Poster Abstract: Towards a Categorization Framework for Occupancy Sensing Systems

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Poster Abstract: Towards a Categorization Framework for Occupancy Sensing Systems

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ABSTRACT

A large share of the energy consumption of buildings is driven by occupancy behavior. Means to minimize this share of consumption depend upon accurate information about occupant behavior. Therefore, it is important to improve sensing systems for gathering such information. However, as research on occupancy sensing systems goes beyond *basic methods*, there is an increasing need for better comparison of proposed occupancy sensing systems. Developers of occupancy sensing systems are also lacking good frameworks for understanding different options when building occupancy sensing systems. This poster abstract motivates the need for working towards a better categorization framework to address both of these problems. For researchers, the categorization framework is also an aid when scoping out future research in the area of occupancy sensing systems.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous

1. INTRODUCTION

Improving the energy performance of buildings is an important goal towards realizing a more sustainable society. An important challenge for improving the energy performance is the impact of occupancy behavior [4]. Occupancy behavior here refers to *all actions of occupants (including presence) that affect building energy consumption* [2]. Occupancy behavior affects both individual equipment in buildings and building-wide infrastructures. Three scenarios have been established towards addressing the impact of occupancy behavior: A) replace equipment and infrastructures in buildings with more efficient ones resulting into less energy consumption while maintaining the occupancy behavior, B) involve occupants in changing their behaviors towards less energy consuming behaviors, and C) improve the intelligence of equipment and infrastructures to better adapt to occupancy behavior to only spend energy for providing the needed utility and comfort to occupants. In all three cases it is important to gather quantitative information about occupants behavior to document savings related to occupancy behavior in case A, to provide feedback to support behavior change in case B and to use occupancy behavior to optimize control in case C.

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To gather occupancy information, a wide range of occupancy sensing systems have been proposed, developed and commercialized. Here, we define occupancy behavior sensing systems as sensing systems that measure, estimate, model and predict occupancy behavior based on inputs from sensing infrastructures. Examples include systems for presence detection using PIR sensors, visual, stereo and thermal camera-based systems for people counting and systems based on sensor-instrumented spaces to recognize activities of individuals. Development of occupancy sensing systems has also been supported by developments in related areas, including, among others, the areas of location tracking, pervasive computing and sensor networks. These areas together have established many different forms of occupancy sensing systems. When surveying occupancy sensing systems, one has to answer a number of different questions. How do systems differ in types of occupancy information provided? What is the relationship between the system and occupants? What is the spatial and temporal coverage; do the system allow for prediction of future occupancy situations? What types of sensor strategies are applied for monitoring and data gathering; is the environment, objects or persons augmented? What types of modeling strategies are utilized? These questions are not only important for researchers surveying occupancy sensing systems, but also developers of occupancy sensing systems who have to understand different design options. We believe that a categorization framework will aid developers and researchers to better survey, compare, and design occupancy sensing systems. Being able to better survey and compare existing work also makes it possible to use the categorization framework as a reference when scoping out future research. This is especially important as research more and more moves from understanding basic mechanisms to combining different sensor strategies and modalities to provide information on complex behavioral patterns of occupants. Existing surveys on occupancy sensing systems [4, 3] have so far not presented a comprehensive categorization framework for the area.

2. TOWARDS A FRAMEWORK

In this poster abstract we motivate the need for developing a categorization framework for occupancy sensing sys-

tems. In order to put this in context through documentation, we are currently conducting a comprehensive literature survey of existing work on occupancy sensing systems taking into account various features and characteristics. Our initial categorization framework is based on nine categories. These were partly inspired by earlier work on surveys on occupancy behavior in general, and from our literature study. The literature study is conducted by searching for key terms in relevant journals and conferences of the area. The categories of our initial framework are as follows: *Information Type* describes types of occupancy information. *Occupant relation* describes the relationship between the system and occupants. *Spatial granularity and temporal granularity* provides a characterization of resolution of occupancy information. *Spatial coverage and temporal coverage* provides a characterization of the spatial and temporal extent of coverage. *Sensing strategy and sensing modality* describe how sensors are applied and the types of sensor modalities. *Modeling strategy* describes how models of occupant behavior are used to clean, combine, estimate and predict occupancy information from sensor measurements.

Earlier surveys have only considered a subset of these dimensions. Christensen et al. [3] discuss the three dimensions *occupancy resolution, temporal resolution and spatial resolution* mapping to our dimensions *information type, spatial granularity and temporal granularity*, respectively. Nguyen et al. [4] introduce the dimensions of *Activities, technologies and methodologies* that maps to our dimensions *information type combined with temporal coverage, sensing modality and modeling strategy*, respectively. In this work we do not consider the type of building, e.g. , residential, commercial, public or industrial buildings, that a system is used in. However, system goals including privacy protection, needed maintenance, acceptable cost of cause differ among different building types.

We are developing the categorization framework including both subcategories and categorization of systems in parallel. In regards to the outlined nine categories, one can for example categorize two existing occupancy sensing systems as follows:

Agarwal et al. [1] propose a system for detecting the *information type* of occupancy *presence-boolean* with a *system relationship* that is *anonymous*. The system has a *spatial granularity* of *spaces* corresponding to rooms and an *event-based temporal granularity*. The system's *spatial coverage* is spaces considered as individual rooms and the *temporal covarage* is the *now*. The system applies the *sensor modalities* of *Infrared Light-PIR* and *Magnetic Fields-REED Switch* using the *sensing strategy* of *augmenting the environment*. The system apply the *modeling strategy* of conditional rules to model the relationship between sensor input and occupancy information.

Ruiz et al. [5] propose a system for detecting the *information type* of occupancy *presence-counts* with a *system relationship* that is *anonymous*. The system has a *spatial granularity* of *spaces* mapping to zones of interest and an *event-based temporal granularity*. The system's *spatial coverage* is at the *building* level and the *temporal covarage* is the *now* or the *past*. The system applies the *sensor modality* of *EM Waves-Radio-based Communication* using the *sensing strategy* of *repurpose infrastructure*. The system apply the *modeling strategy* of machine learning to compute the occupancy information.

As illustrated above, with a categorization framework we can start to analyze existing work. Such analysis can help scope out future research by mapping the coverage of system design choices. The analysis can for instance be preformed by grouping systems by their design choices and by providing statistics calculated from the categorizations.

3. CONCLUSIONS

In this poster abstract we have argued for the need to develop a comprehensive categorization framework for occupancy sensing systems. We are currently developing the framework based on an extensive literature study. By publishing this poster abstract we hope to gather initial feedback from the community in regards to the development of the categorization framework. Valuable categorization frameworks can account for everything that is known so far and they can predict things to come based on future scenarios, as variations of parameters accounted for and enumerated in the framework. A categorization framework first and foremost shows both depth and breadth of our understanding of the field of research. We would like others to join and, based on inputs from the community, further improve the proposed categorization framework.

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