven approach to model the air handling units, integral parts of the modern HVAC systems found in smart buildings. The authors use Support Vector Machines (SVM) to characterise individual units and indirectly quantify operational modi, occupancy, and usage patterns for targeted building areas. A case study is performed on a reference university building with one year of collected data: temperature sensor readings, outdoor weather, and time-relevant features. This represents one step towards a general approach for handling the large diversity in building characteristics which currently needs time-consuming complex modelling methods limiting the applicability of advanced online control strategies.

The paper titled "Evolutionary Multilabel Feature Selection using Promising Feature Subset Generation" by J. Lee et al. is focused on a machine learning strategy to extract knowledge from the large quantities of data being generated continuously by modern sensor systems, including those in smart buildings and smart cities. The main contribution refers to a multilabel feature selection method that can improve learning accuracy under constrained resources. This works by iteratively creating feature subset candidates and filtering them by means of a computed score value. Results achieved over testing on 14 reference datasets show improvements over conventional feature selection methods such as genetic algorithms (GA) and multiobjective particle swarm optimization feature selection (MPSOFS) in terms of several metrics: multilabel accuracy, hamming loss, ranking loss, and normalized coverage.

The paper titled "Traffic Flow Prediction during the Holidays Based on DFT and SVR" by X. Luo et al. presents an application of machine learning techniques with impact to smart city traffic flow estimation and management. The specific case of holiday traffic is handled by traffic features extraction by means of the Discrete Fourier Transform (DFT), which are then input to a learning algorithm based on Support Vector Regression (SVR). Experimental data is used in the form of traffic values from a Chinese city on two holidays for the interval 2011-2015. The proposed method improved traffic prediction by values between 4% and 17% with regard to baseline methods, while improving the robustness to stochastic traffic flow data.

"Management of IoT Sensor Data Using a Fog Computing Node" by G. Yoon et al. describes a new system architecture and IT platform for integrating distributed sensors into the fog computing paradigm. The article presents the design of the sensor node and touches on key issues such as data processing closer to the source and suitable aggregation primitives, standardised communication protocol integration, and software interoperability. Experimental results prove a consistent network traffic reduction between the node and the server, while the reported values are mapped and checked against predetermined typical sensing patterns.

Conflicts of Interest

The editors declare that they have no conflicts of interest regarding the publication of this special issue.

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