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Modelling and Simulating Collaborative Scenarios for Designing an Assistant Ambient System that Supports Daily Activities

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Abstract. This paper presents the design phase of a work aiming at designing and developing a smart living device for seniors to assist them in their daily outdoor activities. We follow a participative design approach based on scenarios in order to design a socially-adapted device that will be useful to improve seniors' life. To specify our system, we first provide an UML scenario metamodel to abstract all the concepts involved in our system collaborative functioning (interactions with stakeholders, environment …). This metamodel is used to generate different scenarios in order to better define future users 'needs and the system requirements and notably its behavior (represented with BPMN and Petri Nets). A scenario generator has been implemented for that purpose. Finally, we show how to simulate and analyze those generated scenarios using process mining techniques.

Keywords: Scenario structure model · Daily activity scenarios · Scenarios generator · Process mining

1 Introduction

The increasing population of elder people requires that more actions should be done in order to improve their quality of life [1, 2]. One possible means in this way is to provide them with tools that assist them. Nowadays, the technological advances have led to an explosion of the number and functionalities of electronic devices. So far, a considerable amount of progress is made to help and assist seniors in their life such as home monitoring [3], fall detection[4], helpline, geo-location gadgets but all of them are either designed for indoor care or limited to a defined zone [3,4,5]. Moreover, we can notice two main insufficiencies. Firstly, the devices targeting outdoor are not yet

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on the market and still on the experimental stage. Second, results of technological devices are often very unsatisfactory as well as socially inappropriate since they are designed in an ad-hoc way to help a senior with a specific level of frailty and in a particular environment. Furthermore, the study of their acceptance by researchers in Humanities and Social Sciences (HSS) is only performed after the device is operational.

This paper presents the design phase of a work aiming at designing and developing a usable and acceptable living device for elderly to assist them in their daily outdoor activities. This technical device, called Sadikikoi, should assist cognitive disabled people in their daily activities outdoors either through notifications and suggestions to reorder their schedule or to send alerts if troubled situations (lost, fall…) are detected depending on the context. We argue that the building of such a "well thought" technical device, should involve users and their surroundings, HSS and medical experts during all the design and development process. We also believe as demonstrated by Mitzner and Rogers that involving seniors in the design process would increase the system acceptance rate [6]. These observations lead us to follow a user-centered approach. Among the different user-centered approach, we can mention: participative design, contextual design and emphatic design [7]. The work presented in this paper, part of the Compagnon project[1], follows a participative and multidisciplinary design approach based on scenarios. Scenarios express multi-point of view use cases to capture requirements [8]. More precisely, in our context, a scenario describes the succession of the system actions to deal with possible events and activities of a user in his/her daily life. In our project, users, computer scientists and sociologists are involved.

Indeed, the users want to be in the heart of the process and like to be involved at every stage of the project to validate it in compliance with their needs to increase self-esteem and limit their dependencies to the device. The choice of scenario is justified by two reasons. It first helps to take into account several points of view and therefore builds a common language to increase understanding and sharing between the stakeholders. Also, scenarios can be used for different steps of the life-cycle of the system to be built. The paper describes an UML scenario metamodel and shows how it can be used to generate new and more complex scenarios. The generated scenarios are then used to simulate, test and validate different system behaviors, represented in Petri Nets derived from process-mining techniques.

The paper is organized as follows. Section 2 details our scenario based approach: its life-cycle and a guiding example of a scenario. Section 3 shows the proposed scenario metamodel that represents the scenario structure. It is be used to gather user needs through participatory design and also to create a scenario generator. Section 4 shows how to derive the system behavior (represented with Petri Nets) from generated scenarios using process mining techniques. Section 5 illustrates the implemented scenarios generator and its usefulness. Section 6 briefly compares our proposition to related works and concludes the paper.

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[1] The Compagnon project is funded by the Midi-Pyrénées Region. The system to be build is called Sadikikoi

2 A Scenario Based Approach

2.1 The Approach Life-Cycle

Now that we clearly choose to follow a participatory design, we should define how we should proceed to design and develop our system.

The life-cycle approach, given in Fig. 1, describes only the system requirement and the design phases concerned in this paper.

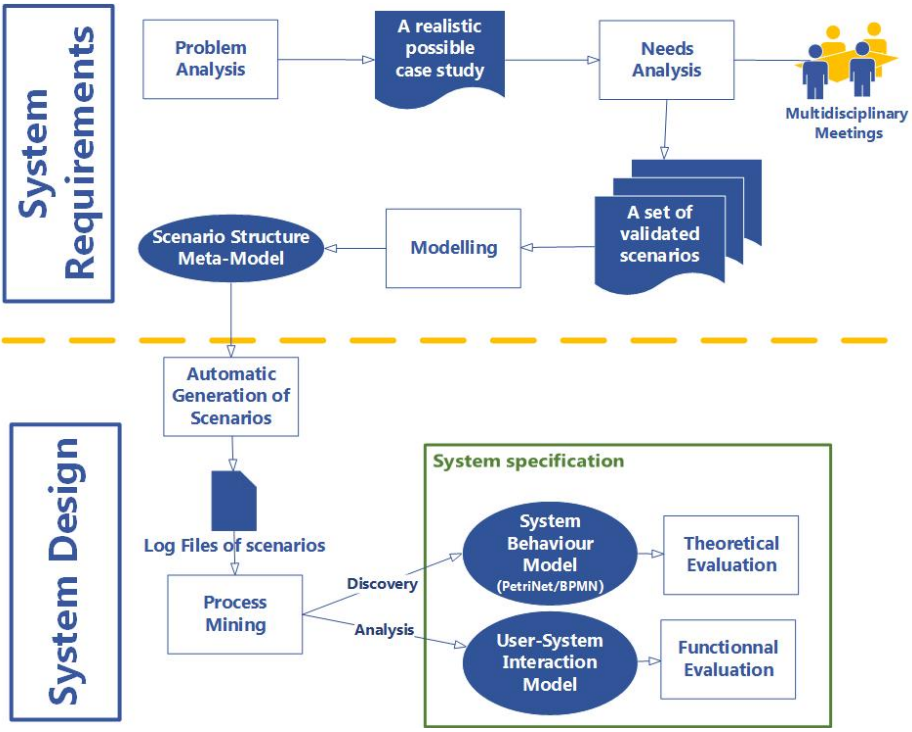

Fig. 1. The proposed approach

***System Requirement Phase*:** we give a first realistic case study in a textual form, as a start point presentation of our system functioning, to stakeholders. Then, we start the needs analysis step with stakeholders (HSS and medical experts) through several multidisciplinary meetings in order to define and validate several possible scenarios. The main focus of this first phase is not to provide occurrences of scenarios but rather their structure. Moreover, through those collaborative brainstorming, we create simple (i.e. can be understood by any end user) and complete (i.e. involves all the elements needed to design and develop our system) scenarios. From those scenarios, we derive a scenario metamodel also discussed and validated by the same multidisciplinary study group. These scenarios represent a succession of user daily possible outdoors activities and system actions. As we chose to use a user-centered design based on

scenarios, different scenarios representing different situations are required to better gather users' needs and define our system functional requirements.

***Design Phase*:** we start by generating and producing a larger and more diverse amount of scenarios using a scenario generator that is implemented with regard to the proposed metamodel. Those generated scenarios are be used, on the first hand, to gather future user's needs and preferences through multidisciplinary meeting, and on the other hand, to generate event logs as an input for process mining: scenario being modeled as process. This mining step, using the ProM[2] tool, allows us to analyze the system interactions and discover its behavior models.

2.2 Meaning and Example of Scenario

Since scenario is the first class-citizen component of our design, we now explain the meaning of a scenario as it is used in our approach and we present in details a simplified example of a scenario that describes the functionality of Sadikikoi system in its environment. We follow the scenario classification framework of [8] that represents four different views for a scenario: purpose, content, life-cycle and form. The *purpose* is to specify the system by simplifying the system functioning description and facilitating the understanding of the system behavior. The *content* of each scenario is a description of the system behavior in its ambient environment. It is represented as a process that describes the different possible interactions between the system and the stakeholders. The description of several different situations, the associated system actions for each situation, and the interactions with the user allow us to specify the needs and expectations of older people. Each scenario has a *life-cycle* i.e. any scenario is first created from discussion or automatically generated by our generator, possibly updated/refined after discussions and used for learning and test purposes. A scenario can be expressed in different *forms*: either as a text which is a standard form that is understandable by all actors or a tabular form (log files) compliant with our metamodel and that enables to get a covering, comprehensive and suitable format for designers.

Let us now present an example of scenario. It involves three actors which are the user, the family and the system. The scenario presents in Fig. 2 by a BPMN[3] model is a scenario where the user starts his day by *going out* of the house and then gets a *notification* from the system to take an umbrella because it's raining. Then, the user goes to *buy a newspaper*. He receives a *goal reminder* message that describes its current planning so that he won't forget his appointments (i.e. doctor, meeting…). The user then goes *shopping* but suddenly he falls down. The system Sadikikoi detects this abnormal situation because the user stops moving for a certain period of time. Even though it is an abnormal situation, the system cannot be sure if the user is just taking a break or if he *fell down* so it *sends a message* to the user and seeks for a response.

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[2] ProM is a generic open-source framework for implementing process mining tools in a standard environment. All information concerning this extensible framework can be found on the URL: *http://www.processmining.org*.

[3] Business Process Model and Notation is a graphical representation for specifying business processes in a business process model

Because the user *ignores the message*, the system reinforces the fact that an abnormal situation occurred. So, the system *sends a message* to inform *the user's family* of the situation. The family *comes to rescue* meanwhile the system continues to *call the user* because this action would help the user to get his consciousness back or may alarm people around him so they can help. Finally, the user *goes back home*.

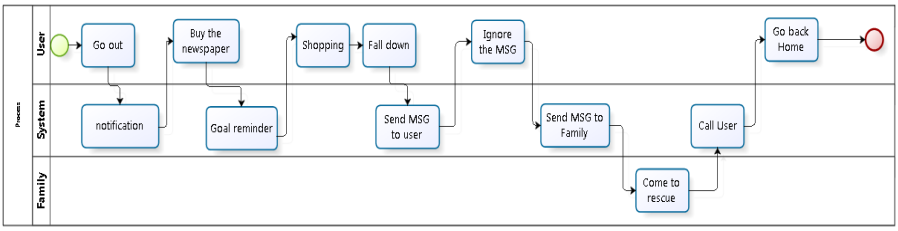

Fig. 2. A descriptive workflow of a scenario example

Obviously, this is a simplified version of a possible scenario. Real scenarios are more complex and contain more interactions between actors and the environment. In order to produce those examples, many interactions leading to several updates have been done either because something was missing or for deleting possible ambiguities. Because we work in an interdisciplinary context, including HSS, medicine and computer science thanks to scenarios a common language among them was created. After we got several validated possible scenarios, we define a scenario metamodel that describes all the required elements to create a complete and comprehensive scenario.

3 A Scenario Metamodel

By formalizing the scenario structure, we will be able to generate more different scenarios that may be presented in different forms (tabular, textual…) without missing an important detail or interaction.

The proposed scenario metamodel describes the key elements and their relationships required to describe the functionalities and behavior of an ambient system that assists seniors into their daily outdoor activities.

This model enables the instantiation of various possible daily scenarios.

Fig. 3 shows the conceptual metamodel, which represents the scenario structure, as an UML package diagram. We have a model composed of three packages: Stakeholder Description, Context Description, and System Action.

1. *The Stakeholder Description* package contains all the information about the human being involved in the system: main user (person with cognitive impairments), preferences, calendar with these various constraints and information about other actors involved in the system (e.g. godfather, family, neighbours ...).
2. *The Context Description* package concerns the different variable elements over time and space. It includes all the user activities, unexpected events and the space-time environment in which these actions take place. It describes the observations and various perceptions of our system.

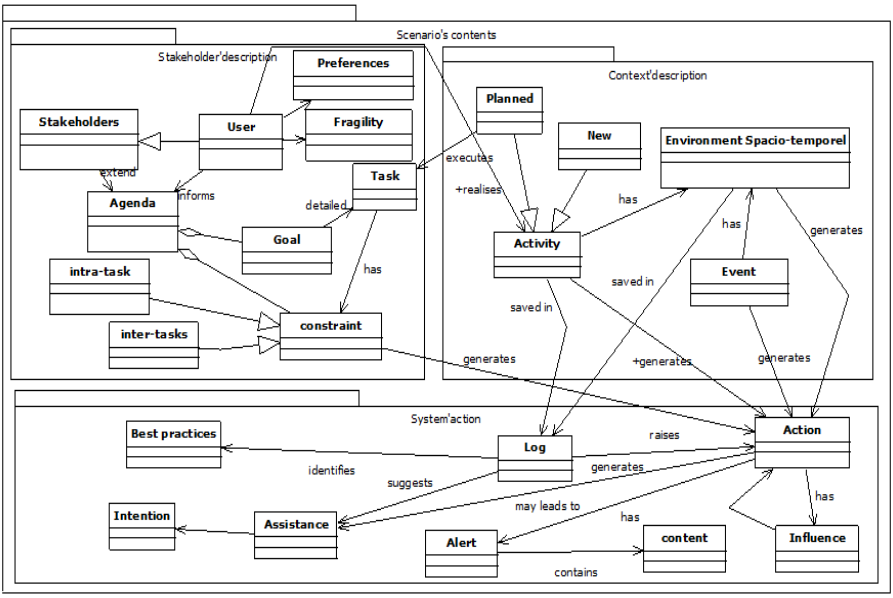

Fig. 3. Proposed Scenario Structure Metamodel

3. *The System Action* package describes the possible actions (suggestions, alerts) of the system and the various interactions between them.

Based on the above scenario structure metamodel, several scenarios where instantiated in order to validate the completeness and accuracy of our proposed model. Some of the concepts used in our proposed model are defined in order to remove any possible ambiguity and provide a better understanding. These concepts are complex and difficult to formalize because their definitions may vary depending on the context of their use.

-TASK: it represents the tasks set by the user in his calendar. These tasks are not necessarily well detailed but can be just goals as they can be well defined tasks with a fixed duration and precise location. So, the task presents the planning of an activity

-CONSTRAINT: it describes a restriction that may have one of these two types: 1.Intra-task constraint that contains constraints within the task itself such as fixing the place and time of its realisation. 2.Inter-task constraint that describes the scheduling between tasks (example: such as TaskA should be done before TaskB).

-ACTIVITY: it represents the realisation of a planned task or an unexpected task. The succession of activities describes the user daily activities outdoors.

-EVENT: the event can be defined through a behavior (e.g. hit someone) or a signal observed in the environment (e.g. it starts to rain) or even a signal from the system itself (e.g. no battery). All these types of events are interpreted by the system perceptions (i.e. data recorded by the sensors of the system). Most events have the characteristic of being short in time, in other words, they usually occur suddenly and in an unexpected way. They can be detected by a change in the value of a variable or the

appearance of a new variable in a given instant. An event can cause different impacts (positive or negative) according to its type and its spatiotemporal environment.

-ENVIRONMENT: the environment taken into account is a temporal and geographic location compliant with the definition of Salembier and al. “The environment describes a stable structure that describes the position with respect to time and space”. [9]

-ACTION: it describes the actions of the system. Each action is defined by a type, level and a recipient. Moreover, each action has an impact / effect on the recipient. An action is described by a state change of system effectors (e.g. the action “Send an unobtrusive signal to the user" can be represented by changing the state of the effector from the stat {vibrator = OFF}) to the {vibrator = ON}).

4 Building the System Behavior by Means of Process Mining

The idea here is to synthesize several scenarios in a single process able to play each scenario. The process produced represents a possible model of the system behavior including the interactions with users and the environment.

In order to use process mining technique, the generated scenarios should be converted into event logs which are used as input of the process mining algorithm called alpha [10]. We create a log file including all the generated scenarios and we deduce a single process model, represented by Petri Nets, synthesizing all the possible combinations. When we apply the alpha algorithm on real scenarios, we got a complex diagram (“spaghetti” like, see Fig. 7) difficult to present in this paper for clarity reasons. Also, we choose to illustrate the results through basic scenarios. For this, let us consider the tasks shown in the Table 1.

Table 1. Description of used tasks in the described scenario

TASK	*DESCRIPTION*	*ACTORS*	*INTERACTIONS*	*TASK*	*DESCRIPTION*	*ACTORS*	*INTERACTIONS*
A	Go out	User		**I**	Send MSG	System	User
B	notification	System	User	**J**	Respond to the MSG	User	
C	Buy the newspaper	User		**K**	Go to the pharmacy	User	
D	Goal remin der	System	User	**L**	Ignore MSG	User	
E	Go to the library	User		**M**	Call User	System	User
F	Walk out	User		**N**	Send MSG	System	Family
G	Shopping	User		**O**	Come to rescue	Family	User
H	Fall down	User		**P**	Go back home	User	

From these tasks, six different scenarios were generated (ABCDEHIJKP, ABCDFHILMNOP, ABCDGHILNOMP, ABCDEHILNOMP, ABCDFHIJKP, ABCDGHILMNOP). Using the PROM tool, the alpha algorithm applied to these six

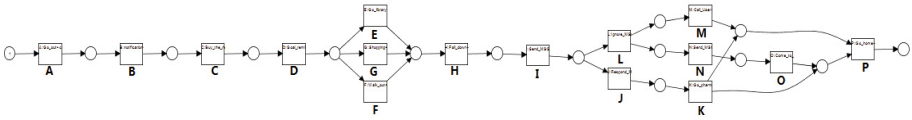

Fig. 4. Petri Net representation of the system behavior derived from scenario examples

scenarios produces the Petri Net shown in Fig. 4. Let us notice that it is a dynamic model that can execute and simulate all the six scenarios previously defined.

In this model, we could differentiate the common repeated elements of the scenarios, possible parallelism and choice actions. This diagram gives us a clear picture of our system behavior in its environment. We also apply a social network analysis on the event log, as shown in the sociogram (Fig. 5) that visualizes the different interactions between the actors of the scenarios.

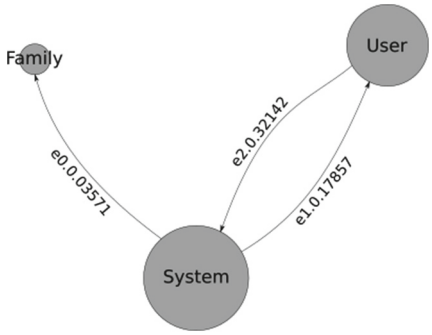

Fig. 5. The social network of the scenarios examples

As you can see, the size of each actor is proportional to the number of his actions and we can clearly see that the user keeps a reasonable level of autonomy. By analyzing those resultant diagrams (Petri net, sociogram…), we build a better understanding of our system behavior and the different required interactions. Moreover, they could be used for future formal validation purposes.

5 Principles of the Scenario Generator

The fact that our aim is to develop an intelligent device that adapts to its environment by learning, the generation of test cases is crucial to forge the learning experience of Sadikikoi system and also to evaluate our system later by analysing its behaviors in response to different scenarios. As the Sadikikoi system is targeting persons with cognitive deficiencies, it would be difficult to evaluate our assistant system by targeted users because it could be inconvenient and dangerous especially in an early stage of the development. So, the idea is that a scenario generator capable of simulating user's activities along with our system actions is needed in order to investigate our system learning capabilities and its efficiency in a dynamic and evolving environment.

From the scenario metamodel used to generate several scenarios understandable from a user point of view, we extract a subset of components needed to describe scenarios from a system point of view. Giving the fact that the generator concerns the dynamic part of the model, the stakeholder' description package is not represented in the generator. We select the following relevant elements:

— ***Perceptions*** which represent all recorded data and collectible by the system via sensors, external applications or internal databases. The generator generates perceptions that represent the system inputs that define the triggers of its actions. The succession of perceptions describes the progress of user daily activities through time.

— ***Tasks*** which define the end of the realization of a planned task in compliance with the scheduling constraints in the planning.

— ***Actions*** which represent the outputs of the system. An action can be a notification, a suggestion or an alert that is executed by an effector (e.g. screen, high speaker…) or an external application.

The generator goal is to create numerous virtual scenarios for a given period of time (e.g. a day, a week…) in order to evaluate the learning capabilities. A scenario is a set of mini-scenarios. A mini-scenario is a group of perceptions and actions defining a meaningful situation such as a realization of an activity or a disorientation situation. The generator works in two steps. The first one generates a set of mini-scenarios. The second one aggregates mini-scenarios to form scenarios for a given period of time. Any element of a mini-scenario may appears several times in one or different scenarios.

Fig. 6 shows a succession of perceptions, ends of activities and system actions constituting a scenario. The associated semantic is given by the scenarist and not considered by the generator. We can notice chronological changes in user's actions/reactions, in the dynamic environment in which he is located and in the system interactions.

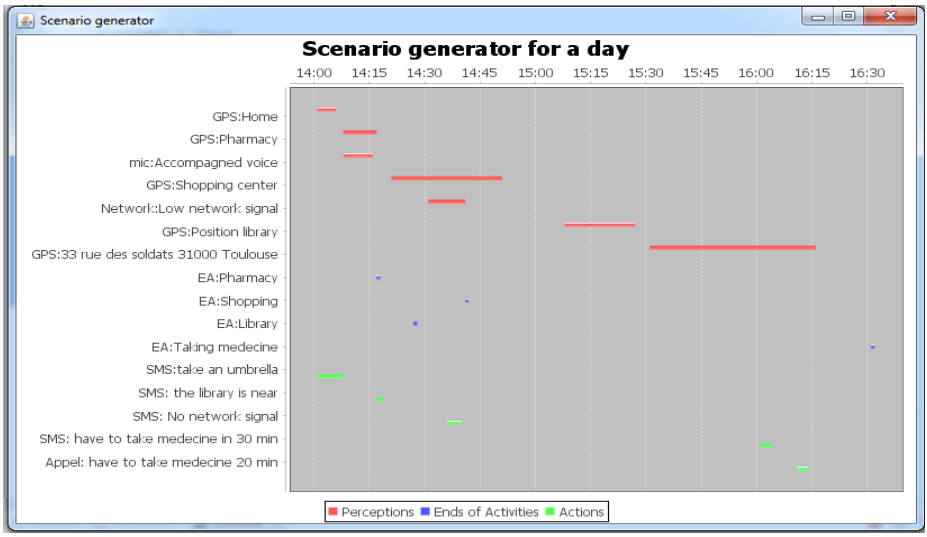

Fig. 6. The scenario generator interface: representation of a scenario day

Many parameters can be modified before generating the scenarios such as the period, which determines the total number of generated scenarios, the frailty of the user with regard of his autonomy level (determining the number of system actions in scenarios). When we applied the process mining, on the generated scenarios partially represented by fig 7, we get the Petri Net diagram (spaghetti form, shown in Fig.8).

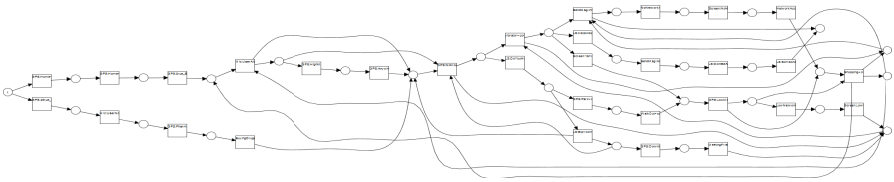

Fig. 7. The diagram discovered from the generated scenarios

For clarity reasons, we choose to represent only a three days period. We can see the complexity of the resultant discovery diagram. Despite its complexity, we can identify the emergence of repeated parts of the process and this could help us to analyse the system behavior and even facilitate the comparison between what should happen and what actually happened later on the evaluation phase of the system.

6 Discussion and Conclusion

This paper has presented a scenario metamodel enabling the generation of collaborative scenarios for defining the functionalities of an assistant ambient system that supports daily activities. These scenarios can be used both to define cooperatively the target system and also to simulate its behavior since they are synthetized as a Petri Net, known to have an operational semantics. This has been made possible by using a process mining technique deriving the system behavior (Petri Net) from scenarios. Thus, this approach based on scenarios can be seen as a guideline to follow a user-centered approach.

We found in the literature different Assisted Living Technologies (ALT) systems that also use user-centered approach for designing systems for vulnerable population. Those works differ from our work according to three points of views: the system's function, the approach used for requirement elicitation and the way scenarios are exploited (definition, structure, diversity…).

To implement user participations, there are several techniques for gathering user needs either indirect (e.g. interviews, questionnaires, focus groups, observations, user testing…) [11] or direct and active participation of future users all along the design and development process (e.g. meeting, workshops...) [12]. Many progresses have been made in ALT-based systems specifically in smart home projects and mobile and wearable sensors. Some successful case studies and deployed systems that follow a user-centered approach are presented below.

The COACH system (Cognitive Orthosis for assisting aCtivities in the Home) [13] supports users with activities of daily living at home. The process used in this work is

interesting because diverse techniques are used such as group discussion, collaborative brainstorming, animated videos scenarios, paper prototypes. In comparison to our Sadikikoi system, in the COACH system neither the scenarios nor the process have been formalized. Moreover, it has been designed through limited number of scenarios (corresponding to lived experiences) indoor while we generate a covering set of scenarios for outdoors practices. The Home Care Reminder System [14] that uses a user-centered process involving formative co-design sessions with six groups of older users. They used interactions with both paper-based prototypes and prototypes running on mobile devices. The similarity with our work is that they used an iterative and inclusive process as we do, but they do not cover all the design life-cycle and no formal scenario structure is provided.

The closest work to ours is the "KITE" project (Keeping In Touch Everyday) [15] that implements a solution on notepad and armband to locate and to keep in touch and communicate with people with dementia for promoting their independence. The interesting point in this successful project is that it involves users with dementia in all the stages of the participatory design process: scoping stage, participatory design, prototype development. Scenarios are built in cooperation with users and based on the real-life experiences. However, the scenarios are not formalized and limited to the stories gathered through the interactions with users while in our case we give a formal and validated model of scenario from which we are able to derive a covering and probable set of scenarios. Moreover, two steps of our process are automated: generation of scenarios and derivation of the system behavior from the scenarios. Finally, our scenarios are a first class-citizen component of Sadikikoi design that is used in the different steps of our process life cycle from system requirement to evaluation.

In future works, we should first start the design of the interface of the Sadikikoi system in collaboration with users. Also, the learning module should be implemented before making tests in a real setting.

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