User Profiles for Smart Homes

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Abstract

Smart homes main goal is to improve the comfort, security and allow energetic savings to its inhabitants. However, the usefulness of smart homes strongly depends on how easy users can take advantage of its existing functionalities. In this thesis, we introduce *user profiles*, a method that accurately captures user preferences, such as temperature, room luminance, shutter status, volume or preferred TV channel. When a user enters any room of the house, the proposed solution will configure the room automatically to satisfy in the best way possible the user preferences. In order to do that, if there are several users in the same room, the system deals autonomously with conflicts between preferences. Additionally, the system identifies manual actions performed by the users and uses that to automatically make small adjustments to their profiles.

The contributions of this dissertation include a review on relevant literature on smart home configuration methods, conflict detection, conflict resolution and machine learning strategies. We provide a practical approach to configure a smart home backed by a conflict resolution mechanism that maximizes user satisfaction. The proposed mechanisms, the developed system and its user interface, were evaluated through a simulation context and conducting usability tests. The implemented solution follows the DomoBus approach.

Keywords: Smart Homes, User Profiles, Conflict Resolution, Machine Learning, DomoBus

1. Introduction

The term "smart home" is used to define a residence that is equipped with network-connected technologies (Wi-Fi, Bluetooth or similar protocols) which anticipate and respond to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technologies within the home (Harper, 2003). The significant advances in the Internet of Things (IoT) market, the increased need for security and the constant demand for energy savings are important factors for its growing popularity. However, although the popularity of smart homes is rising, it is growing more slowly than predicted. That is because it is still necessary to overcome a number of challenges in order to generate widespread interest in this area (Brush et al., 2011; Alam et al., 2012; Wilson et al., 2015):

Flexibility: Systems should be able to accommodate any type of technology without restrictions on their brand, allowing a good level of compatibility between different solutions. This prevents the user from being forced to choose between a single proprietary system and the individual integration of different technologies. In addition, the user must be able to easily extend the acquired solution, complementing it with new components;

Cost: The costs of hardware, installation, and maintenance of these systems are a major concern for users. Likewise, the time required to install, configure, and manage them should not be ignored;

Customization: The system must be able to adapt to each user's routines, tasks, and preferences and recognize that users do not always want the same automatisms. The complexity of configuring the system should be considered, and a balance between customization and automation must be found;

Usability: Confusing interfaces limit the use of the system features. Although users are gradually becoming adapted to more sophisticated devices, it must be assumed that they do not have specialized technical knowledge. Any visitor of a smart home should be able to use its features without doubts or fears of doing something wrong.

As mentioned before, one of the key aspects to the success of residential automation is its abil-

ity to meet the requirements of each user. Different types of people have different requirements and each individual has their preferences regarding the services available in a smart home (Wilson et al., 2015). There is, therefore, a need to characterize each user individually, rigorously capturing these preferences and habits. With this work, we introduce the concept of *user profile*, which corresponds to the set of values or preferences that the user wants for the smart house configuration, which may include, for example, the temperature, preferred brightness for lamps, the favorite TV channel or the preferred music genre. Furthermore, in a dwelling, it is common to have several occupants. Even when people live alone, they can have visits from their family or friends. Different types of people can share the same spaces, giving rise to conflicts between preferences.

Existing literature deals with the creation of automatisms for smart homes in two different ways, through semantic configuration, introducing actions and rules manually (Kao and Yuan, 2012; Maternaghan and Turner, 2013) or through habit recognition (Chen et al., 2012; Iglesias and Kastner, 2013; Rashidi and Cook, 2008). There is, however, a gap to be filled between these two types of approaches. On one hand because of their lack of customization and on the other the overlook of user-centered solutions. In addition, the approaches used to resolve conflicts between user preferences are mostly rule-based or constraint satisfaction problems (Maternaghan and Turner, 2013; Luo et al., 2013; Armac et al., 2006), inflexibly ignoring the intent of their users.

Consequently, it is still necessary to develop automation systems that are able to manage the preferences of multiple users, but do not compromise the user experience. This article presents a solution which will allow a user to set up a smart home through user profiles, supported by a conflict resolution mechanism that will allow multiple users to share the same space even with different preferences. Given the need for adaptation, a methodology is also proposed that automatically adjusts user profiles, since each person's preferences may change over time. The aim of the proposed solution is to address the challenges above by introducing user profiles and following the DomoBus approach.

2. Related Work

There is a great deal of work and literature concerning smart home configuration approaches and general conflict detection and resolution systems. This section reviews the most relevant literature and work, on both of this areas, establishing adequate comparisons, extracting advantages and identifying shortcomings.

Table 1 presents an overview of the analyzed solutions, comparing them in terms of approaches and features surveyed. According to Table 1, many proposed systems for configuring a smart home have habit recognition, which identifies users daily routines and brings a great level of automation to the residence, requiring little or no configuration. Others use semantic configuration to allow users to specify in great detail some individual task that they want to automate. Overall, the idea behind all these solutions is good and they are capable of solving some of the issues previously identified. However, despite all its qualities, there are still some flaws and some points that need to be addressed. This research shows a clear tendency in the home configuration systems, they either are completely autonomous, preventing users from making decisions, or utterly user dependent. Therefore, there is a need to establish a middle ground approach for configuring a smart home.

The surveyed systems for conflict detection and resolution are mostly divided into two categories: rule-based and constraint satisfaction (CS) approaches. Brush et al. (2011) carried out a study demonstrating that users consider rule-based solutions in general to have poor manageability. When household changes and users have different preferences, they have to change all the rules of the system. Besides, rules are hard to debug when they don't work, the users either live with the problems or turn off the rules. Constraint satisfaction approaches are not very flexible due to the need to constantly meet the restrictions imposed. Moreover, scalability of the number of users is also a counterpart, because if there are a large number of conflicting users with contrasting preference values, it becomes difficult to satisfy each one of them. Avoidance approaches only work for well known actions such as a device changing its state, but not for human behavior which is highly unpredictable. The proposed solution by Park et al. (2005), considers user intentions as well as their preferences, in order to better represent their will. This is better than the other options such as rule-based approaches in the sense that is more focused on user satisfaction and it allows for good flexibility and scalability, even though it neglect important aspects such as users hierarchy.

Finally, we believe that the proper way to address the challenges presented previously is through the design of a user-centered solution. We can verify that most of the solutions are unilateral, that is, they only address a part of the problem, and do not present a complete approach. As such, the solution we are looking for should be highly customizable, adaptable and easy to use, resolving conflicts

Table 1: Overview and comparison between solutions in terms of the conflict resolution mechanism, learning of habits and possibility to be configured by any user of the house.

	System	User Configurable	Habits Learning	Conflict Resolution Mechanism
Home Configuration Systems	Iglesias and Kastner (2013)	No	Yes	Priorities
	Bandara et al. (2015)	No	Yes	Avoidance
	Kao and Yuan (2012)	Yes	No	-
	Rashidi and Cook (2008)	No	Yes	-
	Chen et al. (2012)	No	Yes	-
Conflict Resolution Systems	Maternaghan and Turner (2013)	-	No	Rules/CS
	Tuttlies et al. (2007)	-	No	Avoidance
	Camacho et al. (2014)	-	No	Priorities/CS
	Luo et al. (2013)	-	No	Rules
	Armac et al. (2006)	-	No	Rules
	Park et al. (2005)	-	No	User Intentions

if they arise. The conflict resolution mechanism should be flexible in order to accommodate all kinds of preferences and scalable to allow any number of users. We aim to develop a user-friendly system (with great user experience) that can automatically configure a building at the same time that accurately portrays the preferences of its users.

3. DomoBus Framework

DomoBus (Nunes, 2003) is a academic framework whose main objective is to integrate devices of different technologies, such as sensors and actuators. DomoBus supports interoperability across multiple technologies, such as X10, KNX and DomoBus Control Network (DCN), and enables high scalability relative to the number of devices. Furthermore, this framework has been used as a learning tool and as a test bed for new ideas and applications.

3.1. Architecture

The architecture of the DomoBus is composed, essentially, by Control Modules (CM) and Supervision Modules (SM), which are interconnected by a communication network that allow them to interact and cooperate with each other.

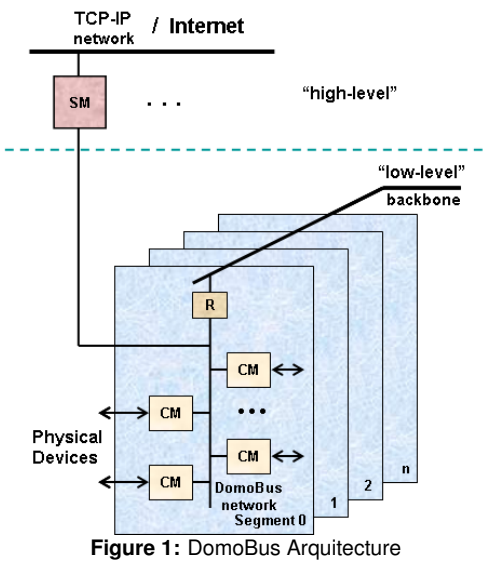

Figure 1: DomoBus Arquitecture

The Control Modules (CM) are small microprocessor-based boards that connect directly to switches, temperature sensors, infrared receivers and other input devices. And they can control power electronics used, for example, to adjust the intensity of lights or to turn on/off small motors, pumps, lights, electric heaters or air conditioners. Each CM is able to control multiple devices and perform different functions, unlike other solutions. Therefore, DomoBus approach can be much more economical and feasible than the alternatives.

The Supervision Modules (SM) are responsible for system management and supervision. They receive information from the CMs, process it accordingly to programmed rules and required behavior, and issue the appropriate commands to the CMs. A system may have as many SMs as needed. Note that a SM can control any CM in the system and that the SMs can interact with each other in order to share information or coordinate actions. To allow interoperability between different technologies it is necessary to map a generic data model for each particular home automation technology.

3.2. Data model

One of the key aspects of the DomoBus approach is its model of a home automation device. The model is very simple and modular, making DomoBus a flexible and expandable system that offers a good level of functionality. To allow different technologies to coexist in the same system, it is fundamental to have an abstraction model to represent uniformly every device.

In DomoBus a home automation device is a generic entity characterized by one or more properties. The definition of any device can be done dynamically, adding as many properties as required to express the functional level needed for the device. For instance, if we want to represent an adjustable light, we can describe it in a generic way

using two properties: a “state” property that identifies if the light is turned on or off, and an “intensity” property that represents the light intensity in a scale from 0 to 100%. This model can easily be used to represent more complex devices, for example, a TV. Assuming it is only relevant to control the state, channel and volume of the TV, only three properties are needed: “state” (on/off), “channel” (1-250) and “volume” (0-20). A similar approach can be used with air-conditioners and other equipments.

3.3. Specification Language

The specification language (Nunes, 2016) is very flexible and allows the description of any DomoBus system, with any combination of devices or properties. Also, it allows the description of the house structure where the system is installed. The use of this specification language facilitates the implementation of generic applications that can work with any system. This specification language uses the Extensible Markup Language (XML) and can be extended easily by adding new elements and attributes at any moment. This information can be reused in different systems. Applications will read the XML specification of a given system and house, and adapt automatically to its content.

3.4. Communication Protocol

Given that home automation devices are represented in such a generic and uniform way, this allows the definition of an also simple and generic way to interact with them, which is based on only three types of messages:

- **GET** – Allows reading the value of a property of a given device; using this message one can, at any moment, monitor the state of any device;
- **SET** – Allows writing a new value to a property of a device; this offers a mechanism to change the state of a device and, so, command it;
- **NOTIFY** – This message is transmitted automatically by the devices whenever the value of one of its properties changes. This allows supervision-level applications or user-interface applications to be always up to date, without the need to continuously send GET messages to know the system current state.

4. Solution Design

The literature studied in the previous sections allowed us to carefully analyze the different types of home systems. Its strengths and weaknesses were studied in order to identify what a domestic system should have and not have to satisfy the users. What functionalities needed to be improved or maintained to develop a truly useful home automation solution. In this section, we present a practical solution to capture, apply and adjust the preferences of users of the DomoBus system and resolve conflicts in shared spaces.

4.1. Solution Features

After considering different possibilities for the development of the solution, we defined these central characteristics:

- **Definition of user profiles**: able to represent the preferences of each inhabitant. Should require a low level of interaction with the system. The profiles will allow the user to configure their preferences in detail, as well as the activities they intend to carry out.
- **Refine Existing User Profiles**: The system adapts the profiles automatically, learning from the manual changes that the user makes about their preferences. Adjusting profiles in real time.
- **Conflict resolution between user preferences**: flexible and that considers several important factors such as the hierarchy of users and the intentions of each inhabitant, adapting to each context.

4.2. Preference Areas

The concept of preference areas has been introduced to allow the user to choose what services from the smart home they want to manage. A smart home can have several areas such as, lighting, privacy, air conditioning or entertainment. Each of these areas is composed of specific properties related to the area in question. For instance, the entertainment area can have properties like tv channel, radio station, volume, while the privacy area can include properties like the blind position.

These areas are dynamic and can be modified in number and type. If, for example, a dwelling does not have adjustable blinds, the privacy area can be removed. In another home, it may be helpful to have a safety-related area. If you need to add or remove properties from an area, you can also do it, for example remove the radio station property and add another one related to the type of music.

Of the existing areas of preference, the user can choose which areas he wants to maintain preference for (only two of the areas, or all of them). Each user should explicitly specify a *preference level* for the areas they have chosen. Specifically,

the preference level corresponds to a scale ranging from "very low", "low", "neutral", "high" and "very high", represented by natural numbers 1 to 5 respectively. The preference level will allow the system to resolve conflicts automatically if users that share preferences for the same areas are found in the same space. Briefly, if a user wishes, for example, the temperature to 23ºC, he should choose a preference level (between 1 and 5) for the air conditioning area.

4.3. User Profile Types

The purpose of this dissertation is to create a highly customizable but at the same time automatic solution. Consequently, three types of user profiles have been created: the generic profile, the activity and the specific profile:

- **Generic Profile** - Practical and effective. It is associated with one or more areas of preference, is fast and easy to configure (requires only an initial configuration). This profile allows the user to set their most regular preferences. It is always available and can be used in several houses (own houses, house of a relative or friend). Its operation is automatic.

- **Activities** - Activities serve a different purpose because they are associated with regular practices such as *read*, *watch television*, or *exercise*. They are manually activated by the user and allow tasks to be carried out spontaneously. For example, for the read activity, a light intensity of 90% can be set and sound volume off. While for exercise activity, a volume of 80% and radio station can be set. The activities are individually configured by each user and are also independent of the dwelling.

- **Specific Profile** - This profile is auto-activated and allows users to specify their preferences according to a room (for example the living room) or set of rooms (for example all kitchens). This type of profile also allows you to individually configure the devices in a room. Consequently, due to being highly configurable this type of profile requires a investment by the user. It may be useful, for example, if you want to set particular conditions for working in the office.

The table 2 summarizes the main characteristics of each user profile type. *Note that the specific profile is only compatible with any housing if the user does not specify any concrete devices or rooms.

4.4. Conflict Detection

Assuming that the system will be used within a smart home, the location of the users should always be known. Our algorithms use this information to resolve conflicts and apply user profiles. This information can be obtained through the use of smartwatches, smartphones or an equipment that allows the automatic recognition in the entrance and exit of a division. Knowing this information it is possible to determine if the profiles/preferences of the users who are in a shared space are in opposition and immediately apply the conflicts resolution mechanism.

4.5. Conflict Resolution

The conflict resolution strategy is based on the solution presented by Park et al. (2005) and takes into account the user preference levels for each of the areas of preference. In conflict resolution, the final value of each property is calculated separately. For example, the value that the system assigns to the light intensity property is calculated separately from the value to be assigned to the temperature property. A new parameter was introduced to the original equation that represents the hierarchy between users. Since all users have a level of access, it acts as a hierarchy, ensuring a greater impact on conflict resolution for users with greater access.

The solution to the *cr* equation, will be what the system will apply to the property. The variables *La* and *Lb* represent the preference level of user A and B, respectively, over the preference area. The variables *Aa* and *Ab* correspond to the level of access or privilege that users A and B have before the system. The Pa and Pb variables are the values that users A and B, respectively, prefer for the property. The equation allows the addition of more users.

$$c_r = \frac{La \times Aa \times Pa + Lb \times Ab \times Pb}{La \times Aa + Lb \times Ab} \quad (1)$$

On the other hand, in situations that exist enumerated values, such as, television channels, radio stations, favorite types of music, the approach will have to be something different because its not possible to counterbalance concrete things like a channel. In order to solve these types of conflicts it is then proposed that these situations be solved using a table. We assign each of the available channels a value, which corresponds to the multiplication of the user's preference level (for the entertainment area) by their access level. In a situation of a tie, the system gives priority to the TV channel that has the largest number of users' watching. Finally, if there is also equality with the number of users, priority will be given to the preference of the user who has been in the division for the longest time.

Table 2: Overview of the different user profile types

	Profile Types		
	Generic Profile	Activity	Specific Profile
Operating mode	Automatic	Manual	Automatic
Compatible with any home	Yes	Yes	Yes*
Allow room config.	No	No	Yes
Allow device config.	No	No	Yes

4.6. Profile Refinements

In order to better represent changes in user's preferences over time, it is useful to have a dynamic adjustment mechanism for their profile. This mechanism, which may or may not be active, allows that when a manual change is detected in a device, a profile adjustment is triggered, recalculating the value for the changed property. Thus, whenever a user manually modifies a value of a given property, the system will automatically update its profile. The adjustment that is made to the profile takes into consideration the magnitude of the change made and the number of occasions that the same property has already been changed. Changing a property once should not mean much, but changing it continuously means that the user is not satisfied with the value of the property and the change should be more meaningful. To achieve this end, the following function is proposed:

$$a_p = \ln(kn) \tag{2}$$

In this function, *k* represents the value of the manual change made by the user and *n* the number of changes made to the property. The variable *n* starts at 1 since refinement is only performed at the time of the first change on a property. The function used has a logarithmic growth, which is gradual, to not change drastically the user preferences. The stability of the value of a property must also be taken into account. To do so, as time passes, the value of the variable *n* will be decremented automatically, reducing the weight of changes that have occurred for a significant time. This will only consider changes that correspond to frequent adjustments. Profile refinement can also be disabled and enabled as mentioned, and it is also possible to retrieve the original profile. In situations where there are multiple users in the same space, the mechanism is disabled because it is not possible to identify the user who made the change.

4.7. Architecture and Technologies

The final solution consists of two main components. The Profile Manager is the tool responsible for creating and managing the profiles used. Users interact directly with the tool through a graphical interface that links all operations. There is also a second component responsible for applying and connecting the mechanisms of the solution. This second component is intended to apply user profiles correctly, resolve conflicts between preferences, and apply optimizations to profiles. The result produced are actions on the environment in which the users are. Data persistence is achieved using a XML file, from which user profiles are read and saved. The domobus communication protocol is also used to apply actions over the devices, in order to satisfy users preferences. The adoption of this protocol allows to implement all mechanisms in a real system if needed.

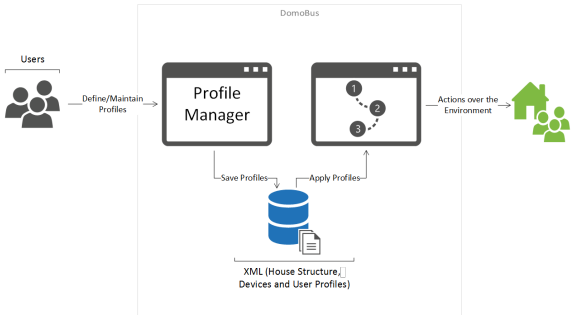

Figure 2: Solution Architecture

For the development of the solution, we choose the Java language as well as the software *NetBeans IDE*. The JavaFX and JFoenix libraries were used together with the Scene Builder software to simplify the creation of the user interface. The graphical component of the application uses a library based on the *Material Design* made available by Google, this design is standardized and similar to what we find in tablets or smartphones, thus facilitating the use by any user. Profile Manager works on Windows, Mac OS X, and Linux.

5. Validation

This section describes in detail the implementation of the solution prototype which has two main objectives: (1) develop a graphical interface for users to manage their profiles and (2) test the use of user profiles, conflict resolution mechanisms and adjustment of the profiles. For this reason we have developed two tools, the Profile Manager, which allows users to define their preferences and establish their profiles, and a simulator, whose purpose is to validate using concrete scenarios the effectiveness

of the profiles and their mechanisms.

First, different practical scenarios were used, which make possible to understand the usefulness of each feature. Subsequently, a series of evaluations were conducted with a group of users. The main objective is to gather information about user expectations, opinions and difficulties interacting with the Profile Manager and ensure that the main objectives have been achieved (regarding usability and user experience). These two evaluation methods allowed us to validate the completeness and effectiveness of the solution.

5.1. System Prototype

Profile Manager is a software designed for smart home inhabitants or visitors to define, edit and view their user profiles. Since the purpose of this dissertation is to develop a user-centered solution, one of the tool's highlights is usability. Its intuitive and practical interface allows users to quickly learn, making profile creation efficient. The core functionalities of the application are: access control, user's management, and profile's management.

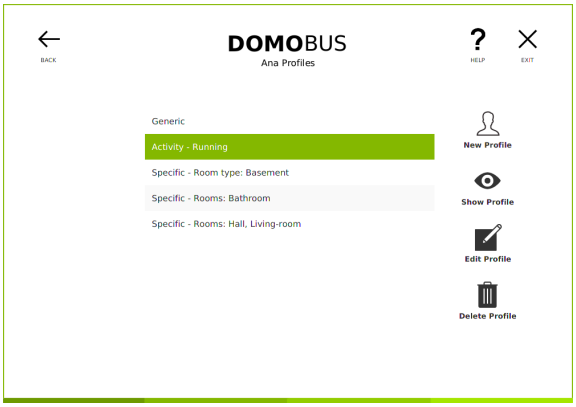

Figure 3: User's Profile Management Menu

After successfully logging in, regular users go directly to the profile management window (see Figure 3). Here user profiles are displayed as a list, sorted by profile type. In the bar on the right side of the list there are multiple buttons, namely: *New Profile*, *Show Profile*, *Edit Profile* and *Delete Profile*. Their names are self explanatory.

In the process of creating a new profile (Figure 4), first you must designate the type of profile you want to configure: Generic, Specific, or Activity. In the case of selecting the Generic Profile (one per user) you will be encouraged to configure one or more preference areas. To define a new Activity, the process is similar to that of the Generic Profile, the difference is that the Activity also has a name associated with it, to facilitate its identification. Lastly, the Specific Profile must also include a division or several divisions (including Room Type), where you apply the preferences.

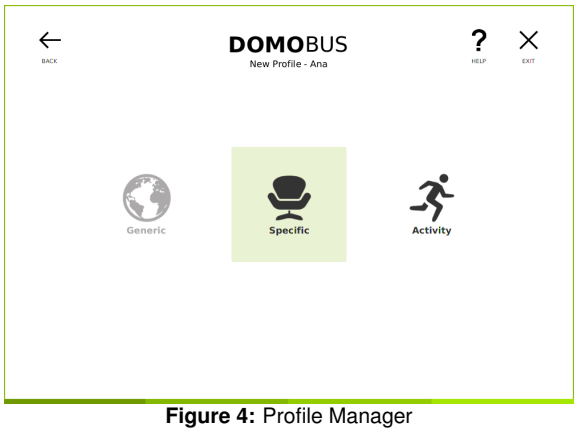

Figure 4: Profile Manager

In addition to the documentation produced (like the User Manual), all menus have also a specialized help. Interface elements may be unknown to some users if they ignore the manual reading, for this reason, there is quick tips to immediately contextualizes the user.

The main objective of the simulator (presented in the Figure 5) is to apply the mechanisms conceptualized in the previous section and guarantee their usefulness in real scenarios. The simulator assures three fundamental aspects. The correct use, according to the situation, of the different types of profiles configured by the users. When multiple users share the same space, confirm that the conflict resolution mechanism adopted is actually effective. Finally, ensures that profiles continually adapt to changing user preferences.

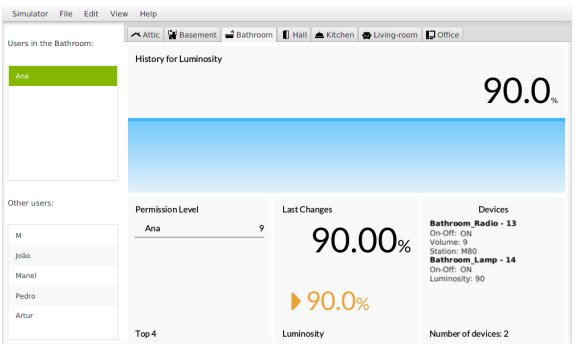

Figure 5: Simulator

The simulator allows users to explore multiple scenarios. It is possible to obtain and compare information on the current state of the profiles, properties and devices of the dwelling. The main features offered are:

- **User Control** - concretely one of the central points of the simulator. This feature gives the possibility to move the users of the DomoBus system in real time to any division. Moreover, this functionality allows to explore numerous combinations between the preferences of

users and observe the application of all the mechanisms developed;

- **Supervision and Information** - the simulator allows to activate and deactivate the Activities configured by the users. Information about the state of housing, divisions, devices and profiles is displayed;
- **Profile Statistics** - for each refined profile it is possible to analyze the graph corresponding to the automatic changes made on the profile, in order to follow its evolution;
- **Communication with DomoBus** - Through the use of the communication protocol of the DomoBus system our application communicates directly with other applications that use the same protocol. This is especially relevant because we can, for example, see real-time information made available by devices.

5.2. System Scenarios

The different scenarios proposed correspond to some practical examples of application of the user profiles and underlying techniques. These scenarios described below allow to understand the functionalities of the solution, as well as understand its usefulness:

Table 3: Usage Scenarios

Scenario	Description
Morning rush	Every morning before going to work 'João', likes to turn on the TV channel SIC in the kitchen, to view traffic information. When entering the bathroom, the user enjoys 90% light intensity and to listen to the M80 radio station.
The living room Activity	A user is in the living room reading a book and starts a movie of his interest in the TV. As such, he selects the 'Watch Movie' activity that recognizes his lighting preferences, temperature and blindness level.
Conflict in the Kitchen	When preparing breakfast, 'Ana' likes to listen to the RFM radio station and the luminous intensity level at 80 %. 'Pedro' enters the kitchen at the same time as 'Ana' to prepare his breakfast too. However, this one has preferences over the radio station, preferring RFM, the temperature at 24º C and the luminous intensity level at 55 %. Later, Joao joins and he likes the temperature at 21º C and the light intensity level at 40 %.
Refinemente of a Profile	'John' had an ideal level of the light intensity of 40 % on his profile. However, this level no longer suits his needs. So he changes this value 5 times, manually, to 90 %.

5.3. Usability Evaluation

The usability evaluation consisted of 8 tasks that allowed users to explore the Profile Manager and use all the available features. Thus it was possible to ensure full coverage of the tool and receive feedback on the user experience. Users started by performing simple tasks such as creating a user, and in the end, they were asked to create a more complete profile. Users have created the three types of profiles and deal directly with the associated concepts, such as preference area, preference level, properties and their values.

In total, 9 users participated in the evaluation of the Profile Manager. In the group of participants all were familiar with the use of smart phones, tablets or personal computers. The evaluations were carried out in person, in this way it was possible to follow the whole process of interaction with the tool. In the end, it was still possible to share ideas and discuss some aspects of the solution.

All users performed the same set of tasks. For each task the average and the median were determined in relation to execution time, number of errors and user experience, in order to statistically analyze the results.

5.4. Results and Discussion

The results of the implementation of the user profiles and the respective mechanisms were very positive. The simulator allowed to carry out several experiments with the user profiles and the multiple possible combinations. We used the different scenarios presented in the subsection 5.2 together with the simulator, to guarantee the completeness of the solution. Some users even used the simulator to control the movement of the inhabitants and confirmed the application of the profiles they defined. There were several positive points to be retained, namely the validation of the mechanisms developed, the effectiveness and completeness of the solution when put to the test by concrete scenarios. The additional functionalities implemented in the simulator to compare, present and query information were particularly useful to follow all changes to the profiles and devices of the divisions, keeping the user always informed.

Regarding the usability evaluation, it can be seen from the graph of Figure 6 that the average time to create a Generic Profile (task B), an Activity (task E) or a Specific Profile (task F) was about one minute, indicating that most users performed the assessment correctly and within the expected time frame. The individual average of the remaining tasks (create an user, viewing current profile configuration etc.) did not exceed 35 seconds. It is important to note that most users did not read the user manual, they have freely navigated through Profile Manager without knowing any details about creating a profile. It can be seen that the profile creation time has decreased as users knew the ap-

plication better, even though the task of creating the Specific Profile is the most complex. These observations indicate the efficiency and ease of learning of the application.

No mistakes were made in user creation (task A) and user removal (task H). The task that registered more errors was precisely the creation of a Generic User Profile (average of 1), clearly influenced by the initial lack of knowledge of the application interface. However, all users were able to recover from the errors successfully. In the creation of the Activity and Specific Profile it was observed a reduction of the errors committed for half, due precisely to the ease of learning of the interface.

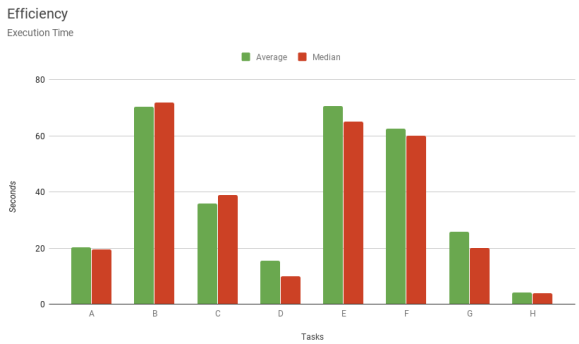

Figure 6: Execution Time

As far as the user experience is concerned, it can be said that it was one of the very positive points of the evaluation. The graph of Figure 7 allows us to observe the results of the questionnaire to users about their experience with the Profile Manager. All tasks have achieved a high rating, on the scale of one to five, in which five means that the task was very easy to accomplish and one that it was very difficult.

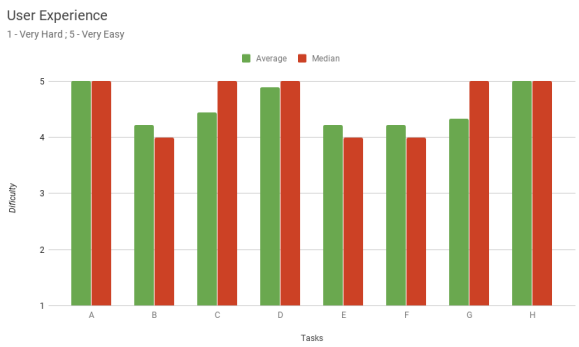

Figure 7: User Experience

User assessment is a vital phase in the development of a user-centric solution, and these results effectively verify user's satisfaction with the use of the application and features.

6. Conclusions and Future Work

The popularity of smart homes has increased in recent years. However, its disclosure has been slow compared to what was anticipated, since current solutions still have some limitations (Brush et al., 2011). Existing systems are mostly based on technology-centric approaches rather than simpler, user-centric solutions (Andrés et al., 2016). The success of smart homes is directly linked to the satisfaction of user needs and ease of use.

In this context, the present work introduces the concept of *user profile*. A profile offers the ability to customize the system, allowing users to express their preferences in a detailed or generic way. Three types of profiles were proposed, the *Generic Profile*, the *Activity* and the *Specific Profile*. The Generic Profile has as main characteristic the easy configuration of the preferences of a user, independently of the dwelling. The Activity gives the user the possibility to define and activate, at any moment, their preferences to perform a certain task. The Specific Profile guarantees the possibility to configure in detail the parameters of certain devices and also to personalize the preferences according to the division of the house. Because not all users share the same preferences, there is a need to resolve conflicts between different user requirements. The resolution mechanism takes into account multiple factors, namely the hierarchical level of users, the preference expressed by users for a particular aspect, the number of users involved and the order of arrival in space. In addition, a mechanism has been proposed to refine a profile that takes into account the number of times a user manually changes a property of the environment and the magnitude of that change, automatically adjusting its profile.

To validate the potential of the presented solution and its respective mechanisms, an application was developed to manage the profiles of different users and to simulate the operation of a house, following the DomoBus model. The management and creation of user profiles is ensured by the Profiles Manager. The developed simulator allowed to evaluate in practice the effectiveness of all the developed mechanisms, using a set of scenarios representative of the daily life of the users. The mechanisms worked successfully and showed good results. The results of the evaluation with the real users concluded that they were able to create their own profiles in less than a minute and a half. The final solution received a very positive feedback regarding usability, efficiency and user experience, fundamental aspects of a user-centric system.

6.1. Future Work

In the next step of the *User Profiles* project might be relevant to improve the user experience as well as the portability of the system, for instance, it could be interesting creating and editing profiles directly from a smartphone or through web pages.

Furthermore, It may be worthwhile to introduce an explicit feedback mechanism during conflict resolution, which continually improves with the feedback provided by users.

Additionally, It would be also interesting to automate the definition of the generic profile of each user, as well as introducing the energy optimization aspect to the user profiles. This can increase the degree of customization of profiles, hence attracting more users to use the system.

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