Guest Editorial Special Section on Building Automation, Smart Homes, and Communities

I. Introduction

INFORMATION TECHNOLOGY (IT) penetrates virtually all aspects of our lives. It integrates processes that are normally disconnected. With the help of IT, it is possible to link the operation of factories and combined heat and power stations with energy markets, weather forecasts and public transport schedules in order to reach an optimum for the respective energy grids. Building Automation, Control and Management Systems (BACS) are a prominent representative of this discipline. Forty percent of the energy consumption in developed economies stems from buildings [1], making BACS a perfect candidate for climate and carbon measures. By for instance accessing internal facilities like heating, ventilation and air conditioning and linking it to enhancing information like room bookings or weather forecasts, building automation can substantially contribute to the efficient operation of the building. Beside a pure efficiency impact by running equipment in their optimal points of operation, it is often the understanding of the underlying processes that enables energy efficiency measures like customer feedback/involvement or optimized scheduling and dispatch of energy-relevant resources like heating/cooling or ventilation.

Besides this popular and dominating benefit in energy usage, BACS can improve health parameters, comfort, safety and building security. Key issues are interoperability, sustainability, and availability. Interoperability enables multivendor installations and secures investments for the customer. Being able to replace components of manufacturer A with something from manufacturer B only works if open standards are used. Sustainability means that technology in buildings is expected to work for decades, which is a special challenge for information technology and its fast innovation rates. Availability addresses the fact that infrastructure that directly interacts with buildings just has to work. Nobody has interest in blind controls or automatic doors that do not behave as expected.

This Special Section of the IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS covers a number of brand new aspects of building automation and control networks and their applications. Beside the fundamental, technological aspects of communication services, packet transport, networking, and higher layer services, it is also the applications that are discussed here. While distributed and open BACS that are in use today were designed in the 1980s, it is especially the new influence of computer sciences like self-organization, semantic descriptions, and information security that constitute the new areas of development. As BACS link the cyberworld with the physical one, they are subject to careful but important development. This issue presents selected aspects of modern and future BACS and shall serve as inspiration and reference for further development.

Digital Object Identifier 10.1109/TII.2013.2281939

II. Summary of Papers

A. Signage System for the Navigation of Autonomous Robots in Indoor Environments

This paper [2] presents an RFID-based signage system which guides and gives important information to an autonomous robot. The robot is expected to use the signage system in a natural way as humans do during the way-finding process. A navigation algorithm is also presented to specify the searching process of the signals and their interpretation.

The signage system has been implemented in a real indoor environment and the navigation algorithm has been successfully proved in the autonomous and social robot Maggie. The experiments were carried out on the third floor of a building. It has been proved that signals are a great support for autonomous robot navigation, when they do not have a previous knowledge of the environment.

Unlike other related works, the designed system is able to complement topological with geometric information. Moreover, it does not required previous topological maps. The robot can use the signals to guide itself and, in case of getting lost or not reading a signal, the robot can keep navigating using other signals to orientate itself again. This work represents a base for possible applications in "smart homes." This technology could be applied not only for improving the people's quality of life, but also, for facilitating the navigation of the robots which assist them at home.

B. Using Time-of-Flight Measurements for Privacy-Preserving Tracking in a Smart Room

In this paper [3], the authors described a method for real-time person tracking and pose estimation in smart rooms based on the time-of-flight (ToF) camera technology. While there have been significant advances in the computer vision research community in detecting human presence and classifying human activity from video, occupants would no doubt be unsettled by the impression that their room was "watching them." This paper proposed to use ceiling-mounted single-pixel range sensors to estimate human occupancy and pose in real time. The idea is to mount a sparse array of single-pixel range sensors on the ceiling of a room, which can detect the height of any object under them.

The authors describe algorithms for tracking humans, disambiguating humans from furniture, and coarse pose estimation, and analyze how the algorithms' performance degrades as a function of element spacing. The ToF images are severely down-sampled to preserve the privacy of the occupants. The tracking algorithms use grayscale morphological image reconstruction to avoid false detections, and are designed not to mistakenly detect pieces of moving furniture as people. Robust pose classification is achieved by using a maximum-likelihood estimation method that is based on a simple Markov model. Both real-world experiments and environmental simulation have been conducted to validate the proposed algorithms. It has been show that the algorithms work effectively even when the sensors are spaced apart by 25 cm.

C. Profile-Based Control for Central Domestic Hot Water Distribution

A main goal of hot water distribution research is to improve system's efficiency, i.e., to fulfill hot water requirements minimizing energy and water losses. In this paper [4], the authors presented a novel control strategy based on habit profiles for the management of central domestic hot water (CDHW) systems. The advantages of habit profiles to improve CDHW control are checked, the benefits of profiling methodologies for the overall management of buildings are investigated, and the exploitation of buildings' energy information for more realistic use rates and simultaneity coefficients is covered.

The proposed strategy is implemented in a simulated environment. The deployed database contains hourly information of DHW consumption of more than 700 dwellings, distributed in 8 multifamily buildings or housing developments, from 2002 to 2007 in the Basque Country (Spain). It has been shown that the best balances among comfort, water waste and energy consumption are reached by temperature control, demand recirculation and the proposed profile-based strategies. Temperature control results in a general, satisfactory solution, but ignores the unbalanced behavior of the demand within the network. On the other hand, demand recirculation reaches the best figures, but provided the fact that users inform previously of consumption intentions and are forced to wait a prefixed time. The profile-based strategy avoids such drawback and still achieves an excellent performance, very close to the demand recirculation rates.

D. Methodology to Find Influential Members in Prosumer Community Groups

This paper [5] raises a new idea to analyze the potential social network, or the prosumer community groups in the advanced power system. In particular, it addresses the problems of prosumer assessment and ranking, i.e., finding the influential members in the community group. The paper proposes a few criteria such as prosumers' ability to generate more energy, historic energy profile, and energy sharing with other members. The paper also designs the simulation to verify this methodology. In their simulation, four criteria are used including criterion A where the ranking points are proportional to the energy shortage computed from 50 kWh, criterion B where the ranking points are proportional to the excessive energy computed from 50 kWh, criterion C where members not meeting 50 kWh can buy energy from others until they reach 50 kWh energy boundary, and criterion D where it adds iterative nature to the final ranking points of a member. These simulations with those criteria demonstrate the effectiveness of the technique.

E. AWNIS: Energy-Efficient Adaptive Wireless Network Interface Selection for Industrial Mobile Devices

This paper [6] presents a new adaptive method for energy efficient wireless network interface selection control. This is important since most mobile devices have multiple wireless network interfaces and data transfer in wireless communications consumes significant amount of energy. In addition, communication environment change issues due to, e.g., noise, distortion in the transceiver circuit of strong motors and static frequency changers need to be considered. The paper uses a dynamic network interface selection interval to connect to energy-efficient Wi-Fi based on the analysis of energy consumption and delay of the mobile device through mathematical modeling. This is a quite interesting and practical topic. The simulation results demonstrate that the proposed scheme improves the energy efficiency with the guarantee on data transfer delay.

F. Semantic-Based Resource Discovery and Orchestration in Home and Building Automation: A Multi-Agent Approach

This paper [7] proposes an interesting distributed multi-agent framework for home and building automation, which targets to autonomously coordinate and control appliances and subsystems in some environment. The paper designs a multi-agent framework based on a semantic enhancement of EIB/KNX standard. It uses the knowledge representation and automated reasoning technologies such as the discovery and orchestration of resources in common domotic solutions. It also allows the negotiation among the most suitable home services based on the user needs and device driven interactions. A case study using a power management problem demonstrate the effectiveness of the proposed technique.

G. On the Discourse of Energy as Material: Future Feedback Technologies and Directions for Experiencing Energy

This paper [8] presents a survey to discuss the users' feedbacks for smart meters. The authors analyze the real-time residential energy feedback displays and examine how users experience such technologies through analyzing and summarizing the mid-term and long-term survey conducted in practice. With their responses, the users give statements about their use of technology in their everyday routine as well as in utilizing the devices in ways they actually were not intended to. Such kind of data can be used to conduct additional discourses with newly defined questions as well as rethink the usage of feedback devices for end users. The qualitative data from the survey help find the impact of the social variables of user interaction with real-time feedback.

H. Semantic Context-Aware Service Composition for Building Automation System

In this paper [9], the authors present a design of the Service-Oriented Architecture (SOA) based Building Automation System (BAS), which brings web technologies into building automation. SOA provides independent, standardized and self

describing services which is a desired base for automatic, dynamic, and self configuring distributed systems for BAS. The paper integrates the web service, SOA and semantic web into BAS to dynamically coordinate devices/services in accordance with the context. To validate the scheme, a prototype system is developed to illustrate and test the effectiveness and efficiency of the proposed technique. Future work will focus among others on integrating energy saving services into the BAS to take advantage of intelligent user behavior.

III. Summary and Conclusion

This Special Section of the IEEE Transactions on Industrial Informatics focuses on brand new aspects in the area of building automation and energy savings in and with buildings. The papers cover a broad range of applications, including:

- Context and user awareness, user interaction, and surveillance.
- Ambient Assisted Living and Smart Homes.
- Simulation.
- Smart energy management in buildings.
- Complex control applications.
- Building network aspects.
- Dependability of building automation systems.
- Software aspects.
- Distributed sensor networks.
- Communication protocols.
- Case studies.

The presented papers show the growing-together of more and more previously distributed areas of research with a particular focus on energy saving and integrating the user. User behavior is no more seen as something like an unpredictable source of disturbance of well-balanced processes, but methods are developed that allow creating models of user behavior [3] and interaction as well as anticipation thereof. Moreover, user behavior becomes a valuable information source in terms of smart reactions, which can be seen in [5] and [8]. On this base, similar developments can be discussed on large scales, i.e., the city level. Another development related to the user of a BAS is that of household robots. In the future home, a butler-type robot will be in charge of many housekeeping tasks. However, the road to this future is still long and paved with topics like indoor navigation [2]. Finally, hurdles in installation and maintenance hinder the spreading of BAS to end users. Methods for easier management and commissioning of the system are presented in [7] and [9], introducing software-based approaches. Both papers also target energy saving applications, while [4] focuses on the energy application (in this case hot water distribution), and uses user profiles as additional input source. Finally, [6] presents an even more energy saving-oriented application in the area of wireless communication, however, also needs user input in order to select among appropriate links.

As a conclusion it can be noted that research in building automation today almost always includes aspects of energy usage, distribution, and savings as well as user models. Additionally, the software architecture of a modern BAS becomes ever more important. Thus, interdisciplinary approaches and multidisciplinary teams are required to work out new solutions, as the research area of building automation keeps growing.

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