Routine Creation in Multi-User Contexts: Improving the Quality of Life through Conflict Resolution

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Abstract

This paper presents an approach to detecting and resolving the conflicts that may arise when different users create routines for a shared smart home. By interacting with a virtual assistant, end users can create routines, namely sequences of actions operating on smart devices, which are triggered by a specific event. The virtual assistant is able to detect a possible conflict between a routine under creation and an existing routine, and guide the user to its resolution. The final aim is to prevent household conflicts and lead to more peaceful and harmonious coexistence among smart home users living under the same roof.

Keywords

Virtual assistant, IoT ecosystem, Routines, End-User Development, Conflict resolution

1. Introduction

Virtual assistants (VAs) are more and more present in smart home environments playing an intermediary role between home inhabitants and their Internet-of-Things (IoT) ecosystem, which includes smart sensors and devices such as smart TV, air conditioner, smart lights, and the like [1]. A VA is composed of a hardware component, the so-called *smart speaker* (e.g., Amazon Echo, Google Nest, and Apple HomePod), and a software component that manages the conversation between the users and the smart speaker (e.g., Amazon Alexa, Google Assistant, Apple Siri).

VAs typically provide a companion mobile app that can be used by end users to create routines for managing the behavior of IoT ecosystems. Routines comprise a name, a trigger used to activate the routine itself, and a sequence of actions that are executed when the trigger fires. For instance, the user can define the routine "Good morning", select as trigger a specific time on specific weekdays, and finally choose different actions to be performed at that time on those weekdays on one or more available smart devices (e.g., switch on the coffee machine, raise the blinds in the bedrooms, and play music through the VA speakers). Routine creation can thus be regarded as an End-User Development (EUD) [2, 3, 4] activity aimed at the customization of smart home behavior.

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In [5], we showed that routine creation could be moved from the companion mobile app to the VA itself. Indeed, multi-modal interaction made available by a smart speaker with a touchscreen can be exploited for this task, fostering the computational fluency [6] of non-tech savvy users who are neither experts in routine creation nor aware of this possibility in the mobile app.

Interaction with virtual assistants is generally designed with a single user in mind. Today, the plurality of users, their coexistence, their different needs, and the relationships between them are not considered: VAs just offer ways to personalize individual interaction with the IoT ecosystem by creating multiple personal accounts. This approach does not consider the reality of smart homes, which are multi-user environments where conflicts regarding shared spaces and resources may arise due to different needs, preferences, and habits.

Equitable division of resources is not always possible; it may be the case that these resources are limited and therefore shared among multiple users in the same time interval, generating conflicts that must somehow be detected and resolved. For example, within a smart home, it may happen that different users disagree on the level of lighting in a room because of the different activities they intend to perform (watching a movie vs. reading a book); or that different users, who intend to perform different activities (listening to music and listening to an audiobook), want to use the same playback device, such as an Amazon Alexa smart speaker, in the same time interval.

In particular, one of the main points of conflict may be routines created by different users and scheduled to be executed at a certain time or when a certain condition occurs.

Our research explores how conflicts between routines can be detected at routine creation time and possibly resolved - not with an automatic/intelligent intervention of the VA itself, but with a human-driven process.

2. Literature on Conflict Detection and Resolution

Several studies have been reported in the literature proposing suitable solutions to detect and resolve various types of conflicts that may arise in an environment inhabited by several people where limited resources need to be shared. The suggested approaches can be divided into three main categories: *automatic*, *mediated*, and *combined*.

Automatic approaches, which are usually called rule-based approaches, do not require user intervention; rather, the system finds the best solution by following a set of rules predetermined by the designers and implemented in the system. There are several strategies for automated conflict resolution: some of them are based on a fair principle, which does not prefer any user, but instead calculates the average value, when possible, of user preferences (e.g., room temperature is calculated as the average value of the temperature values liked by users); while other strategies adopt a first-come-first-serve (FCFS) approach, where the first user accessing the service or device has full control of it [7]. More sophisticated strategies base their operation on user preferences and/or priorities to provide the most appropriate solution to the context [8, 9, 10]. Within this category, there are some systems that base conflict resolution on variables rather than static parameters, i.e., measures that vary according to context and transient situations, such as users' health conditions [7, 11].

Unlike those of the first category, the mediated approaches always involve user participation in conflict resolution [12]. This approach is close to the normal conflict resolution mechanism that occurs between human beings, where an exchange of information and opinions useful to find a shared solution occurs between them [13, 14]. In the case where the conflict is resolved through user intervention, the system could play a passive role, simply waiting for the person's decision, or it could actively participate in conflict resolution by providing the user with possible solutions to the problem to choose from, based on the preferences of the users involved [15, 16].

Lastly, the combined approaches include conflict resolution strategies that combine the first two approaches [17]. Depending on the type of conflict and the users involved, these systems decide whether to resolve the conflict independently or require user participation.

3. Types of Conflict in Routine Creation

Considering routine creation on VAs like Amazon Alexa, a conflict can occur when actions belonging to two different routines are meant to be performed on shared devices (e.g., listening to music vs. listening to the news through the same smart speaker) or when the same action is included in two routines but requires to be executed with different preferences (e.g., listening to classical music vs. listening to hip-hop).

A specific type of conflict arises when actions modify environmental variables (e.g., temperature degree, environment noise, lighting) for which users would like to set contrasting values due to different underlying motivations. For instance, a home inhabitant interested in energy saving would be more inclined to switch off the lights or lower the heating temperature at a certain time, whilst another inhabitant could be paying more attention to health and might desire that the temperature never goes below 19 Celsius degrees. Underlying motivations can also be related to different users' activities: e.g., reading would require the light on, whilst sleeping would require the light off.

We can also classify conflicts on the basis of how routines overlap in terms of the time of execution and duration and in terms of the actions included in routines that conflict with each other. Considering time, two routines overlap partially when the two time intervals do not completely coincide, while they overlap completely when the two time intervals are identical. On the other hand, we speak of overlap of two routines, from the point of view of their component actions, when some of the actions in one routine conflict with those in another one (partial overlap) or when all the actions in the two routines conflict with each other (complete overlap).

When discussing conflicts between routines, it is appropriate to distinguish the time at which they are detected. In fact, such conflicts can be detected either at *creation time*, when the user attempts to save a new routine, or at *run time*, when a routine is invoked by the user or when it is executed on its scheduled time. Depending on the time at which conflicts are detected, the resolution strategy must change: in the first case, it is possible to prevent the creation of conflicting routines, whereas in the second case, it is possible to intervene only at the time of the invocation of the second routine, partially or totally restricting the actions of one of the two routines involved.

4. A Combined Approach to Conflict Resolution

Our combined approach was defined by considering Amazon Alexa VA and Amazon Echo devices. Therefore, due to some technical limitations, not all possible types of conflicts have been investigated. So far, we have focused on conflicts between two scheduled routines and have dealt with conflict detection and resolution at creation time.

From the literature review on the topic, it emerges that it is necessary to integrate and combine more than one strategy for conflict resolution to design an effective approach. We point out two important aspects that have to be considered and among which the right balance has to be found:

- *Decision-making autonomy of the virtual assistant*: the virtual assistant must be able to detect and resolve all conflicts arising between scheduled routines autonomously by applying predetermined rules. For this to happen, the conflicts must have a clear nature – i.e., they must be caused by an explicit temporal overlap of the actions of the two routines involved.
- *User decision-making power*: the user must be denied the possibility of creating a new routine that conflicts with an existing one, but, at the same time, they must be allowed and guided to make changes to their routine to eliminate any possible conflicts. In addition, in all those situations where the presence of a conflict is possible but not certain, the user must be informed of it and let free to decide whether to ignore the notification or to confirm the presence of a conflict and proceed with the routine modification.

In our approach, to detect conflicts, the system uses a set of rules to be applied during the creation of the second routine for checking all actions that concern the control of a device or an environmental variable. For a conflict to exist, there must be a temporal overlap between the actions performed in the two routines. Determining whether there is a temporal overlap between two actions is easy when they start at the same instant (e.g., one action involves playing music at 3:00 p.m., the other turning on the TV at 3:00 p.m. in the same room, thus affecting the same environment variable) or when the duration of at least one of the two actions is explicit (e.g., one action involves turning on the TV at 7:00 p.m., another action involves playing music from 6:50 p.m. to 7:30 p.m.).

An important aspect not to be underestimated is the naturalness of the conflict resolution process: the virtual assistant should, on the one hand, act as an impartial and fair agent, and on the other hand, it should simulate what really happens in a domestic environment where there is a hierarchy among the occupants. The proposed approach assigns each user a priority level depending on their age to replicate such a hierarchy: Children (0-15), Youth (16-25), Adults (26-70), and Seniors (71+).

However, the exclusive use of priority as a decision-making parameter would marginalize low-priority users (starvation), who would see their requests often denied, regardless of their motivations and needs. This turns out to be a significant problem in those cases where low-priority users have important motivations for carrying out their actions, while the motivations of high-priority users are superficial. Consider, for example, the case where the conflict involves two routines programmed to control the lighting in a room, the first created by a user belonging to the Youth category, who needs to study for a university exam, and the second created by an adult who just wishes to relax watching TV. Clearly, in an environment where people respect each other, considering the motivations for which the routines were created, the adult user would spontaneously grant control of the room to the younger user.

To replicate what happens in an environment inhabited by people who respect each other, the system should be equipped with a mechanism that also considers the relevance of users' actions in deciding the outcome of a conflict. Each user will therefore be asked to assign a ranking to a set of motivations for routine creation: *cleanliness*, *energy conservation*, *entertainment*, *health*, *physical activity*, *relaxation*, *rest*, *study*, and *work*. We call this ordered list of motivations user's *preference*. By having the user's *preference* and motivation for why they are creating a routine, the system can resolve the conflict with an existing routine by comparing the priority each user implicitly assigns to their routine using the preference-motivation pair. Using such a mechanism, the virtual assistant can also accommodate the needs of low-priority users if by this comparison their routine results to be more relevant.

The first strategy used to resolve the conflict is based on the preference-motivation pair, which prioritizes the routine whose motivation occupies the highest position in the respective preference rankings of the involved users. If the two motivations occupy the same position in their respective rankings, the system attempts to resolve the conflict by applying a second resolution policy based on users' priority comparison. If a further case of parity is found, the system resolves the conflict using the last policy, first-arrived-first-served, which, between the two conflicting routines, favors the one created first.

Once the conflict is resolved, if the routine to be retained is the one that is already existing, the virtual assistant will notify the user who is creating the second routine that it is impossible to finish the creation process and will allow changing the routine definition to avoid conflict to happen. Otherwise, the virtual assistant will delete the old routine, notify the affected user of this decision, and save the most recent routine.

There is a special case where the existence of a conflict is not clearly determined: since most actions cannot be assigned a duration beforehand, it is necessary to decide on time thresholds for each type of action, within which the system signals the presence of a possible conflict. Consider, for example, the case where two routines, programmed to be performed only ten minutes apart, involve playing music from the smart speaker and turning on the television in the same room. Since both actions do not indicate an explicit duration, a system would not detect a conflict. There must be defined a time threshold defining an interval of time in which the action's effect is still ongoing: e.g., for music playback, one could think of an interval of thirty minutes. If the routine under creation will attempt, during this interval, to access the same device or the same environmental variable, the system notifies the occurrence of a possible conflict and provides the user with the opportunity to decide how to behave: either ignore this conflict possibility or proceed to prevent it. Of course, the virtual assistant can do no more than merely inform of the possible occurrence of a conflict without trying to resolve it. This is because the occurrence of such a conflict is not certain but only hypothesized since the virtual assistant cannot determine *a priori* the actual duration of the actions. In fact, going back to the example above, it could be that one of the two users wants to listen to music for only ten minutes, thus not causing any conflicts. This is just one example in which the role of users and therefore, human intervention in the decision-making process is fundamental.

5. Discussion and Conclusion

End-user development for smart homes has been studied for about 15 years, and different AI-based approaches exploiting natural language processing and voice-based interaction are currently proposed in literature [18, 19, 20, 21]. Indeed, in household environments, one cannot hypothesize neither that inhabitants with a high degree of computational literacy are present nor that computational fluency can be taught in this context like reading and writing [22]. On the contrary, computational fluency can be encouraged and supported by means of easy-to-use tools that may engage users in personal and shared meaningful activities [23]. We worked in this direction, proposing to move the routine creation activity from the mobile app on a separate device (the smartphone) to the VA itself, which supports a multi-modal dialogue based on visual messages, touch gestures, and voice messages. We demonstrated that, notwithstanding a lower efficiency in terms of time for routine creation when compared with the use of the companion app, there is an improvement in usability and user experience since the users are more engaged by such type of interaction and find the EUD activity easier to learn [5].

In this paper, we made a step further by exploiting the VA (and its smart speaker) to manage possible conflicts that may arise in multi-user environments, favor collaboration among family members or housemates, and improve the quality of life in smart homes. Conflict resolution in this context can be regarded as a wicked problem in that there is no unique and always valid solution that can be specified a priori, but conflict resolution depends on the situation and often may require a direct debate between users, beyond the mere system use.

The approach described in this paper takes into account the design trade-off [24] between a totally automatic conflict resolution strategy that can be implemented through AI algorithms and a complete user-driven approach that might require a high effort from the human even when the situation is easy to manage or can be initially screened by an automatic system. Thus, our approach aims to realize the so-called *Intelligence Augmentation* [25, 26], where the technology does not replace humans but empowers them; specifically, in our case, the system detects if an actual or potential conflict will occur, proposes a solution when there is a clear outcome, or provides the user with different suggestions when the conflict is not certain and more than one solution can be put in place. This idea follows the human-centered AI way of thinking [27], which expands from an AI algorithm-focused view to a human-centered perspective in which humans always keep control over the technology.

Traditional human-centered interaction design methods have been adopted to implement an Amazon Alexa Skill for end-user development of routines with conflict resolution: iterative prototyping allowed us to obtain a preliminary version of the Skill that has been evaluated with a 3-member family and a group of 4 housemates. All the participants were able to complete the assigned tasks and provided positive feedback about the proposed approach to both EUD and conflict resolution.

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