Recommending and Configuring Smart Home Installations

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Abstract. In this paper the *Casa Vecchia* smart home planning and configuration system is presented. This knowledge-based application was developed with the goal to support inhabitants of private households in the technical enhancement of their homes. The Casa Vecchia project, in the context of which the presented system was developed, was a longitudinal field study in the research area of active and assisted living (AAL). In a four years period 20 households of elderly people in the rural area of Carinthia, Austria were equipped with smart home technology and the inhabitants' experiences with the technology were researched. Results from the project with regard to needs and requirements for household smartness motivated the development of the system presented in this paper. The system is consisting of a *recommender component* which demonstrates the possibilities and benefits of smart home technology on a general level, and a *configurator component* which is able to deal with specific characteristics of living environments allowing for an individual and custom design of smart home systems.

1 Introduction

Fast technological progress has an impact on all areas of life, also in the residential sector and the *average dweller* is overwhelmed by the possibilities to enhance a home with smart technology, these are systems or components which provide an enhanced level of functionality. They can be, for example, remotely controlled, programmed, combined with other components and integrated into other systems. Today a multitude of smart devices for the home is available, but as [19] points out, a decision is not easier by default, when the number of alternatives to choose from is high. Considering the potential dangers, such as having to deal with a patchwork of incompatible subsystems, which [14] labeled the *remote control anarchy*, it is not surprising that the spread of smart technologies in the private residential sector stays behind expectations up to now. In the professional building sector, smart technology has been more successful. This is probably related to a crucial difference between the public and the private building sector. In the public and industrial building sector, initial installations, changes and enhancements of smart components are typically neither decided and planned nor installed by the users themselves. The basic infrastructures are in the responsibility of professionals, and maintained by qualified personnel, taking into consideration suitability, compatibility issues, etc. Decisions about technical enhancements of private homes are typically made by the inhabitants or they are at least involved in them. But in general, this group of people is characterized by a low level of expertise and knowledge with regard to state-of-the-art technology and by a limited willingness to invest efforts, both contributing to *bounded rationality* [21]. This problem domain therefore constitutes a promising application area for recommendation and configuration technologies [6].

In regard to the problem raised, home owners or tenants today are in a difficult situation. If they are interested in the possibilities of smart technology, they have to collect information which typically is distributed over online and offline resources. To be able to understand if such technology is applicable to their own needs and living circumstances, the existing resources are not appropriate. They are, for example, based on simulations of possible functions and features demonstrated by generic depictions of living environments. It is difficult for technical lay persons to map the presented features to their own needs. To get more precise and serious information, experts have to be consulted. The related efforts could involve inestimable costs, either in terms of financial investments, expenditure of time or both. An appropriate software tool could, on the one hand, support users in learning about the potential benefits and costs of smart home technology. This could be based on, for instance, general examples of what the technology is capable of and in this way support *preference construction* [20]. This is partly covered by existing sources. What is missing is, on the other hand, a tool that is able to demonstrate benefits and possibilities of smart technology to a user in an individualized and customized manner.

To be able to cover both aspects, an appropriate tool has to consist of two parts, whereas the general benefits of smart technology can be conveyed by *recommender technology*. To illustrate possibilities for particular living environments, *configuration technologies* can be used, which are able to deal with, for example, custom product features and connectivity issues. The approach presented in this paper is emphasising the necessity of a combined approach to support users in questions and problems related to smart technology for their homes. It is an outcome of *Casa Vecchia* [12], a research project performed in the domain of active and assisted living (AAL). *Casa Vecchia* constituted a longitudinal field study focusing on the possibilities of smart home technology in a specific field of application. Within the project it was investigated if and how smart technology can support elderly people in rural areas to manage their lives more independently and with an enhanced level of comfort. Around twenty households in the federal state of Carinthia, Austria, inhabited by elderly people in different family constellations were part of the project for the period of four years. The households were equipped with sets of smart components, the participants were observed in using them

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and also frequently interviewed regarding their experiences. In order to equip the participants' households with appropriate smart technology, contextual inquiries [2] were conducted and numerous planning and design meetings were carried out. The involved efforts, the planning, design and installation of the customized smart systems could only be realized in a small number of locations. This led to the idea to automate and computerize the process to have the possibility to address broader shares of prospective users in the future. The result was an initial version of the *Casa Vecchia* home planning and configuration system developed with the goal to support the systematic planning of a smart home system for private households, considering the individual requirements of inhabitants as well as the infrastructural characteristics and constraints of their respective living environment.

The remainder of this paper is organized as follows: In Section 2 we discuss work related to the application of *intelligent systems* in the context of smart homes. In Section 3.1 we introduce basic functionalities of the recommender part of the system and also present examples of the corresponding user interface. Thereafter, in Section 3.2 we provide a detailed insight into our smart home configuration tool. With Section 4 the paper is concluded.

2 Related Works on Intelligent Systems in Smart Homes

Decision support systems or recommendation technologies are already used in a variety of contexts. Different approaches are the basis of concepts such as collaborative filtering [18], content-based filtering [15] and knowledge-based recommender systems [4]. However, only a few research works address recommendation technology in the context of smart homes, for example [10] propose the usage of collaborative filtering in (professional) building automation. Knowledge-based approaches, cf. e.g. [8], have been used to support users in smart homes by recommending actions based on historical activity data, [13] illustrate the possibilities of recommender technologies to manage digital contents and services. The applicability of a specific type of recommender technology, however, depends on the problem to be solved. A hybrid approach to address this aspect was proposed by [11], which is based on the combination of different recommendation technologies that can be individually applied depending on the problem at hand. For example, advises for saving energy can be given on the basis of collaborative filtering whereas critical incidents (such as the detection of smoke or fire) are resolved with knowledge-based methods. Summarizing, related work has a strong focus on the *application* of recommendation technology as enhancement of smart home systems that are already available to their users. The problem domain addressed in this paper is the phase of *planning and designing* such a system.

Collaborative and content-based filtering approaches are not applicable to this domain due to the fact that the required rating data are not available in an appropriate granularity. Typically, people do not install smart home equipment very frequently. For this reason a knowledge-based approach was chosen which calculates recommendations on the basis of a predefined set of recommendation rules (*constraints*) rather than on the basis of rating information. One of the challenges is the variety of smart home systems and components, which has to be considered in the development of such knowledge base. This challenge could be addressed by the identification of commonalities of smart systems and components available on the market, for example, in regard to the needs the systems are covering. A basic taxonomy was created by forming categories on the basis of such needs. Related work to build upon has been done, for example, by [16]. The classes of needs the authors differentiate are entertainment, surveillance and access control, energy management, home automation, assistive computing, and health care. In the work of [9] comfort, autonomy enhancement, and emergency assistance are differentiated and [1] distinguish between the quality of living, reducing costs, or providing services for health care. Based on the related work the following categories of needs were seen to be relevant in regard to smart technology:

- *Controllability*: Remote control, combined switching of devices to support certain scenarios, e.g. watching TV (close blinds, dim lights, switch on TV).
- *Cost saving*: Reduction of energy consumption by identifying devices currently not in use. Automatic control of devices based on time parameters or sensor data (e.g., no activity recognized for 10 minutes $\rightarrow$ switch off lights in the respective room).
- *Health support*: Controlling devices which are hard to reach, specifically of interest for people with movement restrictions. Remote health status monitoring by the observation and analysis of activity data.
- *Improving Safety/Security*: Access control by auto-lock mechanisms. Automatic switch-off of potentially dangerous devices (e.g., electric stove, iron). Alerting functions when inhabitants are not at home but activity is recognized.

The second dimension used for forming categories is based on the characteristics of components smart home systems are consisting of. Although providing a high variety of functions and being based on different technical features (e.g. connection via radio, bus or power line) and form factors, the components can be condensed into basic categories based on their features. The categories presented in the following are based on a scheme proposed by [7]:

- *Sensors*: Measuring data or status in the environment they are installed in, e.g. motion sensors.
- *Actuators*: Triggering events on the environment they are installed in, e.g. remote controls.
- *Input Devices*: Providing the possibility to interact with the system on a higher level, e.g. desktop computers, tablets, smart phones.
- *Output Devices*: Enabling the observation of the system's status and the notification of users, for example, embedded computers or environmental displays.
- *Gateway Components*: Building a central point of communication with and between other devices and offering the possibility of parameterization, configuration, and programming.

The features of the two categorization schemes are included in the knowledge base [4] and cross-linked. For example, if a user is interested in enhancing security (need category: Security), this can be managed by observing corresponding devices.

3 Overview of the Smart Home Installation System

The *Casa Vecchia* smart home planning and design system consists of a recommender and a configurator part. The user is guided through the problem domain, whereas the first (*recommender*) part is focused on informing the user about the general possibilities of smart home technology and the elicitation of preferences. Based on the preselections made in these initial steps, the *configurator* enables users to customize a smart home system for their individual living circumstances and needs.

3.1 Casa Vecchia Recommender

After a welcome screen explaining the goal and introducing the upcoming dialogue, the users have to select smart features which are of highest interest for them (see Figure 1). The aspects the recommender part of the system deals with are related to the categories described above and consisting of the following elements:

- *Major interests/goals*: Security, energy, control
- *Technical Requirements*: Stability, emission, ease of installation, installation costs, maintenance efforts.
- *Building characteristics*: Apartment or detached family house, one or more floors.
- *Scope of planned efforts*: Initial installation in a new building, comprehensive renovation, partial modernization, do-it-yourself enhancement.

The recommender takes into account the elements, rules, and constraints in the knowledge base and assures that only information appropriate to the context is presented. The initial dialogue is - depending on the selections made in the previous steps - consisting of 5 steps on average. The primary goal of this stage is to point out potentials of smart home technology in general, to elicit needs and to support the *construction of preferences* in the sense of [20].

The selections made by the users influence the procedures in the back end of the system and the components recommended at the end of the process. For example, if the user states that his living environment only has one floor, stair elements are not shown in the configuration phase.

In this phase the selection of criteria is not limited, potential conflicts are pointed out but not corrected. This is because the user can always change settings during the dialogue. If conflicts persist until the end of the dialogue, they are explained and resolved.

3.2 Casa Vecchia Configurator

After having completed the recommendation part the user is guided to the configuration part of the system. The transition is visually emphasized by a change from a text-based to a graphical interface, the latter enabling the users to sketch the floor plan of their living environments with drag&drop (see Figure 2). The users can use simplified design elements to sketch a variety of rectangular floor plans. In this way rooms, hallways and stairs can be sketched and doors or windows can be positioned. After having finished sketching the floor plan with the basic elements and having labeled the rooms, the next step is to position devices that are currently present in the user's home (3. This constitutes an important advantage of our approach. It is not necessary for the user to identify whether a smart component is available or appropriate for his or her purposes, but the configurator automatically identifies appropriate smart components on the basis of the user's preferences (energy saving, safety, etc.), the floor plan and the devices the user has positioned. This functionality is based on rules implemented in the knowledge base. Examples for such rules are:

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On Building Level:
Electric smog is an issue (=yes) ⇒
smart-home-system-type (=wired)
Low price relevant (=yes) ⇒ smart-home-system-type
(=wireless)
if Electric smog is an issue (= yes) and Low price
relevant (= yes) ⟹ conflict
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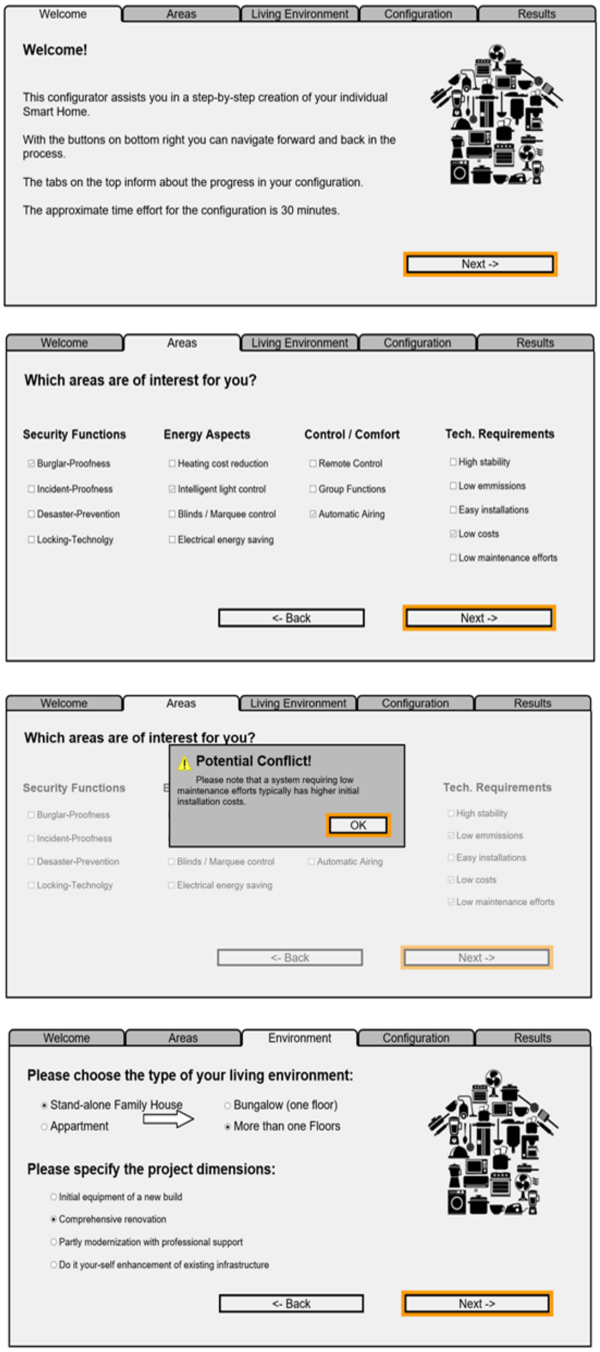

Figure 1. Example screens of the recommender part of the system, illustrating the criteria that can be selected by the user. The pop-up depicted in the third screen shows an example of a potential conflict.

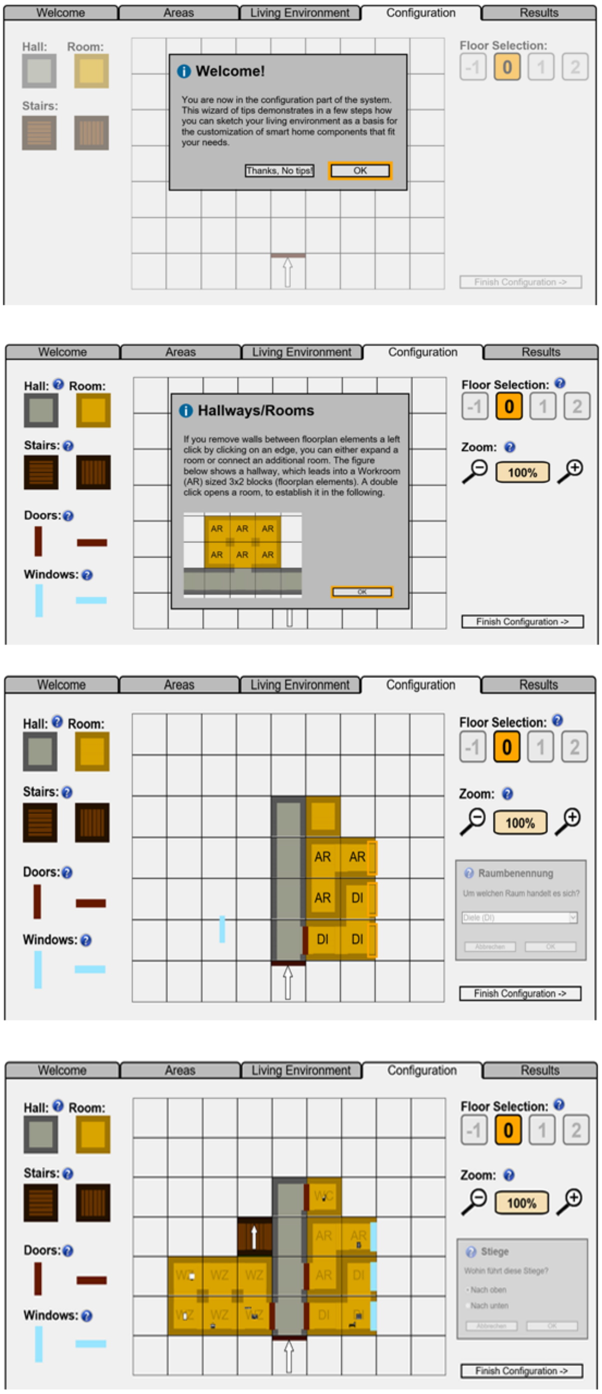

Figure 2. Example screens of the configurator interface. In the top part of the figure, the first screen of a user tutorial is shown. In the tutorial the essential steps of the configurator are demonstrated. The second screen shows a help pop-up which can be accessed via the question mark symbol positioned next to each element. Screens three and four on the bottom show different stages of floor plan design.

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On Room Level (e.g. Kitchen):
Goal.Security (=yes) and Electric stove (=yes) ⇒
stove-sensor (=yes) and
stove-actuator (=yes)and kitchen-smoke-detector (=yes)
Goal.Support (=yes) and Fridge (=yes) ⇒
fridge-door-contact (=yes)
Goal.Comfort (=yes) and Automated Lights (=yes) ⇒
lights-actuator (=yes) and motion-sensor (=yes)
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In the phase of configuration potential conflicts are identified and advises to resolve them [5] are given. As an example, the requirement of high stability leads to the recommendation of a wired system whereas requiring a low price would result in the recommendation of a wireless system. In this case the user is informed about the conflict as well as possibilities to resolve it. Other possible conflicts / constraints that can occur are, for example:

Conflict 1: *Remote control AND saving energy*
Remote control requires the system running 24/7 which contradicts the need of energy saving. This can be resolved in different ways, either totally (remote control or energy saving) or partly (permanent operation of specific components only, e.g. heating).

Conflict 2: *No electric smog AND low price*
Low emission can only be ensured with a wired system. This is more expensive than the wireless alternative and causes higher installation costs. This could be resolved by either accepting a higher emission or higher costs.

Conflict 3: *Remote support AND privacy/security concerns*
Support from outside can be provided only if the system is allowed to distribute data. If privacy is important, this form of support might be problematic. The conflict can be resolved, for example, by emphasizing that transferred data is encrypted and only available to a predefined group of persons.

4 Conclusions and Future Work

In this paper, the *Casa Vecchia* smart home planning and configuration system was presented which constitutes a combination of recommendation and configuration technologies. The target user group is private home owners or tenants who could, due to missing domain knowledge, benefit from a system supporting profound decisions related to the technological enhancement of the home. Such a system has to provide both, an adequate knowledge base which is able to match user needs to the functional range of smart home components and the possibility of customizing smartness to an individual living environment. The prototype system presented in this paper was initially developed by [17] and is implemented in HTML5 and other state-of-the-art web technologies and can therefore be used on conventional computers as well as on tablets and smart phones.

Another difference to first implementations is that the new version is rather based on graphical interaction than on textual dialogues. An outcome from the evaluations of the first prototype has been, that questions regarding the numbers and positions of devices present in a household, such as TVs, are more difficult to answer in a textual manner than by positioning them on a sketch of a floor plan. The graphical representation enabling drag & drop significantly increases the acceptance, usability, and convenience of the system.

The presented recommender/configurator combination has many advantages. Beside end users, other stakeholders could also benefit from such an approach, for example, service providers. The results generated by the system represent a structured and more precise description of user needs which could lead to lower costs for the prepa-

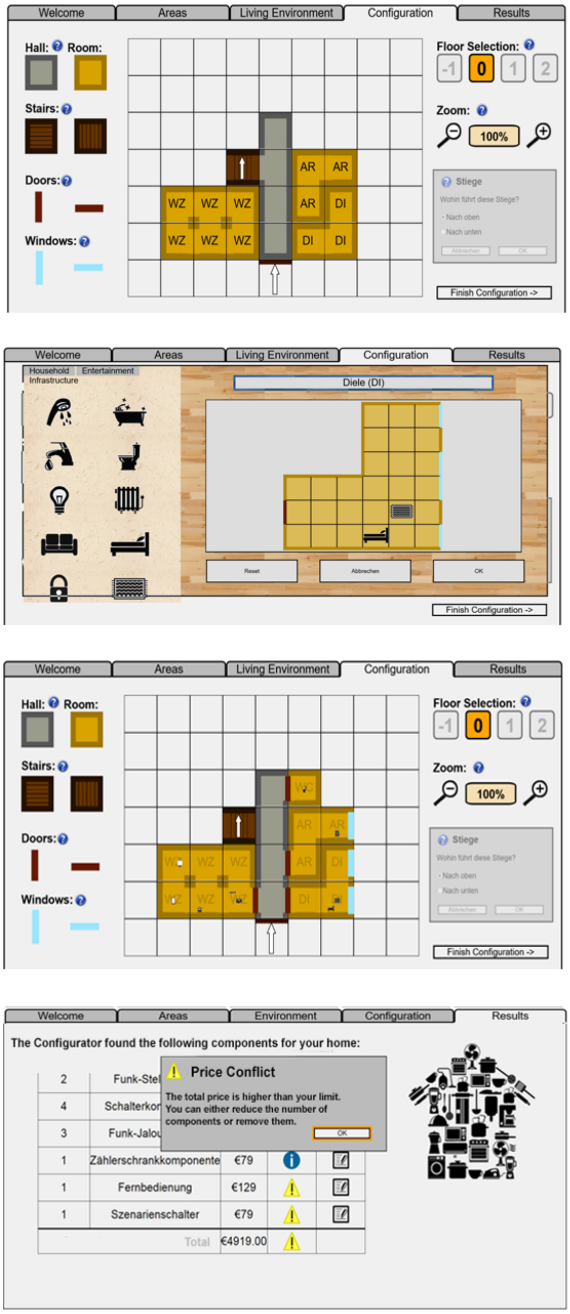

Figure 3. Example screens of the drag & drop interface of the configurator in the top part of the figure. On the top a final floor plan sketch is shown which contains rooms, a hallway, and stairs. By double-clicking on the respective room shape (in this case the "l-shaped" room located bottom right) a detail view of the room is opened which enables the positioning of devices. The user can choose different electric devices as well as installation components (e.g. faucets) and furniture and drag them on the room shape. When the user has finished the selection, he gets back to the floor plan overview and the devices just positioned in the respective room are shown as miniature symbols. The bottom figure shows the result page with the list of smart components the system finally recommends, with the possibility to edit and change in case of existing conflicts.

ration and adaption of offers, more cost efficient installations due to clearer requirements (in the form of a floorplan), and a reduction of errors in the planning as well as in the installation phase. On the side of the customer, easier preference elicitation and a better understanding of the system and its components can be expected. A detailed empirical evaluation of the presented smart home planning environment is the central focus of future work.

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