Placing information at home: Using room context in domestic design

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Abstract
Residential and commercial buildings are responsible for about 40% of the EU's total energy consumption [2]. With current consumption feedback systems, dwellers have the opportunity to get disaggregated real-time energy feedback about their consumption. However, there is often an absence of additional context information, so that the user is not able to derive energy efficient behavior from their energy data. Against this background, this study presents a concept, where indoor-positioning data on room level are used to contextualize energy data. This makes it possible to expend visualizations of current consumption feedback systems and develop new kind of user-interfaces that support everyday-activities.

Author Keywords
consumption feedback; eco-feedback; context-awareness; home energy management system; hems; indoor-positioning

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Current smart metering technologies allow fine-grained data collection, but with increasing volumes of data, its

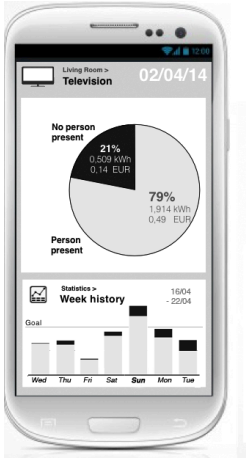

Figure 1. Using room-context information to enrich eco-feedback visualization

Figure 2. Using room-context information to simplify home controls

visualization is gaining complexity. Therefore, current research focuses on how to make feedback more informative and action oriented. Concerning this, context aware feedback is discussed as a promising approach. For instance, Costanza et al. [1] present an interactive feedback system, where users could tag their context directly within their consumption feedback. Neustaedter et al. [5] use data from the personal calendars to contextualize the consumption data of the users. Also, people's location at home helps to contextualize and individualize the feedback. Jahn et al. [4] e.g. use the users position to present eco-information for the devices at hand. Guo et al. [3] use an active user treatment approach with an RFID based check-in/check-out, to get the position of a user and personalize the consumption data with it.

Room as a context information

This study presents the concept of *room* as a context information. Rooms play an important role to structure domestic routines and domestic energy consumption. For instance, lights should be switched off, when leaving the room, radiators are typically controlled on a room level, etc.

From this backdrop various design studies were developed that illustrate how room information could be used to enrich the provided feedback and to contextualize the user interfaces of mobile home energy management systems (mHEMS).

Making eco-feedback more meaningful

In particular, one question was, how room context information could be used to improve state of the art eco-feedback visualizations (like real-time, historical, comparative, aggregated, disaggregated or normative feedback). Therefore, it can be distinguished between four non-exhausted, visualization categories where room-context information could help to make feedback more meaningful for the user:

- Analytic charts identifying spenders in the home
- Time series consumption graphs enriched by dwellers' presence information
- Person and domestic activity centered consumption visualization
- Domestic scoreboard systems

Schwartz et al. [6] have demonstrated that dwellers distinguish between the consumption of background services (typically always-on devices like the refrigerator and freezer) and activity related consumption (like watching TV, light for reading, etc.). This distinction is also used to define consumption as waste. Generally, activity based consumption is closely related to a person's presence. Therefore, the actual place of habitants of a home is a strong indicator for energy being wasted (e.g. light in a room where no one is present is a waste of energy). The room context information could therefore be used to identify spenders, which are defined as potential energy wasters. Analytic charts on device level make such spenders visible. For example, the device level chart in Figure 1 shows that 21% are potentially spending by splitting the overall consumption into consumption with presence and without. Such graphs help users to control their habit of switching devices off when not needed.

Further presence information could be used to enrich time series consumption graphs in various ways. For

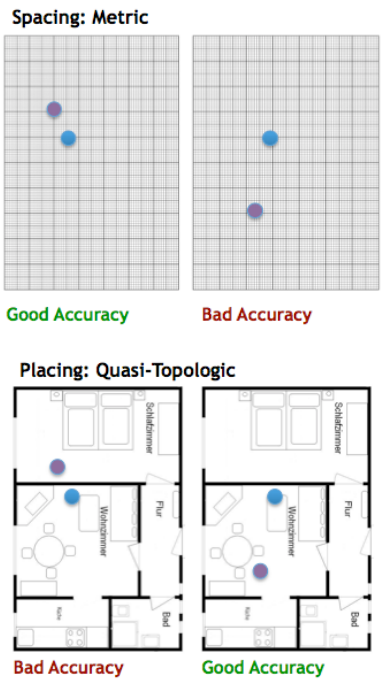

Figure 3. Difference between "space-oriented" and "place-oriented" localization

instance, historic feedback graphs commonly show a curve of the device's consumption in a daily, weekly or monthly range. Such graphs on a room level could be added by the peoples' presence time in that room (e.g. assign a color to each dweller and coloring the graph's background accordingly for the time the person was in the room). Such graphs may make it easier for the dwellers to identify consumption patterns and match them with their own behavior. The third improvement reverses the previous visualizations showing the consumption of actual person's immediate environment over the time. This person-centered visualization in combination with the previous one allows gaining new insights and surprising facts about one's own domestic energy practices. Finally, the room-context information could be used to define new indicators for domestic scoreboard systems like average room temperature when people are present and non-present. Further, this information could be used to personalize recommendations, tips or statistics.

Simplify smart home controls

In a further step the second question was, how the room context information could be used to adapt home control panels. Here, two categories where room-context helps to reduce the panel complexity and to nudge people to switch off spenders are identified:

- Adapt the control panel to the devices of the actual room
- Make aware about spenders outside the room

A current problem of touch control panels are the large number of switching options that can lead to a cluttered design. Architectures solve, for example, the problem of complex control panels by making use of rooms as a domestic order system: *A room only includes the controls for the room*. This is a smart choice as most people are often interested in controlling activity-related devices, which typically are in the persons current surrounding. The room context information helps to adopt this strategy by showing only the controls of the actual room on the user interface. This radically simplifies the complexity of home control panels.

Exceptions are devices outside the room that were not switched off for laziness so that they still consumes energy. To nudge people to switch off these devices, the control panel should make aware about these spending devices as well. Figure 2 presents an approach for this demand, where the control panel is split into two sections:
The top section shows the controls in the actual room. The bottom section shows the detected spenders outside the room. Focusing on the controls that are important in that context, the panel is more structured and the number of switching options is greatly reduced.

Spaces and places at home

On the technical level, especially, low-cost solutions, which do not require an active treatment by the user and provide an historic data storage, are rarely in this topic. The approach in this study reduces cost and installation effort by re-using existing domestic IT infrastructures, assuming that most people have smartphones and that several WiFi signals are typically receivable in apartment buildings. This allows a system to locate the user's actual room in a heuristic manner by adapting existing approaches of WiFi-fingerprinting for indoor positioning. Yet the major difference between localization is that they are *space oriented*, thus relying

on metric error measures defined by the distance between the actual and the estimated position (see Figure 3). In opposite, the room localization is *place oriented,* relying on a quasi-topologic error measure defined by the ratio whether the actual room is estimated correctly or not. In addition, the solution implemented in the prototype has a user interface that empowers non-expert users to conduct the needed training process of the algorithm and adjust them in case the signal infrastructure is changing.

Outlook

A fully functional prototype was developed for android-based tablets to study the design concepts. This prototype uses a WiFi-fingerprinting method to collect room-based indoor-positioning data to enrich disaggregated information about the energy consumption. Within this prototype the context-aware control panel and some of the described visualization categories were implemented. The correctness of our localization algorithm and the user friendliness of our training process solution were technically evaluated. In addition, interviews and workshops are made with users about the perceived usefulness, shortcomings of the design concept and how the concept should be realized. The first results are quite promising that room-context aware systems are a step forward to a more meaningful eco-feedback. In a next step the system should be examined in the wild and the further development of the system should be made with the dwellers in the Living Labs within a participatory approach.

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