Smart3E: Enabling End Users to Express Their Needs for Smart Homes

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***Abstract*—The rapid development of Internet of Things (IoT) technology makes smart homes a reality, where many user-centered service scenarios are yet to be built. For such applications, it is of utmost importance to let end users express their needs easily on the one hand, and these users' expectations can be interpreted by the smart home systems accurately on the other hand. Unfortunately, existing requirements languages are not for end users to express their needs in daily terms. An easy but expressive requirements language is required. This paper carries out a survey on suitable and expressive requirements description language for smart homes. Based on the results, a user requirements description language *Smart3E* is designed for *e*nabling *e*nd user *e*xpressions. This paper also puts forward the challenges that are needed to be addressed when allowing end users to express their needs freely in smart home domain.**

***Index Terms*—Internet of Things, Smart Homes, Requirements Description Language**

I. Introduction

Smart homes, a kind of IoT-enabled systems, connect a variety of household devices to provide intelligent services experience to end users. They promise higher quality of life with increased comforts and convenience. However, currently many smart home systems are criticized as they only support remote control and allow end users choosing the services from a few predefined functions instead of expressing their needs freely. In summary, these systems are not sufficiently taking user requirements into account [2]. There are proposals to collect feedback from end users for helping to elicit requirements [1]. But these efforts may be limited to deliver richer function list and the status quo of only allowing end users to choose existing functions has not changed.

Designing languages for allowing end user to express their needed services in smart homes has been highly-demanded [2]. In fact, this has been a well aware fact in the smart home domain. A language called trigger-action programming (TAP) is proposed for allowing end users without programming experience to express their requirements. TAP has already been adopted in many IoT platforms such as IFTTT, SmartThings, Homekit and Alexa. It takes the form of "IF <trigger> THEN <action>" and the rule-based representation can be used to express the behaviors of the home automation. However, using TAP rules needs end users to give precise device operation instructions and they are far from sufficient to cover the users' broad variety of desired behaviors and expectations [3]. Currently, new smart devices are constantly emerging and service scenarios may also become more and more abundant. It is not realistic to let end users write their own device scheduling plans consisting of precise device operation instructions. One of the solutions could be to let end users only give the requirements and the system generates the device scheduling plans that can fulfill the requirements.

However, existing requirements languages in RE community are not very suitable for smart homes. Heavyweight requirements modeling languages, such as KAOS and I*, are for professionals, not for end users. Lightweight requirements description languages, such as EARS and boilerplates, are easy to master, but they only focus on what a "system" should do or respond instead of what the "user" wants in a smart space.

To make the smart home truly "smart", we believe that the system must at least understand the needs of end users expressed in everyday language about their daily life scenes, rather than just listen to the end user's instructions. This paper conducts a survey study on the preference of end users when expressing their needs about smart homes and designs an end user language *smart-3E*. We also identify the challenges in understanding the end user requirements descriptions and generating the executable IoT device instructions to deliver expected services to end users.

II. Research Method and result

The survey is designed with four groups of questions. All the questions are listed at http://re4cps.org/survey. The first (including Q1-Q5), is for collecting the demographic data of participants. These questions relate to participants' gender, age, marriage, education, whether they have computer science related majors, and whether they have smart home knowledge. The purpose is to show the participants' representativeness.

The second (including Q6-Q8) is for evaluating participants' familiarity with smart devices. In which, Q6 and Q7 are to figure out whether the participants are familiar with functions of traditional devices (such as air conditioner) and smart devices (such as tower fan). Q8 is for finding out whether they know the energy consumption of the devices or not.

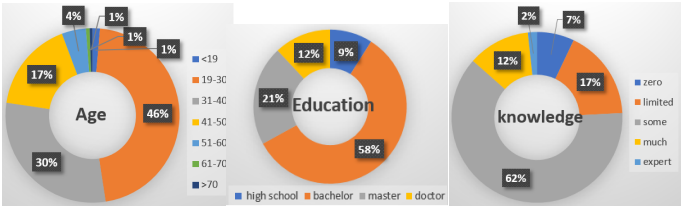
The third (including Q9-Q18) aims to learn how participants usually express their service requirements of smart homes. Among them, Q9 to Q14 are to find whether they prefer device related or unrelated expressions. Q15 and Q16 are for

helping determine whether participants are capable of dispatch the devices. Q17 is for investigating the expressions including keywords "always" or "never" in requirements descriptions. Q18 invites participants to freely write their own requirements for certain service scenes, e.g. in kitchen, in daily terms.

The fourth considers the user preferences that relate to non-functional and quality-based factors, such as safety, privacy, energy-saving etc. Three questions (Q19-Q21) are designed to acquire the natural expressions about these properties.

This survey was conducted by the process: (1) questionnaire distribution via social media in China and accessible academic communities; (2) collection of the feedback; and (3) data analysis, which lasted for a month at the end of 2020. 572 participants were invited and 567 valid answers were collected.

The results of demographics analysis is as follows. 266 (46.91%) participants are female, and 291 (52.38%) participants are married. The ages distribute from under 18 to over 71 as shown in Fig. 1(a). The educational background of participants is comparatively high, which can be seen from Fig. 1(b). 268 (47.27%) participants have computer related majors, but their knowledge about smart home are different which is shown in Fig. 1(c). From the above statistics, we can see that the participants are representative in terms of gender and age, for end users with comparatively high education level and computer knowledge.



(a) age (b) education (c) smart home

Fig. 1. Demographics analysis result

Other results are as follows. Most participants are not familiar with the functions and energy consumption of smart devices. They give device-related and device-unrelated expressions, "always" and "never" requirements, time and space related expressions as well as non-functional preferences. Details can be found in Annex at http://re4cps.org/documentation#posters.

III. Language and Challenges

This section presents our thoughts on the language design.

a) Requirements description language Smart-3E: The survey results indicate that template-based language for functional requirements is suitable. Some of the templates are given in table I. The non-functional preferences can be attached to the functional requirements, which can be safety, security, energy-saving, privacy, etc.

b) Challenges to the RE Community: Two main challenges are faced for realizing smart home requirements.

Challenge I: Dynamical generation of service plans for on-demand requirements. The service requirements of smart home may vary from person to person and from time to time. Unified predefined services can not reflect intelligence. Moreover, service suitability is constrained by the natural environment. It is highly needed for smart home systems to be equipped with the capability of dynamically generating the on-demand device scheduling plans for delivering services.

TABLE I
REQUIREMENTS TEMPLATES IN *Smart-3E*

Type	Requirements Template
device-related requirements	if <trigger>then <event>(in location)
	if <trigger>then <state>(in location)
	<state>should always hold (in location)
	<event>should never happen (in location)
	<state1, state2, ...>should never occur together (in location)
Device-unrelated requirements	preferred <attribute>is <value>(in location)
	<attribute>should always/never be above/below <value>(in location)
	if <trigger>then <effect>(in location)
	<effect>should always hold (in location)

Challenge II: Non-functional preferences aware service plan selection. Appropriately responding to non-functional preferences is a manifestation of higher intelligence. The scheduling of devices needs to consider non-functional preference when delivering services. How to dynamically perceive the non-functional preference and adjust the service plans in a timely manner is a very challenging problem.

We have done some initial work. A tool called *DSIGS* (*D*evice *S*cheduling *I*nstructions *G*enerator and *S*imulator) is developed, which can be accessed at http://re4cps.org/dsigs. It accepts the requirements description in this template-based language, parses the statements and automatically generates the device scheduling plans.

IV. Conclusion

This paper conducts a survey that motivates the research of understanding the end user requirements. We then designs a requirements description language *Smart-3E* in smart home domain. A tool *DSIGS* is initially implemented that can understand the end users' requirements written in this language and generate the service plan. We identify main challenges to RE community on understanding the end user requirements and generating executable IoT device instructions in smart home domain.

Acknowledgments

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