Configuration and Mass Customization of Domotics to support SMEs and their Customers

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Abstract. In the recent years, smart home systems and components, also known as domotics, have been literally mushrooming. Today hundreds of different systems are available on the end-consumer market. However, because of the difficulty for the end-consumer to overlook the variety of products, the percentage of real smart homes (fully equipped and not only characterized by the presence of single smart components) is far behind the estimations. A related problem is that off-the-shelf products cannot be easily installed and require the support of professionals.

The latter, often working in small and medium-sized enterprises (SMEs), have to deal with the situation of having to install products of their own portfolio in heterogeneous technical infrastructures, and, increasingly, combine them with products from doubtful origin. Due to a lack of compatibility/interoperability of smart home systems, this can constitute a big challenge. Even minimal standards, such as those present in other fields of ICT (e.g. USB connectors), are not existing in the domotic area. These and other problems finally led to a still weak penetration of smart home technology. However, there are ways to overcome the problems involved, one of them is Mass Customization in Combination with Configuration presented in this paper. The approach is applied within the Interreg funded project Mass Customization 4.0 (MC 4.0) and aims at designing (mass) customized solutions for domotic systems based on configuration technology.

1 INTRODUCTION

Today hundreds of different smart home systems or components are available, in the industrial and public building sector, but increasingly also on the end-consumer market. The latter is characterized by a variety of mainly off-the-shelf products. Today, every store for electronic appliances, hardware store or even supermarkets, offers smart home products from different brands that promise a better life to their buyers in terms of comfort, safety, energy-saving, and so forth. A literature review by [1] illustrates the diversity of smart home systems on the basis of the technical foundations (Zigbee, WLAN, Bluetooth), interoperability issues, or related costs.

However, it is difficult to give a precise number of different systems available, because they differ from country to country, depending on, for example, governmental regulations for electrical devices. To get an idea of the magnitude, we refer to the smart home software platform OpenHAB (Open Home Automation Bus) [8], which aims at integrating smart home components and systems of different manufacturers. OpenHAB supports the integration of around 400 different systems, in different categories that are, in a broader sense, domotics. The range goes from infrastructural technologies such as Zigbee or Bluetooth, over Webservices (Weather, Calendaring, etc.) to domotic systems and subsystems from different manufacturers (Ikea, Philips) to control heating, lighting and cooling. The latter constitute the majority of devices supported by OpenHAB.

The sheer number of systems highlights the difficulty for the end consumers to keep an overview of the available products and to identify whether a specific product could support their needs. Supporting information and advertising material cannot answer all questions, because off-the-shelf systems typically cannot just be placed into the living environments such as smartphones or other stand-alone smart devices. Domotics have to be integrated and their installation and maintenance at least require the support of technically experienced people, oftentimes certified professionals, such as electricians.

The latter - speaking of the typical situation in Austria - are employed in small and medium-sized enterprises (SMEs) with an - in general - small and manufacturer-specific product portfolio. Due to the diversity and manifold availability of smart devices emphasized above, they are increasingly confronted with the problem of having to compete with companies that address customers via alternative channels (online or consumer markets) and, as a result, increasingly have to deal with the integration and combination of their own products with products and devices from such other sources of supply.

An example of a situation a professional might have to deal with occurred in the past in the household of one of the authors. The house was equipped with basic smart home functionality, such as controls for lights, heating and blinds. When the children in the house were small, their sleep was monitored with a baby-phone. During this period, the blinds in the household occasionally did not work properly. The smart home's central gateway operated on LAN/WLAN to enable remote control (via Web interface) and on 433 MHz radio frequency for the communication with the attached components (such as the blinds). Due to low robustness (the system was one of the first generation wireless smart systems, around the year 2005) malfunctions occurring from time to time were rather the rule than the exception. The standard strategy in such cases was to check all components of the system for appropriate connection, reset and restart the software-based components, but in the concrete case, no improvement of the situation resulted. It finally turned out that the baby-phone also operated on 433 MHz radio frequency and interfered with the smart home system. Many other examples from past projects could be given, illustrating the challenges for consumers and local professionals that are related to the proliferation of smart home systems.

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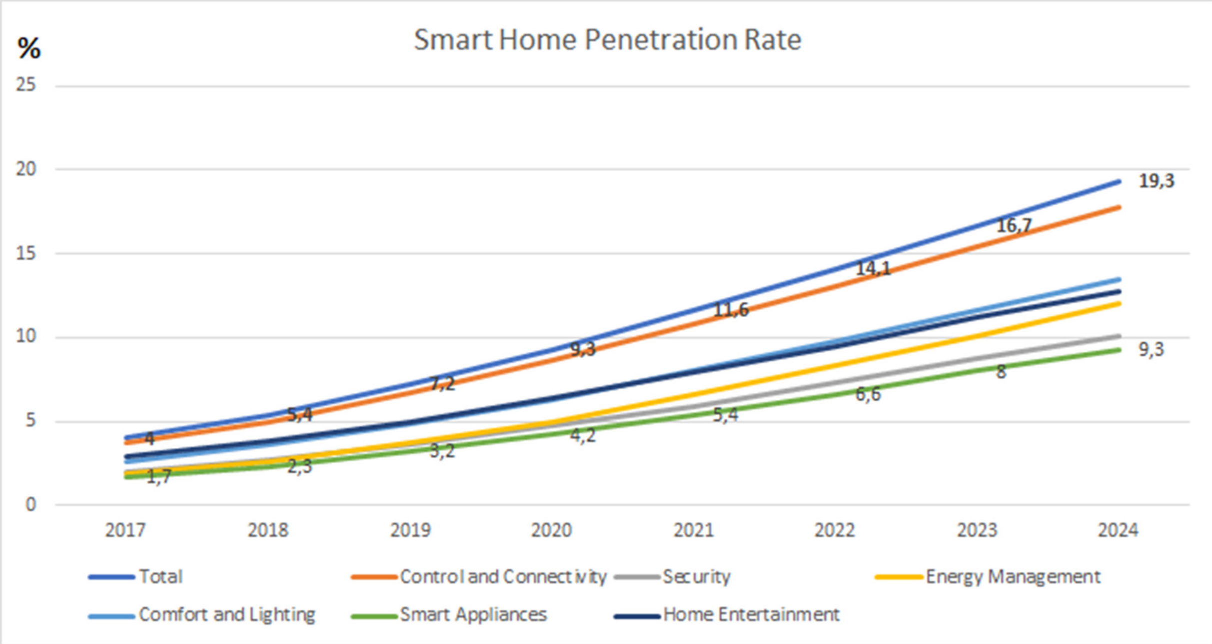

Figure 1. Penetration Rates and Estimations for the development of Smart Homes, adapted from [5]

The project MC 4.0 addresses the related challenges, by the involvement of companies from the field of domotics representing the perspective of the industry. The second important column of the project is an appropriate scientific approach providing the industrial partners and their end consumers with state-of-the-art know-how. Research challenges in different domains have to be faced in this context. To be able to better support end-consumers as well as SMEs, which both cannot be assumed to be ICT experts, a special focus is put on the user experience/usability of the digital tools developed in the course of the project [6]. The other research gap to be filled is to find appropriate tools to apply and adapt to the area of domotics systems. In the case of configurators, related work on, for example, system interoperability, system configuration [10] or distributed configuration systems [16], [17] have to be taken into account.

The remainder of the paper is structured as follows. In the background section, the project MC4.0 and the research-led approach is presented, followed by a detailed description of tools and methods applied to overcome the emphasised problems. The paper finishes with a conclusion and an outlook on future work.

2 BACKGROUND

The activities described in this paper take place in the context of MC 4.0, which constitutes a cross-border cooperation between Italian and Austrian partners from industry and academia.

2.1 Overview of the MC 4.0 project

One of the main goals of the project is to establish a communication platform in the area of domotics, consisting of two main parts. The first part is represented by real world support centers at different locations in the project area, the second is an online portal providing the possibility for information exchange and bringing together experts and interested companies working in the field of smart living. The sustainable goal of the project is to support small and medium-sized enterprises to develop mass-customized smart home solutions for their customers, give them instruments to stand out from the competition (specifically from online supply channels) and in this way improve their market position. This is realized by several means, one of the most important ones is to deal with the aforementioned large number of available smart products and the resulting number of combinatorial solutions. The major problem to overcome in this regard is the still insufficient compatibility/interoperability of available smart home systems and their components. Minimal standards, which exist in other areas of ICT (e.g. USB connectors) are hardly existing in the domotic area. These and other problems led to the current situation in the smart home sector in which real smart homes (fully equipped and not only characterized by the presence of single smart components) are far behind the estimations. Although the growth rates are high, the spread of smart homes is not significant when compared to other technologies. The concept and term *smart home* has been announced in 1984, at about the same time when the personal computer was introduced. The latter (and its derivates) is present in almost 100% of homes in developed countries, smart home systems are [5] in 2020 still in the single-digit percent range, see Figure 1.

3 ADOPTED APPROACH

The methods applied in MC 4.0 to deal with the related obstacles and challenges are Mass Customization and Configuration. Before going into detail on the application of the methods, the central concepts are defined.

At first it is important to illustrate our understanding of the concept of Smart Home. According to [15], *..a smart home is a home that incorporates advanced automation systems to provide the inhabitants with sophisticated monitoring and control over the building's functions. For example, a smart home may control lighting, temperature, multi-media, security, window and door operations, as well as many* *other functions."* A state-of the art smart home would also enable remote access via internet/smartphone and individual programming. However, most of the off-the-shelf systems do not provide such a level of "real smartness", they hardly integrate different subsystems in a building (e.g. lighting, shadowing and multi-media), provide adequate programming facilities or advanced AI-functions such as learning from user behaviour, adaptive functions, etc.

The next important concept is Mass Customization. Several definitions of Mass Customization exist. We refer to the one of [13], because it describes best what is planned in the course of MC 4.0. According to [13] Mass Customization is the *"...Production of personalized or custom-tailored goods or services to meet consumers' diverse and changing needs at near mass production prices. Enabled by technologies such as computerization, internet, product modularization, and lean production, it portends the ultimate stage in market segmentation where every customer can have exactly what he or she wants."*

The third central concept of MC 4.0 is Configuration, as an enabling technology for Mass Customization. According to [14] *"Configuration is a basic form of design activity where the target product is composed from a set of predefined parts in a way which is consistent with a given set of constraints."* Configurators are applied in a process where users specify, change and tune their requirements and the configuration system provides feedback. The challenge for configuration is that it should, in principle, allow for a combination of all instances represented in a system, more precisely in the system's knowledge base.

Potentials, but also challenges for Mass Customization and Configuration in the smart home domain are manifold. MC 4.0 is focused on two main areas. The first is energy-related aspects in the context of homes, such as the thermal insulation of buildings, the energetic conceptualization of heating and cooling, and other climate/building envelope related aspects. The potentials of configuration in this domain are discussed, for example, in [2].

The other area, which is the focus of this paper, is domotic appliances aka. smart homes. The first important step in the application of configuration technology in the context of smart homes is to utilize the appropriate technological basis, preferably based on state-of-the-art AI. When taking a closer look at the end consumer market of smart home solutions, there are already observable attempts to support consumers in the configuration of individual smart homes by utilizing AI. As example, Busch & Jäger provide tools labelled as smart home configurators on their websites (see [9]). They are based on designing a floor-plan (or uploading an existing one) on the basis of which smart components are proposed that can make the customer's living environment smarter. Merten [11] call their configurator the *Wiser* configurator. The configuration process starts by asking the users a few questions about their needs and goals (renovation or new building, local or remote control, infrastructure to be integrated such as heating, lighting, etc.). The dialog finally results in a list of smart products which the provider considers as useful, related to the selections done by the user in the previous steps of the dialogue. The two examples are representative for the state-of-the-art of similar platforms (mainly websites) labelled *Configurators*. However, to our understanding, the majority of those systems are - in the sense of [14] - recommender systems rather than configurators. They offer pre-defined standard solutions instead of individualized ones combining "all possibly allowed instances" [14], or, in other words, solutions that optimally fit to a consumer's circumstances rather than representing standard product combinations. With a few exceptions (e.g. the possibility to use own floor plans) these systems do not appropriately take into account the current living situation of a user, the infrastructural conditions and the needs the customer wants to have fulfilled by a smart system.

Our approach to configuration is a different one. Our goal is to focus on the end-customers and their living conditions and guide them in the process in order to find appropriate solutions. We refer to an approach which Mayer [4] calls a goal-driven approach where users tell what they want. A critical feature - and relevant research issue - in this regard is the user interface of the configurator [6] which has to provide appropriate customizability (e.g. is available on different platforms), offer appropriate starting points and the possibility of incremental refinement (the latter ideally in a way to support "playing around" with different variants, in a sense of gamification/game-based configuration [3]). Although the end-customer and their needs in the context of configuration is the focus of this paper, the access to the system for the SMEs is of equal importance. Both target groups and their requirements and needs are emphasised in the following.

3.1 End Customer

The end customers have to be "picked up" from where they are; most probably in a situation when they are considering making their living environment smart. For this purpose, our approach is to initially ask a few questions about the customer's goals (which is also done in other concepts, such as the aforementioned [9, 11]). Goals can be, for example, enhancing safety and security, increasing comfort, saving energy, etc. Another step would be to get information about the infrastructural conditions of the living environment that should be made smart. Aspects such as the number of floors, the age of existing infrastructure (wiring, fusebox) are of essential importance for the generation of possible solutions, the configurator would perform. A segment of a possible decision tree and the features addressed is given in Figure 2.

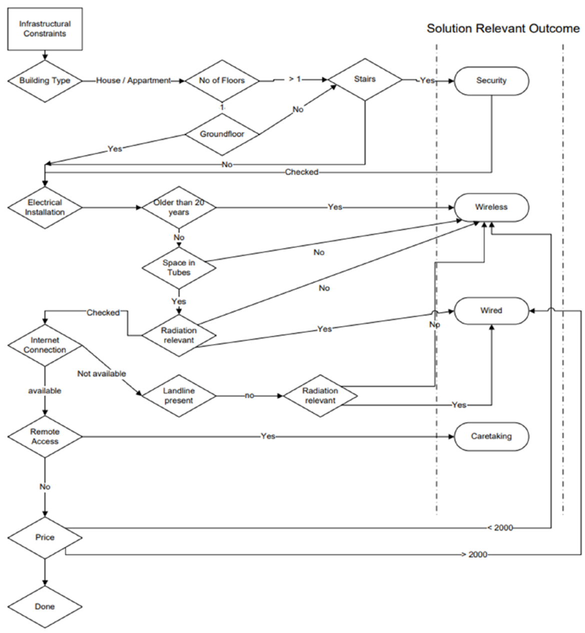

Figure 2. Dialogue decision tree example

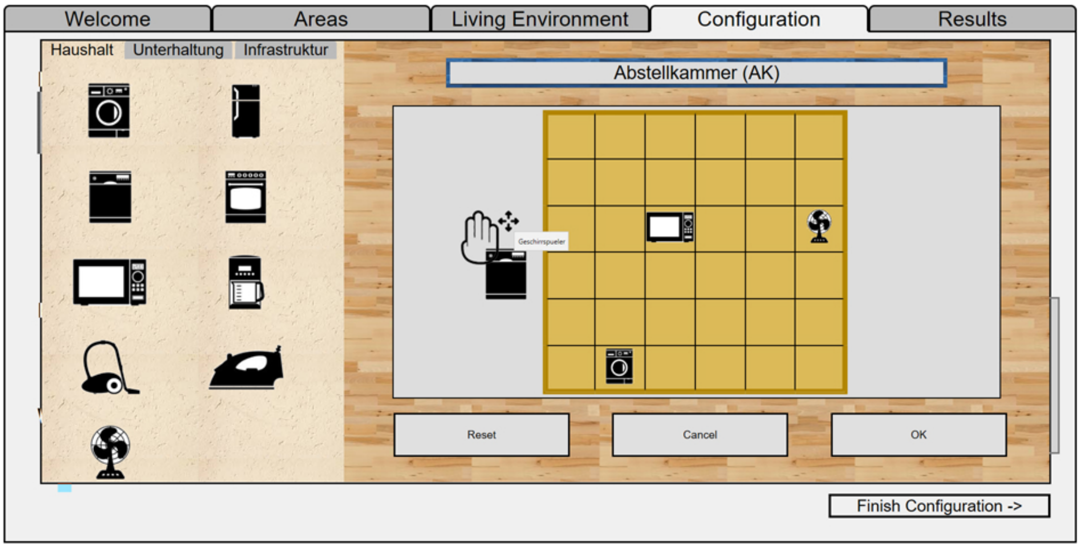

Figure 3. Snapshot of the Configurator Interface Prototype - showing how to place existing components

Another central feature that differentiates our approach from others on the market is that the proposed solutions take into account appliances and components which are already present in the household of question. Information on these aspects can be conveyed to the system by the possibility to drag and drop example components (such as TV sets, light bulbs, radiators, furniture) on the appropriate position of a floor-plan. This step is represented in Figure 3, showing one screen of a conceptual prototype of the configurator to be developed. Competitor systems ask users about needs, partly take into account conditions such as floor plans, but quickly propose smart components whose relation to the user's living conditions and needs are questionable. By asking users more detailed questions about the current situation, the quality of information (what [4] calls semantic information) is considerably higher and the solutions that can be proposed are more appropriate. Additionally, the collected information is more useful for the professional who is utilizing the system as a supplier offering a customized and individual solution to the customer.

Based on the information provided by the customer, the configurator ideally can already pre-calculate appropriate solutions in the back end, or at least propose suitable components to the professional who evaluates the request of a customer. The pre-calculation is based on attributes of appliances that are stored in the system. As an example, when customers state that they would like to increase safety and put a kitchen stove on the floor plan, the stove shall be integrated with an auto switch-off function (either when a smoke detector is triggered or when all inhabitants have left the house). In Austria, kitchen stoves are typically operated by 3-phase 380V current, which would require specific components for the integration in a smart system [7]. However, this knowledge is commonly available and would just have to be entered (e.g in the form of attributes) into the configurator system. Another important category of knowledge to be considered in this context is individual knowledge of a certain professional (electrician, installer). The possibility of entering and sharing (at first in the consortium of MC 4.0, later in a larger community) such knowledge should also be supported by the platform. An example in this regard could be the documentation of the interference problem between the baby-phone and the smart blinds mentioned above in a kind of forum.

3.2 Professionals, SMEs

Most of the configurators available online (such as the two of [9, 11] mentioned above) provide an option to contact a professional who would be able to consult customers in their wish to utilize smart technology. However, this is often based on a switch of tools (Configurator -¿ E-Mail) and efforts that have been invested by the users (e.g. designing a floor plan, answering questions in a dialogue) are not appropriately exploited (as has been emphasized in the previous section). With our approach, users would be enabled to provide information in a significantly higher detail and quality in the system that is also used by the professional. In this way no information is lost and it makes it easier for the professional to calculate more serious price estimations based on more precise information about the technical possibilities of enhancing the living environment with smart technology. Information on the existing infrastructure (as shown in Figure 3), for example, enables the professional to identify misunderstandings or false expectations on the side of the customer and allows for clarification/correction and the proposal of alternative solutions or enhancing features, which offer themselves in the given constellation.

Another difference to other approaches and an important goal of MC 4.0 is to increase the exchange of information and know-how on a regional, cross-border (regions in northern Italy and southern Austria) and local level. Locality is important in general, but specifically turned out to be important during the Covid-19 crisis, when the drawbacks of globalization and the limits of remote service providers were drastically recognizable. It is a problem, when systems do not work appropriately and suppliers have their support facilities online or at remote locations, maybe even overseas. Therefore, support, information exchange and improvement of cooperation in MC 4.0 is not only based on an online platform, but also by offline facilities, the so-called DEA (DEvelopment and Application) Centers, which will be a contact point for end consumers as well as companies working or being interested in the field of smart living.

3.3 Technological considerations

The already mentioned challenge of choosing appropriate technology has been partly addressed in the previous sections, e.g. in connection with interface design issues. In the case of configurators, it is important to take into consideration related work on system interoperability, system configuration (cf. e.g.[10]) and distributed configuration systems (cf. e.g. [16, 17]). A critical part is the backend-system offering a variety and flexibility that is needed for the described purposes. The planned solution is based on the system VariPDM [18], which constitutes a base system that contains the core data model and basic functionality for product life cycle management. Most importantly, in terms of requirements and constraints of the project, the backend-system can easily be integrated/connected to existing technical infrastructures of the involved professionals and SMEs. In this way, efforts for adopting a new ICT system are reduced and the provision of customized products, combined with reduced costs and increased efficiency is realistic. Some of the features of VariPDM are a flexible data model that allows for adaptation during and after the implementation. Items in the system can be either fixed or configurable products, allow for the creation of relationships to establish product structures, and the application of rules (e.g. revision rules). Mechatronic-oriented product management enables the coverage of product data originating from different design disciplines, such as mechanical engineering, electronics and software development, respective attributes can be mixed in one and the same product. This is specifically important in a heterogeneous domain such as smart living. The same flexibility provides for the management of related documents, items and product data, as well as user management.

4 DISCUSSION AND CONCLUSION

In this paper, we have presented the approach, related challenges and problems of applying mass customization and configuration technology in the context of the project MC 4.0 which is located in the domain of Smart Living. The goal of the MC 4.0 project is to enable local SMEs to provide custom Smart Living solutions to their customers, and to support them in the realization of those solutions. This requires considerations regarding the basic technology, not only in the phase of the configuration, which is in the focus of this paper.

A related challenge to be addressed in the course of the project is how to deal with the different requirements of SMEs involved in the project in terms of interfaces to existing ICT-infrastructures, product portfolios and business segments. The platform should, for example, support electricians as well as plumbers, companies offering shadowing as well as those being experts in multi-media solutions (e.g. multi-room audio, projection). Supporting the individual work method is as important as putting a focus on the integration of these different viewpoints to provide a ”one-stop-shop” for domotic questions and solutions to the customer.

The future challenge is to also provide support in the phases of implementation and maintenance. A platform that offers itself for this purpose has already be mentioned, Openhab [8], which already supports the integration and combination of around 400 systems and components in the smart home sector. It is the task of the scientific partners, the scientists and researchers involved in MC 4.0 to establish the configurator platform described and the features required on the side of the end consumers as well as the professionals on the one hand, and also support the target group in the installation and maintenance of the resulting solutions on the other. This includes further challenges and questions, for example, how to deal with solutions the configurator would propose, which are based on the combination of components that are optimally covering the needs of a customer but are from different manufacturers. Due to contractual restrictions, an SME might not be able to provide this solution. A possibility to solve the problem could be that the MC 4.0 offers contracting and cooperation alternatives which make possible the implementation of a smart home system consisting of components from more than one manufacturer. Dealing with such problem will be subject of future work in MC 4.0.

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