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Enabling personalisation of remote elderly assistance

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Abstract
One of the goals of Ambient Assisted Living (AAL) solutions is to extend the time that elderly people can live independently in their preferred environments by using ICT technologies for personal healthcare. However, in order to be optimal, remote monitoring services and health-related interventions should be strongly personalised to specific individuals' requirements, preferences, abilities and motivations, which can vary among the elderly, and even dynamically evolve over time for the same person depending on changing user needs and context-dependent conditions. In this paper we present an End User Development (EUD) tool for the personalisation of context-dependent assistance by non-technical users in the AAL domain. In particular, we have considered applications for remotely monitoring and assisting elderly people at home through sending multimedia messages and reminders, as well as changing the state of various domestic appliances (e.g. lamps, heating system, TV) and devices available in the context surrounding the user. The design and development of the tailoring environment has been carried out in an iterative manner, informed by the feedback that was gathered through empirical evaluations done with older adults and caregivers.

Keywords End-user development · Ambient assisted living · Personalisation rules

1 Introduction

Nowadays, context-dependent adaptation is acquiring increasing importance in many applications and services covering a plethora of different domains. With the advent of the Internet of Things (IoT) its relevance is even higher given the increasing number of user environments characterised by the presence of sensors, objects and devices, according to which applications need to dynamically tailor their behaviour. In addition, applications that are targeted for highly

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assorted populations, also have to be dynamically customized according to the needs of specific end users. All these aspects are especially relevant in the Ambient Assisted Living (AAL) domain, particularly for solutions targeting the elderly population. Indeed, older adults are a highly heterogeneous target group in terms of familiarity with technology, activity level, number and quality of social relationships and physical and mental well-being. This translates into highly diverse requirements, making it challenging for developers to design technological solutions which fit all of them. In addition, elderly also have specific aging-related requirements that are likely to evolve individually over time. In such environments it could be very difficult for developers to foresee all the possible context-dependent scenarios (and associated customizations to support in the software) because there could be some unanticipated (at design time) needs that should be incorporated at runtime, when the application is actually used. Fortunately, the increasing affordability and availability of technology has also promoted new types of participation by end users in the creation process of software to improve the flexibility and acceptability of technological solutions by final users who at some point might want to incorporate new behaviour in their applications. End User Development (EUD) approaches [16] can be particularly relevant since they cover methods and tools that allow non-professional developers to create or modify their applications, without assuming specific technical background from their users.

In this paper we present an environment enabling end users to customize the behaviour and appearance of Web applications and associated appliances in a context-dependent manner, by using an intuitive trigger-action paradigm. The solution can be applied to remote assistance applications, since in-house monitoring of elderly using intelligent ubiquitous sensors has emerged as a useful AAL service due to its potential of increasing the independence, safety and quality of life of the elderly while minimizing the risks of living alone and avoiding the costs of more expensive hospitalization solutions.

Combining the data originated by the sensors installed in the elderly's house and exploiting the tool for dynamically tailoring the applications' support, both elderly (having some familiarity with technology) and people providing informal and formal care to them (e.g. family members or medical staff) can be empowered to, for example, set up vocal reminders, visual alarms and multimedia messages for promoting a healthy lifestyle of seniors, check their adherence to medication, support monitoring functionalities, so adding new personalization possibilities not foreseen at design time, and specified in a context-dependent manner. The personalisable actions supported by the platform range from user interface modifications, to sending multimedia messages, to the possibility of changing the state of domestic appliances (e.g. lamps, heating system and TV) and to the possibility to provide richer prompting information to seniors by using the multimedia capabilities offered by controlled devices (e.g. tablets, computers, mobile phones) available in the context surrounding the user. The resulting environment has also been tested by a set of elderly people and caregivers.

The main research question we want to address in this work is to understand whether a EUD tool based on the trigger-action paradigm can be usable and useful for caregivers and even seniors (having some familiarity with technology) to specify personalised context-dependent behaviour to support more autonomous life of seniors at home. In particular, in this paper we mainly focus on the evolution of the personalization rule editor, which is exploited by end users to define their personalization for elderly assistance. The editor has been designed and developed through iterative cycles, and has been validated through multiple user tests. After each test, the editor visual structure and how to interact with it has been improved taking into account the feedback received from the participants.

2 Related work

In the AAL domain, the emergence of tools for older adults based on ambient intelligence paradigm has been identified and reported [11, 21]. In particular, Demiris and Hensel, after doing a review of some AAL smart home projects, highlight the need of going beyond systems just aiming at supporting extensive monitoring of residents where the results of the associated analysis are generally available to health care providers only, thereby emphasising the need of pursuing approaches better empowering patients/residents to play a more active role in the care process so that their actual needs are taken into account, also to increase users' technology acceptance.

In addition, still in the AAL domain, also the need of providing older adults with personalised services has emerged [27]. Previous work in this area include the contribution by Carmien and Fischer [20] who present the Memory Aiding Prompting System (MAPS), an environment that can be used by caregivers to create scripts for people with cognitive disabilities to support them in carrying out daily tasks. Tetteroo et al. [25] propose TagTrainer, a physical rehabilitation technology that supports physiotherapists in the creation of customized rehabilitation exercises for people with neurological impairments. Each of the latter two contributions addresses a specific class of target end users (respectively: people with cognitive disabilities and people with neurological impairments) who need 'mediators' to have their customisations realised (respectively the caregivers providing support for cognitive exercises, and the rehabilitation therapists). Since our work targets quite active elderly people, in our case the boundaries between 'clients' and mediators' are more blurred as even the elderly themselves (having some familiarity with technology) can directly specify their customisation needs through the provided platform.

One further relevant aspect concerns tools helping seniors reach their goals with IT products by working with their caregivers. One example is the work of Zhao et al. [30] who present the CoFaçade approach helping elderly people to reach their goals using digital artefacts by working collaboratively with helpers. In this approach, seniors use a simple interface having a small number of customizable triggers, which are mapped to procedures that accomplish high-level goals with any IT product. The caregiver uses a customization interface to link triggers to procedures that accomplish recurring high-level goals with IT products. To demonstrate the effectiveness of their approach, the authors implemented a prototype using a handheld physical trigger interface and a desktop customization interface for defining procedures for both computer applications and consumer electronics. While this approach goes in the direction of supporting the elderly in their everyday tasks, differently from our solution they do not consider context-dependent aspects that can modify the execution of procedures.

Also less recent work considered the need of enabling the elderly to customise their applications and environments. A tangible interaction technique using magnetic cards to empower the elderly in augmenting their ambient environment with software-driven personalized behaviour has been presented [10]. In particular, NFC-enabled magnetic cards allow elderly users to create personalized behaviour for their ambient environment and a digital memo board acts as a place holder for active behaviour ensuring the metaphoric resemblance of a memo board and post cards. However, this work is deeply centred on tangible interaction, while we consider Web applications because they can operate through a plethora of different devices.

Previous work [9] aimed to provide means to let end users create rule-based smart behaviour through the notion of object augmentation. However, in that work the developers still play a central role since they have to define, implement and install an augmentation module, while end users are expected just to configure the augmentation once it is installed by developers.

The trigger-action approach is emerging as a useful paradigm to allow people without experience to connect and integrate devices and services. Lucci and Paternò [17] reported on a user test with three Android apps (Tasker, Atooma, and Locale) supporting it. It revealed that the one able to support most features (Tasker) was the least usable in terms of task performance and errors, thus revealing the need for more careful design of such environments.

IFTTT (IF This Then That, https://ifttt.com/) is a well-known tool that allows people without programming experience to create simple applications according to the pattern IF <something happens> THEN <do some action>. IFTTT allows for connecting widely used Web services. However, compared to our approach, which allows for combining multiple triggers, it has lower expressiveness, since it does not allow users for combining multiple events and action, whereas previous work [26] found that even inexperienced users can quickly learn to create programs containing multiple triggers or actions. Another contribution [1] reported on a test with IFTTT and Atooma and provided some indications for the design of new tools, which included that they should support the combination of more than one trigger and more than one action in the same rule. This shows that the trigger-action approach seems suitable to support EUD of context-dependent applications, but needs to be improved in order to allow users to express various desired combinations of events and corresponding actions. For this purpose, some authors have considered the 5 W model [12], in which five standard questions are analysed when specifying rules. This allows users to provide complete descriptions but it could make the specification phase too elaborated, especially for people without technical background. Corno and others [6] have explored the use of semantic Web ontologies to support the creation of more complex rules but it is difficult to model them in such a way to be easily understood by end users.

In addition, as highlighted in [14], rule-based approaches, and in particular trigger-action rules, could raise some ambiguity in their interpretation due to potential discrepancies in end users' mental models. An established theory of mental models has been used [19] to guide the design of interfaces for EUD so that people can easily comprehend and manipulate logical expressions. According to such theory, people find it easier to conceptualize logical statements as a disjunction of conjunctions (an OR of ANDs), as opposed to other logically equivalent forms. Thus, the authors propose a paradigm to facilitate the specification of complex logical expressions, which however is still far from providing general solutions. Coutaz and Crowley [8] also point out the importance of supporting deployment under real-world conditions, incremental installation of devices and services, and meaningful feedback and feedforward, and i report on actual usage by older adults and caregivers of the proposed personalization environment.

In this work, we consider the TARE platform [13], a platform for supporting adaptation of Internet of Things applications. It has been used for tailoring the behaviour of a students' home [5] to investigate the opportunity and feasibility of using its strategy for tailoring applications; however, that work considered young people (students), which is a rather different population from the one considered in this work. In particular, in this paper we present how the tailoring environment has been designed to better support customisation of context-dependent applications supporting elderly based on feedback received in various iterations. Thus, the contribution of the paper is to present the evolutionary design that a personalization platform supporting EUD through trigger-action rules has undertaken -through a number of evaluation cycles- in the specific domain of AAL, and show the results of such iterative design that can inform applications and tools with similar goals.

3 The personalisation environment

3.1 Requirements

An initial requirement elicitation activity was carried out [3], in which we addressed mainly two classes of stakeholders: elderly users and informal caregivers. We involved both user groups from the earliest stages of the design phase, so that their views, knowledge and feedback could be fed into the design and development of the platform. For each type of stakeholder separate processes were conducted to understand current practices, as well as opportunities for meaningful customizations in the AAL domain.

We submitted a questionnaire to 71 older adults. The large majority of respondents was in the age group of 65–74 years (64%), followed by 21% in the group between 75 and 85 years, and 11% between 55 and 64 years. A minority was over 85 years old, none of the respondents was younger than 55 years old. Since the considered sample was mainly composed of active and overall healthy elderlies, on the one hand it came out that continuous monitoring due to health issues is scarcely required. On the other hand, the need for not only having features tailored to specific individual abilities, but also to specific lifestyles and living environments significantly came out. Transparency, data control, and social aspects were identified as other relevant user needs.

Two interactive workshops, one survey and three personas were carried out with the aim to analyse the types of daily routines and health-related activities which informal caregivers are confronted with daily, to understand how elderly people interact with their caregivers and whether opportunities for personalisation can be identified. In the end, a fully gender-balanced group of eight people aged 55–80 years participated over the two workshops. Caregivers report that elderly people having strong dependency needs require help with their hygiene. Moreover, healthy nutrition (including a sufficient water intake) is another important factor for elderly. Indeed, with ageing, the metabolism slows down, so while fewer calories are needed than before, elderly need more of certain nutrients, therefore they should be supported in properly selecting food that gives them the best nutritional value, according to their own health status and possible specific diseases they suffer from. In addition, informal caregivers highlighted the need of providing support with mild changes in memory and other thinking skills that are common as people age e.g. forget to switch off appliances, which is especially critical for e.g. stoves and irons. Moreover, several older people mentioned the need of being helped by a "medication plan": as individuals get older, comorbidity becomes more frequent, thus there is the need of personalised support in properly managing multiple medications. The need for personalisable or adaptable solutions was found for two main dimensions. The first was to improve the usability of ICT based solutions, due to the different abilities and experience of the target population, and provide the most adequate content to the end-user, based on user's preferences and needs. The second aspect is the social dimension, which should be considered not only for promoting social activity among elderly, but it can also work as a personalised motivator for physical activity [18]. Indeed, as highlighted in [24], motivation is a critical factor in supporting physical exercise, which in turn is associated with relevant health outcomes.

We also analysed the state of the art in the area of AAL solutions for elderly, to identify further user needs as well as key requirements of AAL systems. An interesting work in the AAL domain [23] analyses the issue of older people's trust in AAL technology. Fifty (50) participants aged between 60 and 90 years (average age: 71.3 years) were surveyed about the perceived positives and negatives of using technological support in everyday life. The analysis was based on data collected in semi-structured, face-to-face interviews. Considering a 10-point Likert scale, in the study men had distinctly higher levels of trust in sensor technology than women (7.6 vs. 6.8). In addition, people living together with another person showed higher trust in sensor technology than people living in a single household (7.8 vs. 6.4). Regarding which characteristics formed the basis for trust in technology, reliability and ease of use (both scoring above 9.5) were assessed as the most important aspects, followed by visibility (i.e. the exclusive use of invisible sensors may lead to lower trust levels in AAL) which scored 8.45, whereas costs only slightly influenced (3.90) reliance in AAL technology. In our work the choice of the sensors to address was consistent with such requirements. Cesta and others [2] report the results of a systematic work devoted to the elicitation and validation of users' expectations on AAL intelligent services. They involved about 135 persons among elderly and caregivers for gathering their feedback. Results show that users appreciated the potentiality of AAL solutions in supporting independent living and in improving quality of life, although privacy concerns have been raised especially by elderly people. The importance to make users understand the meaning and the value of what the system can do clearly emerged, highlighting that in this way a service that is considered useful is also more acceptable. The obtained results have then been used to derive a list of priorities associated to services, which can provide advice for system developers, mainly pointing out the importance of building intelligent technology that can be adapted and personalized according to varying users' requirements. These requirements can lead to systems that better respond to the individual needs of supporting the elderly in living independently in their own homes. Along the same line, Kerbler [15] proceeded from the assumption that most elderly people have negative attitude toward technologies, but also that correctly informing potential users, raising their awareness and understanding of the usefulness of remote home care are important for elderly acceptance of ICT innovation in home settings. One hundred fourteen users were interviewed and from the analysis it emerged that services must, in the first place, be in line with the needs, habits, desires, and opinions of those who will use the new technologies and related services. Implementation of these innovations must therefore emerge from a model that actively involves users and identifies them as the main actors in this process. To sum up, the need of having solutions able to take into account the wide spectrum of seniors' characteristics, preferences and routines was acknowledged as a relevant need for smart AAL solutions. As for the factors that can impact elderly's acceptance of AAL solutions, previous work [29] highlights that, in order to get ambient intelligence closer to seniors and to improve their quality of lives, it is necessary to focus on their *deep needs*, which were identified as belonging to four main categories: keep their autonomy and live in their home, stay in touch with their close, feel competent as well as helpful and dignified. If such needs are not being considered enough, seniors will not adopt new technologies or even refuse them. Therefore, Zejda [29] highlights the importance of designing AAL systems reflecting the deep needs of elderly people, so that such systems can likely become not only accepted, but also adopted and even gradually appropriated by users. Our work goes in the same direction, since in our approach the actual consideration of the deep needs of older adults is guaranteed by the fact that elderly themselves (who are the actual 'owners of the problems') or people who have an intimate knowledge of elderly (i.e. caregivers) can directly specify relevant customisation needs through the platform over time without the intervention of external professional developers, so as to neatly match elderly's current living patterns, routines, habits, and preferences.

A relevant role in identifying seniors' needs and providing support to them is represented by those who provide care to them. Consolvo et al. [4] propose a classification of people who provide care to elderly, the so-called *care network members*. Three categories have been identified: the *drastic life changers*, the *significant contributors* and the *peripherally involved members*. The first category is represented by those who made major changes to their own life to care for seniors. Usually, there is one drastic life changer per care network, often the elder's spouse, child, or a professional caregiver: caring for the elder is typically a primary focus for the drastic life changer. The second category of caregivers is represented by those who provide regular care to seniors: care has a noticeable impact on the significant contributor's life, but she is still able to maintain her own life as a primary focus. There are usually at least a few significant contributors in a network, often nearby children and close friends of the senior. Peripherally involved members provide care that is meaningful for the elder, usually involves sporadic social contacts and home maintenance care. For the peripherally involved members, providing care generally has minimal impact on their own life. These members are often children who live at a distance, grandchildren, friends, and neighbours. Thus, in the AAL domain, not only the older adults represent a variegated group of people whose needs have to be addressed, but also caregivers themselves are a heterogeneous group of people, whose requirements, needs and constraints are diverse and closely intertwined with those of the seniors they care about. In this scenario, the ability of providing personalisable behaviour to seniors is valuable not only to better support seniors themselves, but also to properly ameliorate the burden of caregivers, who need to coordinate the care-related activities with needs coming from their own day-to-day lives, and according to the senior's caring situation, which can evolve over time. These aspects have been taken into account in our approach. Indeed, we can expect that some rules will provide direct and concrete support for elderly, other rules will be directed towards better supporting caregivers themselves (e.g. send notification when the elderly enters home, for caregivers' peace of mind) taking into account e.g. the routines of the elderly and/or the preferences of caregivers themselves (e.g. send a SMS-based notification when the elderly stays too long in bed in the morning). Furthermore, other rules can be directed to both of them (remind the elderly and the caregiver when a visit to the doctor is planned in a short time and the caregiver is expected to accompany the elderly to the doctor). Using the platform described in this article, all the different types of caregivers in the care network can easily specify personalisation rules. Indeed, the Personalisation Rule Editor has been designed in such a way to be as most intuitive as possible, so as to well suit all the different types of target users i.e. not only frequent users (like e.g. the *drastic life changers* caregivers) but also those that are expected to use it on a more occasional basis (like e.g. the *peripherally involved care members*). However, it is worth pointing out that, the CareNet Display [4] only targets caregivers (who get from the display relevant information about the elderly), while in our approach elderly can play a more active role (at least those having some familiarity with technology can directly create their own rules). In addition, the CareNet display just provides caregivers with relevant information about the elderly (about e.g. events occurred as planned, or unexpected events occurred, or events that have not yet occurred), whereas our personalisation platform, beyond detecting such situations (thanks to its underlying contextual infrastructure), also allows specifying -and realising- how to react upon the occurrence of such situations e.g. by providing relevant notifications, warnings and reminders in the most suitable modality, and using the most adequate device (thereby not necessarily tying the rendering of such notifications to a stationary, ambient display as in [4]).

3.2 An example scenario

In this section we describe a scenario in which we envisage a possible use of the considered platform and highlight how seniors can benefit from it. Luisa is 80 years old. She is a retired teacher and lives in a large city. Luisa lives alone since many years, as she lost her husband several years ago. She has been healthy for almost all of her life, but in recent years she got diabetes, then she has to do regular blood tests. In addition, due to diabetes, she is also experiencing some vision issues and then she stopped driving, which further worsened her social isolation and mood. In addition to such physical impairments, recently Luisa has started to experience some sporadic and tiny memory slips. For instance, she sometimes forgets when specific door-to-door separate collection of waste should be done (specific garbage should be put outside her house in specific days and time intervals) or she forgets turning off appliances and lights in empty rooms. Luisa herself realises that she is somewhat struggling with some cognitive tasks she easily managed to do in the past, for instance tracking monthly bills is taking a bit longer than usual.

Also her daughter Giulia has noticed that her mother is recently showing some subtle signs of cognitive difficulties. Thus, she convinces Luisa to meet a specialist in order to assess her situation and better evaluate if some kind of interventions could be needed. Luisa acknowledges this. The specialist says that there is no need to worry about this for now, as there is no specific cognitive problem apart from sporadic difficulties connected with normal ageing. Luisa and her daughter feel very relieved about this. However, the specialist suggests using a new system that could support Luisa in her daily activities, provide multimedia reminders and notifications, more easily control appliances in her house as well as monitoring some life parameters whose variation can be a sign of the onset of more serious frailty.

Using this platform Luisa can easily manage some daily tasks at her will. For instance, the system can be set up to detect whether Luisa is not performing sufficient physical activity, and motivates her, based on her current status (e.g. physical activity preferences, health status) in performing further physical exercises. In addition, the system is able to guide her while undergoing her physical exercises e.g. by providing short videos demonstrating the exercises suggested by the physiotherapist that she can perform at home and can change according to her current health status, following a possible worsening (or improvement) of her conditions. Moreover, the system provides Luisa with evidence about the effectiveness of activity monitoring by providing her with easily understandable data: getting feedback about her health status often contributes to reassuring Luisa about her current health situation.

Taking into account the suggestions of the specialist, Giulia sets up many rules for better managing lights in her mother's house. For instance, she sets up lights so that Luisa is more exposed to bright light especially during the winter, which should positively improve her mood. In addition, she also sets up another rule that reduces the intensity of lights and changes the light temperature to a warmer value the last 2 h before going to bed, to prepare the body of Luisa for a good night sleep. On the contrary, another rule is set up to boost and 'activate' the body at the beginning of the day: from the morning the light gradually rises to high intensity and high colour temperatures (cold light).

The system is able to support Luisa in managing their medications and habits, especially when there are some temporary changes affecting them. For instance, when Luisa has to do the blood test, she has to remember to postpone the usual medication intake (done early in the morning) after the test. The same happens whenever the doctor decides for a change of her therapy: the system helps Luisa to remember the changes in her intakes. If Luisa has not taken a medicine and it is time to do it, the system, using the Luisa's most preferred device and according to her current position, shows a multimedia reminder with the image of the medicine to take, and its expected dosage (in a textual manner).

In addition, Giulia sets a rule for better managing the consumption energy in her mother's house. For instance, when the heater or air conditioner is running, all the external windows and doors should be closed. Another rule is created for managing the air conditioner, aiming at using it only on really hot or humid days. In particular, when a hot day is expected, the air conditioning should be turned on earlier than usual, avoiding to wait until the home becomes too hot. Similarly, another rule will start heating early when a cold day is foreseen. Furthermore, through the personalization rules, it is possible to automatically adjust the temperature according to Luisa's habits and activities currently going on. For instance, if Luisa is doing her physical exercises, the temperature in her room will be decreased a bit. On the contrary, over winter weekends, when the nephews of Luisa visit their grandmother, the temperature is set a bit higher than usual to improve the comfort of the children.

3.3 The personalisation rule editor

In this work we used the TARE tool [13] as starting point, which has been re-designed in various versions according to an iterative refinement process that leveraged on a series of evaluations that will be reported afterwards. The resulting environment allows users to define adaptation rules following a trigger-action paradigm, and includes other two modules, the Adaptation Engine and the Context Manager. An overview of the personalization platform is provided in Fig. 1. The Adaptation Engine stores and manages personalisation rules, associating them to the available applications and users; it is also responsible for deciding which rule apply when multiple rules are triggered at the same time.

The Context Manager is a middleware module that receives the state of sensors installed in the context, and informs the Adaptation Engine when a change in the context would trigger the execution of a rule. When it happens, first the Context Server notifies the Adaptation Engine, which then extracts the list of actions from the concerned personalization rules, and sends them to the application for interpreting and executing them. For this purpose, the application contains some scripts able to understand the requests that correspond to the actions to be done

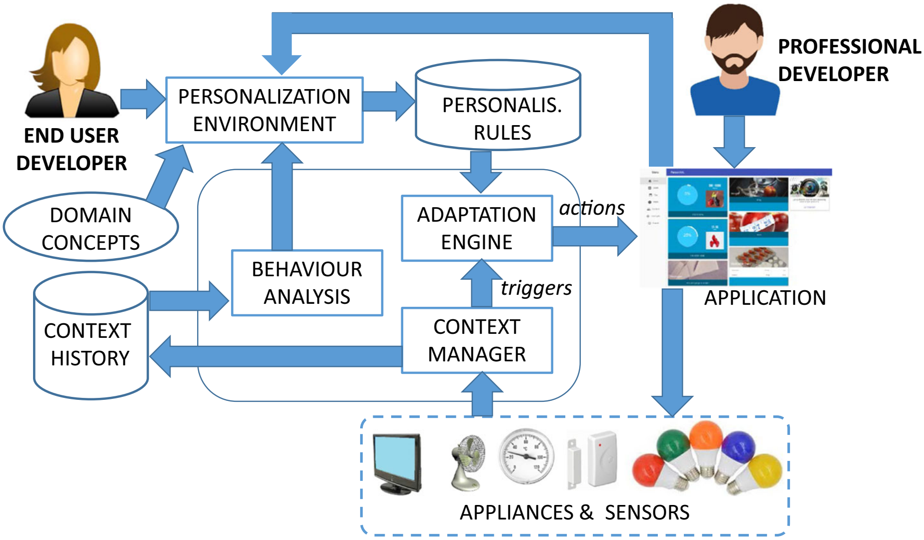

Fig. 1 The architecture of the solution proposed

on the application in order to realise the requested personalisation changes. The Context Manager has also some features to save the history of events occurred in the past, which represents valuable information for the Behaviour Analysis module, to identify behavioural patterns and suggest new possible rules accordingly.

The starting point for the setup of the Rule Editor for the AAL domain considered is a generic definition of the context model (the set of entities which compose the context of use), which includes common entities that can be relevant in all application domains (e.g. personal information such as age, gender, education; environment attributes such as temperature, humidity, light level, etc.), thus it is domain-independent. Then, it has been customised with the support of domain experts (caregivers in our case), to identify domain-specific context entities that will compose the triggers. Below some of the context attributes we identified as relevant for the AAL domain are listed:

- Physical information: walking ability, heart rate, daily steps, body temperature, respiration rate, posture, weight;
- User position inside the house;
- Cognitive information: attention, memory, language;
- Medication: planned and occurred (medicine name, dosage, notification time);
- Motivation (wellness, fitness, health, social);
- Environment attributes: temperature, humidity, gas presence, motion, light and noise level;
- State of the devices and smart physical objects installed in the elderly's home;

All the context attributes compose the domain-specific context model, and are available in the Personalization Rule Editor for specifying personalization rules. The description of the context model (in terms of types of elements available for specify the triggers) is provided in a XSD schema file. The context entities are logically organised in a hierarchical manner. Four elements of *complexType* are at the highest level, and they correspond to the four, top-level elements of the trigger hierarchy, namely: User, Environment, Technology and Social. Figure 2 shows an excerpt of such XSD schema for the AAL domain, in which the *Environment* element has been detailed. As you can see it is an element of a *complexType*, composed of four elements that indicate the type of environmental aspects that are supported in the context model: Date and Time, Physical Object, Ambient conditions, and Weather. Each of such elements is further specified according to a number of relevant elements and attributes. For instance, the Weather element is refined into basic elements (Temperature, Humidity, Wind and Weather Condition). Temperature includes, as its attributes, its type (integer), its xPath, and the default unit of measure.

When an instance of the platform is created for a specific environment, it has to be customised according to two aspects: the considered context of use, and the application to personalise. For the context of use, the customization depends on the available information and sensors, because they will provide the information to determine whether and when triggers are verified. The application is considered to customise the possible actions that can be actually carried out. For our trials we considered a number of sensors, for which we developed software modules (Context Delegates) that take as input the raw data from sensors and communicate the corresponding relevant information to the Context Manager server, which can use them to assess when relevant events and/or conditions occur. For our user tests we have used the PLUX BITalino chest band (http://bitalino.com/en/), which includes bio-signal sensors providing data associated with heart rate, number of steps, current posture of the user (including e.g. 'supine', 'prone', 'standing'), respiration rate and body temperature. We have also used a Fitbit Charge 2 fitness wristband,

```
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  <xs:sequence>
      <xs:element name="date_time" type="tns:DateTime" minOccurs="0">
      </xs:element>
      <xs:element name="Physical Object" displayedname="Physical Object"
        type="tns:PhysicalObject"
        actualdata="environment/physicalObjectContainer/physicalObject/@name"
        changesto="false">
      </xs:element>
      <xs:element name="Ambient_Conditions" type="tns:Ambient_Conditions" minOccurs="0">
      </xs:element>
      <xs:element name="Weather" type="tns:Weather" changesto="false"> </xs:element>
   </xs:sequence>
 </xs:complexType>
 <xs:complexType name="Weather" displayedname="Weather">
    <xs:sequence>
      <xs:element name="Temperature"  displayedname="Temperature" type="xs:int"
      originaltype="Environment/Weather/@Temperature" xPath="environment/Weather/@Temperature"
      changesto="true" unit="°C">
      </xs:element>
      <xs:element name="Humidity" displayedname="Humidity" type="custom:int"
      originaltype="Environment/Weather/@Humidity" xPath="environment/Weather/@Humidity"
      changesto="true" unit="%">
      </xs:element>
      <xs:element name="Wind" displayedname="Wind" type="custom:string" minOccurs="0"
      originaltype="Environment/Weather/@Wind"  xPath="environment/Weather/@Wind"
      changesto="true" unit="m/s">
      </xs:element>
      <xs:element name="Condition" displayedname="Weather Condition"
      type="custom:weatherConditionType"      minOccurs="0"
      originaltype="Environment/Weather/@Condition"
      xPath="environment/Weather/@weatherCondition" changesto="true">
      </xs:element>
    </xs:sequence>
</xs:complexType>
```

Fig. 2 An excerpt of the XSD schema (*Environment* element) used for specifying triggers

which provides information about physical activity of the user (steps taken, distance covered). Furthermore, we exploit a number of Estimote Proximity beacons to derive the user position. The Proximity delegate application defines three proximity zones: immediate, near, and far, according to the strength of the signal received from the beacons (from a few centimetres to some meters), and it informs the Context Manager that e.g. the user is inside a room (each beacon is associated to a room). The configuration of the environment sensors is composed of an Arduino Uno (enhanced by an Ethernet shield to provide the Arduino board with Internet access) which acts as a master since it receives the data from multiple Arduino Micro (Nodes) connected to it and then it sends those data to the Context Manager. Each Arduino unit is equipped with a NRF24L01 module, which is a transceiver supporting wireless communication between the Arduino micro and the master. As for the nodes, we used an Arduino-compatible sensor for gas (MQ5), another one for detecting temperature and relative humidity (DHT11) and one for detecting motion.

In the context of the scenario previously described, when Giulia wants to set up a rule for her mother, the Personalization Rule Editor should first load the relevant context model, which provides her with a representation of relevant contextual elements (i.e. events and conditions) that can be associated with the triggers that she wants to consider in the rules. For instance, for the personalization rule aimed to improve Luisa's emotional state by acting on lights, the relevant *triggers* would be the current level of illumination in the house, the time of the day and the current emotional status of Luisa, while the relevant *actions* would be acting on some parameters of lights (e.g. colour, temperature).

In particular, triggers refer to elements identified in the contextual model. They are organized according to a logical hierarchy, grouping together related context entities. At the highest level, the hierarchy of triggers consider the following aspects: user, environment, technology, social aspects. Actions can be associated with: appliances commands (to change the state of some actuator); UI modifications (to change the presentation, content or navigation of the application UI); functionalities (to access externals services e.g. weather forecast service); alarms (to highlight some potentially dangerous situations); and reminders (to indicate tasks that should be accomplished).

After Giulia finishes specifying the rule through the editor, the rule is sent to the Adaptation Engine, a software service that subscribes to the Context Manager for being notified about the occurrence of events associated with the rules received in the current context. Afterwards, when the application is activated, it subscribes to the Adaptation Engine in order to receive the adaptation actions when the rule is triggered. When the application receives the actions in JSON format it performs the corresponding personalisation changes.

3.4 An example application

We mainly target elderly people with a good degree of independence, with the goal of improving their quality of life. The personalization platform for older adults has been tested and integrated with various applications providing some support to the target users. For example, one web application considered (see Fig. 3) allows the elderly to control the appliances available in the home environment. Moreover, it also supports remote monitoring (mainly targeting caregivers), thus it includes a number of functionalities providing information about e.g. elderly's health-related data, wellbeing goals settings, planning of the activities, personal profile and main contacts, status of environmental sensors. In addition, within the application it is also possible to control some lights installed in the elderly's home. In particular, the lights considered were Philips Hue lamps equipped with Philips Hue Bridge 1.0. The Bridge is connected both to the Internet (Ethernet connection) and to the lights (ZigBee connection), thus it allows the platform to remotely control the light system. In addition, real time values of steps performed, heart and respiration rate, user body position and temperature are detected through BITalino sensors embedded in a chest band worn by the senior. Weather and news contents are incorporated as RSS feed from external providers based on location information.

The original application had limited possibilities in terms of personalization. The approach proposed allows end users to dynamically change its possibilities by editing relevant rules, e.g. by changing the state of appliances when some events occur, or by receiving motivational messages for improving the current lifestyle of the elderly when an unhealthy behaviour is detected (so as to e.g. reinforce the motivation of users and to encourage them doing exercises).

3.5 Adaptation through personalization rules

Taking into account the features of the considered application (provide remote assistance to seniors), and the capabilities offered by the Rule Editor (in terms of triggers and actions), together with stakeholders relevant in the AAL domain, a number of rules that can be useful in this domain have been identified. In this section we report examples of the personalization rules defined with stakeholders and created using the Personalization Rule Editor.

- If the notification time of a planned medication expired and it does not exist a corresponding occurred medication, send the elderly a reminder (also visualising the name, shape and colour of the pill to take)
- When the user sits on the sofa in the afternoon, turn on the music player and change the colour of the ambient lighting to green to make the elderly relax

Fig. 3 The remote monitoring application considered in the example

- If the user has not yet completed the physical exercises planned for that day send her a reminder encouraging her to finish the exercises
- If motion in the corridor is detected during the night switch on the lights
- If the steps performed during the last week are less than the goal steps and the weather is sunny and the TV in the living room is on, send a motivational message on the TV inviting the user to exit and have a walk
- When the number of steps has decreased of a specific percentage over the last month compared to the previous month send a message to the caregiver and send to the elderly an encouraging message inviting the elderly to do more exercise

- If an appointment is scheduled in a few hours and the weather forecasts are good and the destination is at elderly's house walking distance, suggest the elderly to have a walk
- When the elderly enters the living room in the afternoon, set ideal temperature in the living room and switch to an energy saving mode in the other rooms
- When there are only 2 h left before going to bed (i.e. sleep scheduled time minus current time is 2 h), set the light to a soft colour.

4 User tests

We used an iterative approach in which multiple evaluation sessions informed the design, thus in this section we report on the evaluations carried out on the rule editor prototype and the associated refinements it underwent.

4.1 First user test

Figure 4 shows the initial version of the Rule Editor, which was assessed during the first user test. In order to create a rule, users had to interactively unfold the hierarchy of the triggers corresponding to the relevant main contextual dimension, and when the basic entity was reached it was possible to indicate the corresponding events or conditions (in the example in Fig. 4 it is "when user enters inside living room").

The test was carried out with a sample of 7 participants that included three older people (aged 74–80) and four informal caregivers (aged 45–67). A laptop PC (Lenovo Z570) with a 15.6-in. display was used. People were recruited by a Swiss foundation operating as a representative body for mature people and as a provider of services targeting the elderly [3]. The test session was divided into two main parts. First, the users had to rate the exhaustiveness of the way in which the context of use and the possible actions were modelled. During the first part of the test users were asked (on a 1–7 scale; 1 = very bad; 7 = very good) to rate the

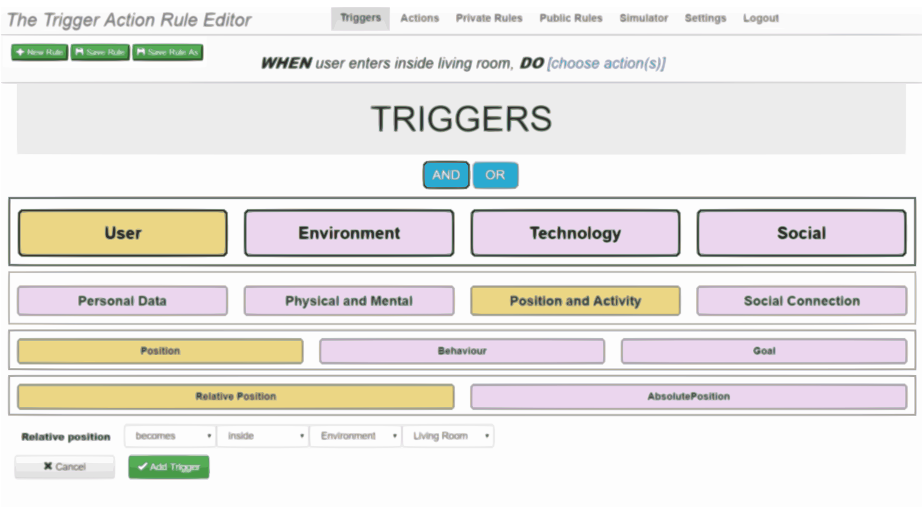

Fig. 4 First version of the Rule Editor

exhaustiveness of the set of triggers that can be specified using the tool (min:3, max:6, median:5), and of the set of actions that can be specified (min:4, max:5, median:5).

The second part focused on the usability of the Personalization Rule Editor. The test leader gave the users some simple rules written in natural language (in German), covering the majority of the contextual aspects supported by the tool. The participants had to specify such rules using it. The same Likert scale as before was used to rate some aspects of the Personalisation tool, for which the following ratings were obtained:

- Usability of the action selection mechanism (min:2, max:6, median:4)
- Usability, in general, of the rule-based approach (min:3, max:6, median:4)
- Exhaustiveness of the set of events that can be specified (min:3, max:6, median:5)
- Exhaustiveness of the set of actions that can be specified (min:4, max:5, median:5)
- Usability of the tool support for reusing previously saved rules (min:3, max:7, median:5)
- Usefulness of describing the rules in natural language (min:6, max:7, median:7)

Although users tried the tool for the very first time, the results of the usability test show that the application and the underlying approach was judged fairly usable and well-structured for participants, who provided quite encouraging feedback. The hierarchies of triggers and actions were rated in an overall positive manner, showing that the tool was able to support the most relevant situations that stakeholders need to manage. While highlighting the usefulness of providing a natural language description of the rule, some participants noted that such a rule description may not be immediately visible when navigating the hierarchies, especially when they are unfolded in multiple levels. In addition, it happened that some users reached the lowest level in the hierarchy without finding the desired element, and at that point they did not realise that it was still possible to unfold other elements on top of the current selection to continue building the rule. This was probably due to a lack of understanding of the difference between folded and unfolded elements. Users also appreciated the possibility of reusing previously saved rules, finding that this support can greatly speed up the process of creating rules. In this regard, users further provided suggestions for improving the UI, e.g. the possibility of selecting values through drop-down menus instead of directly typing values, and taking better into account specific user-related needs (e.g. enlarge font sizes and selection fields to better support users' ageing sight). Among the potentialities offered by the tool, users especially appreciated the fact that the resulting environment was receptive to quickly supporting changes in its behaviour without the help of a programmer.

The feedback gathered in this usability test provided useful material for improving the tool. First, we developed a search function (see Fig. 5), to more easily find a specific trigger element without exploring the whole tree: after specifying the desired concept in the text field, the tool shows the paths of the elements where such a concept is considered within the context model. Then, the user can easily select the most relevant one amongst those listed. When the user selects the desired concept, the user interface shows it in the logical structure of the trigger classification, and provides users with the possibility to edit the corresponding attributes (see Fig. 6). In addition, in order to better highlight the difference between folded and unfolded elements (which was conveyed by a difference in the background colour of the concerned elements), in the new version of the tool we added one further cue ("- "and a "+" symbol respectively) beside each element (see Fig. 6).

After including such improvements in the Rule Editor, the tool underwent an additional test to gather user feedback.

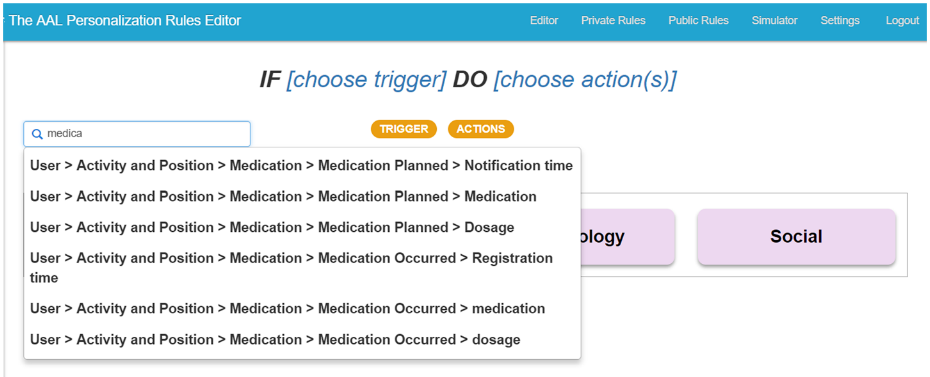

Fig. 5 The new support for identifying context attributes, identified as result of the first test

4.2 Second user test

4.2.1 Participants

Twenty participants were involved in this second test. They were recruited by the institution moderating the test, Sunnaas, a Norwegian hospital specialised in the field of physical medicine and rehabilitation, by placing an advertisement in a newspaper, asking for people over the age of 65. Participants were expected to know how to interact with a browser, either using a tablet or a personal computer, but no further expertise was required. The participants' responsibilities were to complete a set of representative task scenarios in an as efficient and timely manner as possible, and to provide feedback regarding the usability and acceptability of the Rule Editor. The participants were directed to provide honest opinions regarding the usability of the application, and to participate in post-session subjective questionnaires and debriefing.

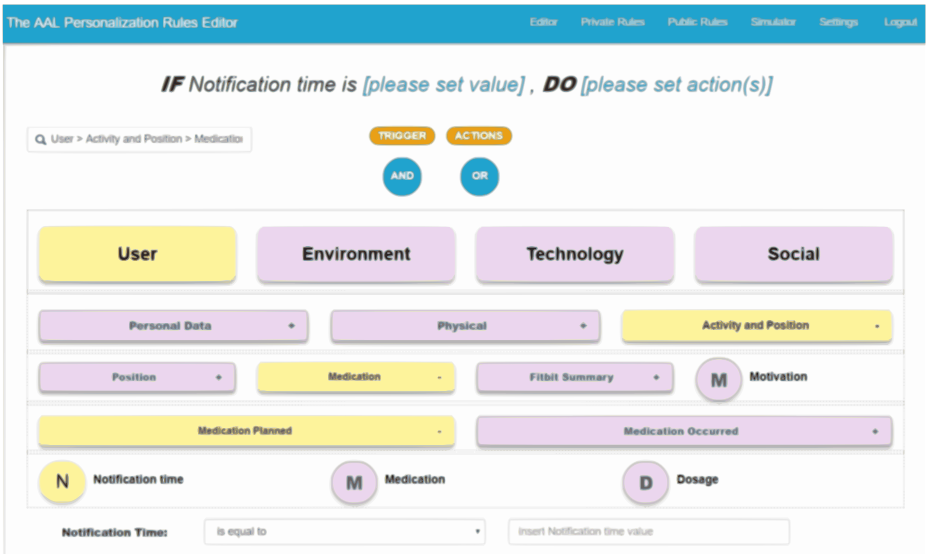

Fig. 6 The element selected through a search is presented in the trigger structure

Participants were not previously aware of the application being tested. Regarding the age distribution, almost all the respondents belong to the age group of 65–75 years (95%). A single participant was 90+, whereas no respondent was younger than 65 years old. The gender distribution was overall balanced: 55% of the respondents were male, 45% female. When asked about health condition, all the participants reported that they did not suffer from any severe impairments. All the participants characterized themselves as older adults, without having a caregiver role.

4.2.2 Procedure

Participants took part in the usability test at the Sunnas Rehabilitation Hospital in Oslo. The tasks were completed using a laptop (ASUS ZenBook UX305, Intel(R) Core(TM) i7-6500 U CPU @ 2,50GHz, 3200 × 1800, Windows 10 Home, Firefox Browser). The participant's interaction with the applications was monitored by a facilitator seated in the same room. Note takers and data logger(s) also monitored the sessions. The facilitator briefed the participants on the application. Participants signed an informed consent that acknowledged that the participation is voluntary and it can cease at any time, and their privacy of identification would have been safeguarded (i.e. the performance of any test participant must not be individually attributable).

The test was organized in two main stages: a pre-test questionnaire and the real interaction with the rule editor. In the pre-test phase, participants completed a demographic pre-test and a background information questionnaire: for each participant we collected their age, gender, if they are a caregiver for a senior, if they have any impairments that might affect the use of the application, and, in case they do, which impairment. Then, after an introduction to the editor, the participants were asked to carry out three tasks concerning the creation of some rules with the Rule Editor. At the start of each task, the participant reads aloud the task description from a printed copy and begins the task. The facilitator instructed the participant to 'think aloud' so that a verbal record would exist of their interaction with the application. The facilitator observed and also annotated any interesting user interactions and comments. After each task, the participant completes the post-task questionnaire and elaborates on the task session with the facilitator. After all task scenarios are carried out, the participant completes the post-test satisfaction questionnaire. Before carrying out the assigned tasks, no specific training was provided to participants, just an overview about the test procedure, equipment and the Rule Editor. The concepts that were required to understand the tasks to be executed were explained as necessary before the corresponding tasks. The difficulty and effectiveness of each task was recorded. Workload was measured with the NASA TLX questionnaire.

4.2.3 Tasks

Due to the short time in which each participant was available, we selected tasks with low complexity. Data introduced by the participants during the test was deleted after the test was completed to make sure that all users begun their test with the program in the same state.

> *Task1*: Users were asked to create a rule having a simple trigger. In particular, they had to create a rule (Rule1) to turn on the living room lights when the user was inside the living room, then save the rule. This task required to specify a trigger involving a condition.

Task2: Users were asked to create a rule to turn on the TV when the user enters the living room (Rule 2), then save the rule. This task required to specify a trigger involving an event.
Task3: This task was composed of two parts. First the users were asked to create a rule that increased the font size on the user mobile device when the user is outside of the home, and then save the rule. Then the users were asked to go back to the Remote Monitoring Application, and imagine that they were viewing the application on a tablet and that they went outside of their home. [The moderator triggered the rule to change the font size, from 16px to 21px, a 30% increase].

4.2.4 Results

Task1 (create the rule having a simple trigger involving a condition) The interviewees were asked how difficult it was to complete the task. A clear majority (15 interviewed persons) reported that the task was easy or very easy. Only one person rated the task as difficult. However, during the completion of the task, 80% needed help. It is worth pointing out that the help provided was not the solution, but just some hints given to users when they encountered difficulties during the interaction with the tool (more details about such issues are described later on, in the "*Further Qualitative Remarks*" Section). In the end 50% of the respondents successfully completed the task without any error. It also turned out that the participants did not notice the possibility to search for triggers.

Task2 (create the rule having a simple trigger involving an event) The majority of the respondents rated this task again as easy or very easy (14 persons). Only one respondent considered the task difficult. Although about 63% of the interviewees needed some hints to complete the task, in the end 74% of them successfully completed it without any error. The majority of the test persons thought that the provided rules were useful or very useful, as only 3 persons rated them as not useful. Regarding the difference between "is" and "becomes" (which are the keywords used in the tool to distinguish events from conditions), it turned out that almost all participants (85%) managed to use it correctly.

Task3 (create the rule changing the aspect of the target application and then simulate the rule execution) The majority (12 persons) considered the task as not difficult. 72% of the respondents could not complete the task without help, but at the same time 72% were also able to complete it without errors. After simulating the application of the rule, most of the respondents (71%) did notice the change in the font size. The majority of the 14 respondents considered such a rule as useful or very useful (only a minority of 2 persons rated it as not useful).

A summary of the test results has been visualized in the following Table 1. As expected, the first task was the one in which users encountered the most difficulties, with the highest percentage of people who needed some hints in order to progress in solving the task, and the lowest percentage of task success without errors. However, both measures improved over the two other tasks, showing that using the tool becomes easier as users get more familiar with it. Since the rules associated with Task1 and Task2 were similar, we asked users to rate their usefulness after carrying out Task2.

It was also interesting to see that, although Task1 did not have very high percentages of task success without errors (we expected this, since it was the very first task), nevertheless it was

Table 1 An overview of the results gathered for the second user test

	Task difficulty	Help needed?	Task success	Usefulness
Task1	Easy/Very easy: 75% Medium: 20% Difficult: 5%	80% needed help	50% successfully completed the task without errors	Useful/Very useful: 70% Medium: 10% Not useful: 15%
Task2	Easy/Very easy: 70% Medium: 20% Difficult: 5% No answer: 5%	63% needed help	74% successfully completed the task without errors	No answer: 5%
Task3	Easy or very easy: 60% Medium: 10% Difficult: 15% No answer: 15%	72% needed help	72% successfully completed the task without errors	Useful/Very useful:70% Medium: 10% Not useful/Not useful at all: 10% No answer: 10%

perceived easy or very easy by the majority of people. The situation changed a bit for Task2 (which nevertheless involved a rule having a structure similar to Task1), where the measures of perceived task difficulty and the one of task success without errors are more consistent. This can be explained by the fact that, as soon as users get more awareness and knowledge in using the tool, they can also more objectively evaluate the task difficulty.

4.2.5 Evaluation of the cognitive workload (NASA TLX)

After completing the tasks, participants answered the NASA-TLX questionnaire, which consists of six subscales (Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration), with the assumption that the combination of these dimensions can represent the "workload" experienced by people performing tasks. All items were generally considered not demanding. Nevertheless, some respondents reported a high mental workload. This can be expected due to the age of the participants and the nature of the Rule Editor, and the wide coverage it offers (rules can be created to deal with many situations, ranging e.g. from appliance and home control, to user interface aspects). The overall raw (non-weighted) NASA-TLX score was 36.3, which is on the low end of the scale, representing a low requested workload.

4.2.6 Further qualitative remarks

The majority of the participant sample of this second test was mainly characterized as active older adults, who are not the primary target users of this application, as the Rule Editor mainly targets caregivers, and secondarily seniors. However, in spite of involving a more 'challenging' group of people, the results of the test showed that such users were able to use the tool to set simple rules and they did not perceive interacting with the Rule Editor as particular demanding in terms of cognitive workload. Also the usefulness of the application was well received, as they especially appreciated the possibility of automating some tasks or being helped in their routines (e.g. receive reminders). Nevertheless, this test was a good opportunity to collect useful suggestions for further improving the tool. In particular, when users needed to unfold multiple levels in the hierarchies, the natural language description of the current rule might not have been immediately visible. In addition, users would have appreciated further feedback indicating the point (and the progress) currently achieved in the process of building a rule (e.g. what they have already specified and what still remained to complete the specification of a rule). Users had some issues in understanding a few technical terms (e.g. 'triggers'), also suggesting having definitions available in the tool. Some users found not immediately intuitive how some elements were classified in the hierarchy (e.g. the "position" element was located under the "activity" element). Moreover, some of them said that the 'save' function was not immediate to find. A particularly interesting suggestion was the need to express events and/or conditions that do *not* hold, as many times checking whether some events have *not* occurred in a particular time interval could be particularly relevant, e.g. for detecting abnormal situations.

4.2.7 The new tool design

We redesigned the tool to address some of the issues identified. In particular, we included a sidebar (see left part of the user interface shown in Fig. 7) to improve user's awareness of the progress achieved in creating rules. From this sidebar it is possible to see what the user has already done in the process of creating a rule, and what else should still be done. In particular, in Fig. 7, on the one hand the "Actions" label has a green background with a tick sign to render that at least an action has been completely specified in the rule, thus it could be considered completed. On the other hand, the "Trigger" part has a grey background colour to signal that the specification of triggers is incomplete, since at least one trigger needs to be defined. Furthermore, from the sidebar it is possible to directly carry out some actions supported by the tool (e.g. modify and delete rules). We also moved the button for saving rules to a more visible position in the UI (see Fig. 7). Figure 4 shows the earlier version of the tool, where the "Save" button was placed in a part of the UI that was judged not very visible by users, as it was included in a menu in the top-left part of the Rule Editor. In addition, the "Save" button (see Fig. 7) is disabled or enabled according to the current

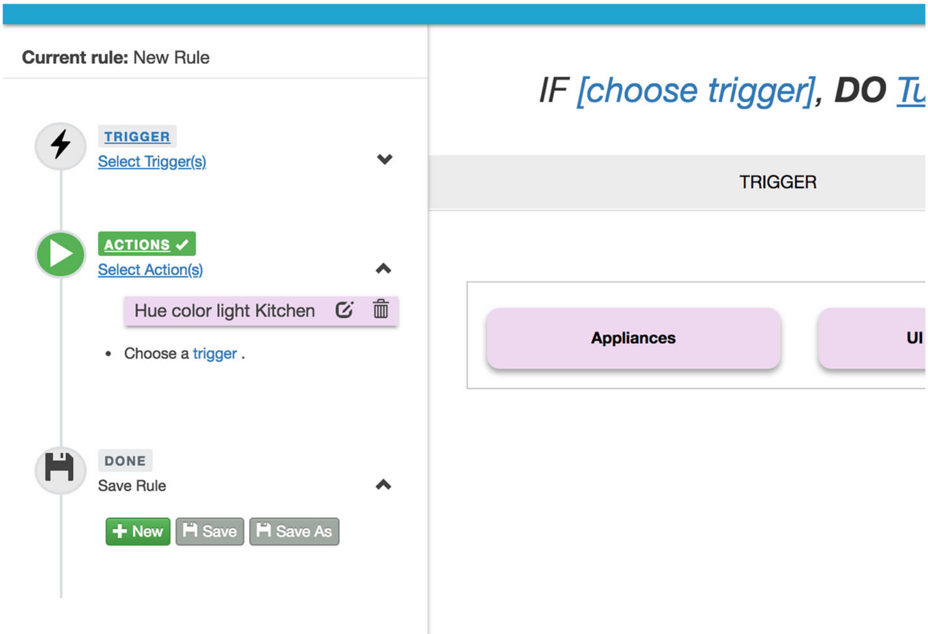

Fig. 7 Sidebar added after the first user test

state reached in specifying the rule: as soon as a user specifies all the parts of a rule (e.g. both the trigger part and the action part), the "Save" button is enabled, otherwise it is disabled.

Moreover, we improved the style used in the natural language description. Indeed, in the new version of the tool we exploited a simpler, more conversational and less technical language to better cater to different user skills and technology literacy. For instance, in the natural language description of rules, instead of using the technical expression "is equal to" we just used "is"; instead of "Please Set Value" we just used "choose value". Furthermore, instead of expressing the sentence representing the rule following the pattern "trigger name + operator + value" (e.g. "when user posture becomes equal to standing"), we used some heuristics to provide a clearer, more conversational/natural style of the language used for describing the rule. Thus, the previous sentence becomes "When the user stands up".

In addition, we further checked that a sensible colour use was adopted, i.e. we changed the colour highlighting the current elements selected in the visualized hierarchy, opting for a brighter yellow (see the difference between Figs. 4 and 7), and further providing an even more simplified design of the UI. In particular, we redesigned the tool in such a way that the need for vertical scrolling (which was activated, e.g. when the user navigated down several levels in the hierarchy) would be highly reduced. With the new version, the user interface dynamically re-organizes the layout of the tree (of triggers or of actions) by automatically folding the visualization as soon as a trigger (or an action) is added to the current rule, so as to avoid visualizing unnecessary information. Along the same line, users could also fold various sections of the sidebar, if they want to hide them from their current view. Moreover, in the previous version of the tool the part dedicated to editing the attributes of the selected trigger was placed under the tree representation, and the user was forced to continuously scroll the page (see Figs. 4 and 6). In the new version of the Rule Editor (see Fig. 8) the parameters editing of the selected trigger is supported through a modal dialog that appears on top of the main window (thus avoiding the need of scrolling).

We also changed some elements in the hierarchy of triggers to better classify their content. For instance, the former "Activity" trigger was renamed into "Activity and Position" trigger since this category also included triggers activated according to user position. In addition, we also provided the possibility of specifying rules that should be triggered when some associated

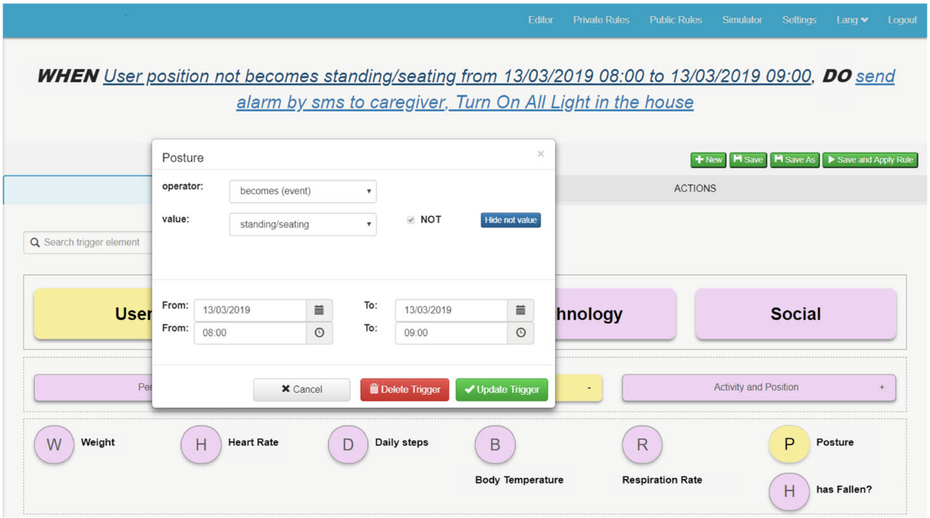

Fig. 8 The new version of the tool (only the right-hand part is visualised), with an example of use of the NOT operator

events or conditions do *not* occur in a specific time interval, by introducing the NOT Boolean operator to be used in the specification of triggers. An example of its use is visualized in Fig. 8, which shows the editing of the rule "IF user does not stand up between 8 and 9 am DO send a message to caregiver and turn on the bedroom light".

In this example, the user wants to specify what to do when the user does not stand up within a particular time interval. First of all, the user has to specify the event which models the change of the user posture (e.g.: *When user posture becomes standing*) and then, by adding the NOT operator it is possible to define the time interval in which the system has to check if the event occurred or not. If the event does not occur within the specified time interval, then the rule is triggered: a message is sent to the caregiver and the bedroom light is turned on.

4.2.8 Implications for design

We would like to derive some more general implications for good design of EUD tools in AAL scenarios.

Internet of Things –based applications frequently involve multiple (and even conflicting) interactions between devices and features, which is challenging for most users due to common mental model errors and biases [28]. In spite of this, one important lesson we learned from our work is the fact that the possibility to specify the desired behaviour in terms of events or conditions (changes that occur in daily life), and associated effects (in terms of activation of reminders, alarms, changes of appliance states), is something that can be understood even by people without any programming experience, who do not know programming constructs and algorithmic ways to approach problem solutions. Connected to this point there is the need of involving end users when structuring the logical organisation of the elements referred by triggers: not only such terms should refer to a vocabulary familiar to users, but also the relationships between elements should make sense to them. This will result in facilitating users in finding relevant triggers within the logical structure proposed by the tool. Moreover, by using the EUD tool, end users are asked to assume roles that are traditionally intended for developers in that they can take control and co-create solutions that fit their own needs and contexts. Thus, the tool needs to be designed in a way that allows end users to be effectively included in the software lifecycle and actively participate in the application development with full awareness of the supported features and the impact that they can have in the real environment. Therefore, it is imperative that users feel in control of the application and be aware of the point currently reached in the rule editing process: we addressed this point by adding a sidebar showing anytime the current point reached by users. In addition, the particular class of users addressed (caregivers, but also seniors having some familiarity with technology), also requires not only to adopt a simple style in the UI, but also to use multiple, even redundant representations catering to different users and to different tasks to convey some key information (e.g. the rule is expressed not only in a natural language form, but its structure is also described in the sidebar, which in turn further highlights possible missing parts and associated actionable feedback).

Although the workflow in editing the personalisation rules is not particularly complex, EUD tool users without a technical background may still need some support to better understand the relevant options needed to progress towards reaching their goals at a given step. Moreover, especially in the AAL domain, the user interface of the EUD tool should guide the user in capturing the most relevant information, even by hiding information that is not strictly necessary for the current task, in order to limit the cognitive effort needed by users (as it happened with our tool, which automatically folds the hierarchy elements that are no more in the attention focus of the user). In addition, the evaluations carried out offered the opportunity to discover from users themselves that sometimes they would specify not only triggers associated with situations that occur, but also with situations that did *not* occur in a specific interval of time. This suggestion could also be relevant in the design of EUD tools in the AAL area, in the view of facilitating the specification of such 'not' rules in the tool in a straightforward manner, without overloading users from a cognitive point of view. In addition, since the tool should be effectively used by formal and informal caregivers whose skills and also care involvement can greatly vary (in terms of effort and time spent on eldercare activities), the tool should be designed to be easily exploited by different classes of users (e.g. those in the senior's care network), ranging from those who exploit the tool on a daily basis (e.g. informal caregivers who live with the elderly), to those who are more occasional users and who especially need to use intuitive techniques that are easy to remember and do not require specific training phases. Indeed, the tool design should encourage progressive exploration of used concepts and it should support quick learning, so that users are able to easily incorporate the technology into their everyday lives at their own pace: indeed, novel solutions need to fit into the given routines and environments of the target groups and should not be perceived as additional effort for being adopted. Finally, the possibility of reusing previously saved rules (as it was supported in our tool) can be an effective way for: gaining better awareness of the support currently given to seniors and/or their preferences/routines; getting inspiration from rules already available to derive new support for improved and more personalised eldercare; facilitating the building of rules (by avoiding starting from scratch).

5 Conclusions and future work

In this paper we present the iterative design and development of a personalisation rule editor for end user development of context-dependent applications, which has been customized for applications aiming at remotely monitoring and assisting elderly at home.

After an initial test with some elderly people and caregivers the platform was redesigned to address their main concerns. The new version was then assessed in a new test done with only elderly, which informed a redesign of the solution, expected to solve the identified limitations and usability issues. Overall, the results indicate that the platform is quite easy to use and is perceived valuable for both end users and caregivers. It allows people who are not familiar with algorithms and programming concepts to still indicate the desired personalization in the behaviour of connected applications, devices and appliances.

As future work we plan to validate the new version of the system in longitudinal studies in the elderly homes to investigate how the use and appropriation of the tool vary over time. In addition, we have also started to investigate the use of machine-learning technique to derive useful rules that can be suggested to target users by exploiting the history of events and previously saved rules.

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