The Transparency of Automations in Daily Environments

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Abstract

This paper outlines a proposal for how to address transparency of automations in daily environments, such as smart homes. The trigger-action programming paradigm has been used to describe and implement such automations in both commercial and research tools. Such automations can be generated through machine learning techniques or directly by the end users. When they are executed the resulting behaviour sometimes is not what end users desire for several reasons, and users have difficulties in understanding and controlling them. Thus, there is a need for proposing design criteria and tools that help people to understand and control what happens with the automations active in the environments where they live, and explain how they work and can be modified to better meet their needs.

1 Introduction

How people interact with digital technologies is currently caught between, the Internet of Things (IoT), where objects are continuously increasing their technological capabilities in terms of functionalities and connectivity, and Artificial Intelligence, which is penetrating many areas of daily life by supporting increasing capabilities of autonomously activating functionalities based on collected data and statistically-based forecasts. In both trends, human control over technology is jeopardized. At the same time, little is happening in terms of innovating how we think and control automations. This is despite the current availability of various types of devices and modalities for supporting user interactions. Thus, there is a need for novel solutions able to support "humanations", which are automations that users can understand and modify.

Trigger-action programming has often been used to describe and implement automations in environments rich in terms of availability of connected objects, devices, and services. It is based on sets of rules that connect the dynamic events and/or conditions with the expected reactions without requiring the use of complex programming structures, and it has been used in several domains, such as home [Salovaara et al., 2021; Ur et al., 2014], ambient assisted living [Manca et al., 2021], robots, [Leonardi et al., 2019], finance [Elsden et al., 2019].

The available automations can be created through machine learning techniques [Srinivasan et al., 2018; Zhang et al., 2020] and then activated, or recommended [Mattioli & Paternò 2021] to users, or can even be directly created by them. However, when they are automatically generated some problems can occur if end-user's perspective is not sufficiently considered. For example, the study reported in [Yang and Newman, 2013] describes how a learning system can fail to understand users' intent or users find that the system's behaviour is hard to understand. Likewise, a survey-based study with participants who have smart devices in their own home [He et al., 2019], reported difficulties in avoiding false alarms, communicating complex schedules, and resolving conflicting preferences. Such issues highlight the importance of providing conceptual and technological support for improving transparency and explainability of such automations.

2 Conceptual dimensions

We can better address transparency if we think about the possible desired levels of user control. We can identify at least four possible **levels of user control**: *perception* (users are able to perceive that some automation is active and working), *understanding* (users are able to understand how such automation works), *prediction* (based on their understanding, users are able to foresee the future behaviour of the system in various situations), *modification* (users are enabled to change something in the automation when its results are not satisfying, i.e. unintended behaviour occurred or has been envisaged).

For example, we can consider a smart home where the heating system is automatically activated when the user is at home and the temperature is below 17 Celsius degrees and time is after 5 pm. The four levels of control indicate that the user is able to detect that in some evenings sometimes the heating system is automatically activated (automation perception). In order to obtain automation understanding it is necessary that the user be able to know what entities are necessary to trigger the automation (in this example, user

location, temperature, and time), in which specific situations they actually trigger the rule, and what the corresponding action is. Predictability is reached when the user is able to understand future behaviour of the smart home [Coppers et al., 2020]. Thus, for example, the user is able to indicate whether at a given time (e.g. 4 pm) the heating system will be active or not. Lastly, if the user is able to modify such automation, for example for activating it at different time and with different temperature, then the automation modification level is reached.
Another relevant dimension is the ***granularity*** of the set of objects involved in the considered automations. The focus can consider a single object, which for some reason is of interest for the user. For example, there is a lamp in front of the user who may be interested in the automations that involve it. The focus can also consider a group of objects (e.g. the lamps that are nearby) or can be more general and consider all the connected objects that are in a given space (e.g. in a room).

One further dimension is given by the ***temporal aspects*** of automations [Brackenbury et al., 2019; Huang et al., 2015]. They can be composed of triggers and actions, and both of them can have different temporal aspects. Triggers can be composed of events and conditions, where events are instantaneous changes in some contextual entity, while conditions are associated with the state of some entities, which can last for some time. Likewise, actions can be instantaneous (e.g. sending a notification) or can have longer duration (e.g. turn on a light). Thus, the combination of triggers and actions can determine different types of situations depending on the temporal aspects of the constituent elements, which should be clearly expressed for allowing users to clearly understand and eventually modify the automations of interest.

One further aspect to consider for automation transparency is their *analytics* in terms of data indicating how they have been used. An automation needs to be created, activated and executed. For the creation it is interesting to know what agent created it and when. Then, it can be useful to know the periods of time when it has been active. They depend on the devices involved and, when possible, the user choices. Lastly, it can be useful to know when and how many times it has been triggered. This information is also useful to understand whether the automation is working as expected or it is activated at wrong times.

3 Tool Support

If we want to provide tool support for the transparency of daily automations we need to think about something that can be used frequently in many locations and situations, with limited effort. In addition, it should be something through which we can immediately interact with the variety of connected objects and sensors that the automations can involve. Thus, an augmented reality smartphone-based application seems to be the most relevant direction to investigate since the smartphone is the device that people more often have with them, and it can be immediate to frame the surrounding objects of interest for then receiving relevant information through its camera. Augmented Reality is a technology that nowadays has reached a widespread application in many domains for its ability to connect virtual and physical elements. However, so far, in IoT applications, it has mainly been used to superimpose digital information about smart objects available in the current user context, primarily concerning their state and capabilities. We need to better exploit this technology for supporting automation transparency.

In order to address the four levels of user control, we can think of solutions able to highlight whether the surrounding objects shown in the smartphone screen are involved in currently active automations, they should be able to explain what automations are active on request, and also allow users to modify them, if they do not meet their needs. In order to support the granularity dimension, the tool should be able to provide information not only on the automations involving a single framed object but also those related to groups of objects, for example a group graphically selected in the smartphone's camera supported view, or the entire current environment where the user is located (e.g. a kitchen), thus it should be connected with some indoor localization technology.

For supporting the temporal dimension one key aspect is to provide explicit indications about whether the elements composing the trigger side are events or conditions. For this purpose, it is possible to use different keywords (*when* for events, *if* or *while* for conditions). One further support is to avoid the creation of automations where the temporal aspects of their components are not meaningful. For example, a trigger defined by the composition of two events with an AND logical operator is almost impossible to occur since it is very unlikely that the two events occur at the same time. Another example of problematic situation is when the trigger is a condition and the action is instantaneous. Since the condition can last for some time, when should the action be performed? Since we can assume that the instantaneous actions should be performed once, then the trigger side should rather indicate an event for identifying when performing it.

One initial possible solution addressing such aspects has been proposed in [Ariano et al., 2022] with the SAC (Spontaneous Automation Control) app, which allows users to freely move around the house, and dynamically receive information regarding the room where they currently are, or regarding a specific object that is identified through the camera of the mobile device. In particular, it works by detecting and localising the object currently framed through the camera and then it augments the reality by showing on top of the image of the target object various information about it and the surrounding environment, and allows users to enter new automations involving that object on the fly. Figure 1 shows the types of interactions and representations that it supports: (left) info on the current room (Living

Room) and the framed sensor; (center) the rules created for the current room; (right) the support for creating new rules.

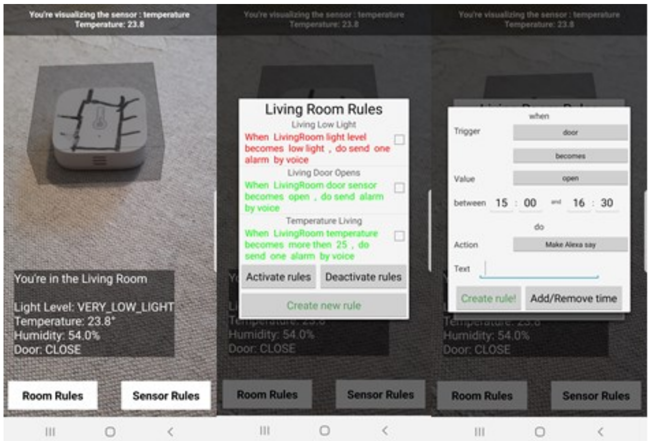

Figure 1: The SAC app (from [Ariano et al., 2022])

A first user study gave positive feedback but in order to fully support transparency a richer set of information should be provided, and also the augmented reality can be better exploited. The Vuforia functionalities were used to support object recognition. They worked sufficiently well but in some cases the sensors had to be manually marked to facilitate their recognition (see an example in Figure 1, left), and users had to be sufficiently close, with the focus of the camera on them for some seconds in order to perform their recognition. Thus, a solution based on a computer vision technique exploiting Convolutional Neural Networks can be more efficient, if adequately trained.

Regarding the automation analytics we have put forward one possible solution in the AAL PETAL project[1], where a prototype platform (TAREME) [Manca et al., 2021] has been designed and developed for supporting caregiver management of automations in the homes of older adults with mild cognitive impairments in order to provide personalised support in their daily activities. The platform includes functionalities for remote monitoring of the automations. Figure 2 shows some of the information that it is able to display.

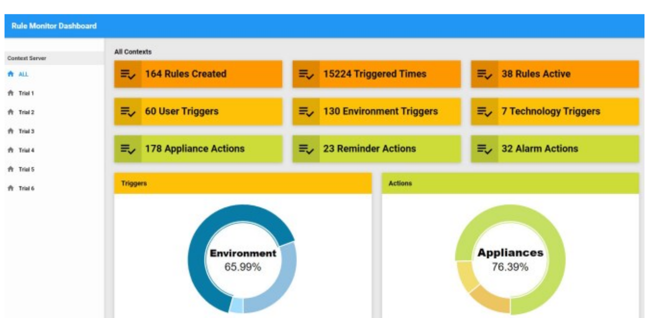

Figure 2: The TAREME Display of some automation analytics app (from [Manca et al., 2021])

[1] http://www.aal-petal.eu/

The platform was able to monitor automations from multiple sites at the same time. In the example reported in the figure there are six trial sites active, and it shows on the top the total number of rules created, how many times they have been triggered and how many are currently active. The tool also supports the possibility to filter the displayed information only for one specific site. In addition, as the figure shows, the tool also categorizes the triggers depending on if they are related to the user behaviour, environmental aspects or some device displays, and indicates how many triggers belong to each category. Likewise, also the associated actions are displayed, classified depending on whether they are performed on some appliance or they are reminders or alarms.

Furthermore, a novel solution based on Compact Prediction Trees has been proposed in the EMPATHY Project[2] for formulating both *step-by-step* and *full-rule* automation recommendations according to a data set of previous automations, with the possibility to easily switch between them when users want to directly define some automation. Thus, over time the user receives suggestions that are being progressively adapted and refined on the basis of the knowledge that is progressively accumulated (namely: depending on the current rule editing stage, and on the rule elements that have been already inserted).

Furthermore, automations can also involve robots, since they are a kind of extension of the Internet of Things (IoT) as they are made up of sensors and actuators and can be connected to Internet services. Some of them can have a human-like shape, and be used in various everyday environments (equipped with several IoT devices/things/sensors). The possibility to detect what happens in the surrounding environment opens the way to exploit triggers that use the events generated by both the robot and IoT objects, and link the robot's behaviour to what happens around it. In the SERENI Project[3], we explore their potentialities in interdisciplinary work for exploiting them to provide serious games for cognitive training of older adults with mild cognitive impairments. The robots will act as personal trainers, also with the support of conversational agents, proposing exercises and communicating through various modalities and stimulating users in cognitive games relevant to their daily life. In particular, one aspect that will also be carefully considered is that of the personality, both of the elderly and that manifested by the robot, so that the robot will play with a more or less introverted personality (which can become apparent through verbal and non-verbal communication). In this regard, appropriate adaptation of the behaviour of the robot can be put in place either by the caregiver or in an intelligent manner, by analyzing the human-robot past interactions. In addition, proper interactive analytics visualisations of the data gathered and associated

[2] http://www.empathy-project.eu/
[3] https://hiis.isti.cnr.it/sereni/

with the use of the games can be provided, so as to enable formal and informal caregivers to assess seniors' progress and to further tailor the interventions, to address possible gaps and issues discovered.

4 Conclusions

In this position paper there are some indications about how to address transparency in daily automations. Such indications are provided at a conceptual design level, and there are also indications about how some tools have addressed some of the relevant aspects. We also indicate how some projects in which we are involved contribute to this research goals.

Future work will be dedicated to extending and validating the identified design aspects and provide associate tool support, also considering important questions to address when explaining automations [Liao et al., 2020].

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