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Applying a Methodology for Developing AmI Systems: the Nursing Home Case Study

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1 Introduction

In this report, we perform a case-study evaluation in order to validate the methodology proposed by the authors for developing AmI systems. The selected case study is a nursing home for the ACube project. The ACube[1] is a large research project funded by the local government of the Autonomous Province of Trento in Italy with the aim of designing a highly technological smart environment to be deployed in nursing homes as a support to medical and assistance staff. The system is based on a network of sensors distributed in the environment or embedded in users' clothes.

The report describes the development of the ACube case-study following the different phases of the proposed methodology, namely: 1) requirement elicitation; 2) identifying and modelling behaviour patterns; 3) automating and evolving user behaviour patterns. Finally, we conclude the report.

2 Requirement Elicitation Process

In this section we explain the requirement elicitation methods and artefacts used to gather user requirements within ACube case study: tropos model, personas and scenarios. More information about the process can be found in [2] and [1].

2.1 Tropos Model

The Tropos Model is used for modelling the set of domain entities when the system is not yet existing. It includes a bird-eye view over the domain in which actors and roles are specified together with their responsibilities and delegations. This view provides an intuition of which interactions occur in the environment. Subsequently each actor is exploited in a goal model, in order to provide details about human behaviour, highlighting the rationale by relating each activity to institutional motivations. The Tropos model designed for the ACube case study is shown in Figure 1.

[1] http://acube.fbk.eu/

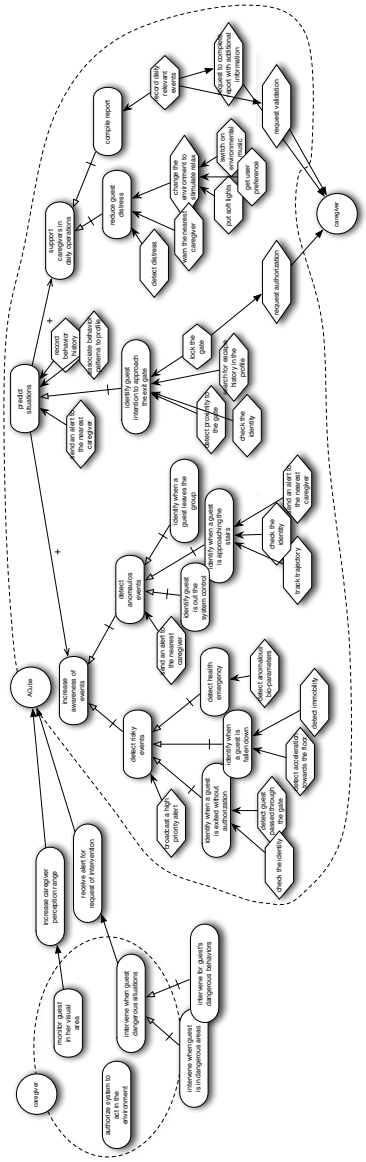

Fig. 1. Tropos model of the ACube case study.

2.2 Personas

Personas are fictional characters with personal features, life stories, goals and tasks helpful to meant to draw attention on users' goals and motivations. The following five *personas* were created starting from data collected in the field:

Name: Sabrina
Age: 40 years old
Description: She has been working as a caregiver in the nursing home for 5 years
Goal: To assist guests in all their daily activities
Problems: She likes the social side of her work. She complaints to have not time for establishing good relationships and to know guests The night turn is the most difficult since she is alone for 8 hours with 36 guests She is not comfortable with technology and thinks the computer is too difficult to use. Wishes: She would like to have more time for improve the knowledge of her guests. She would work in a more friendly structure, in which guests are free to move in and out.

Name: Gianna
Age: 38 years old
Description: She has been working as a nurse for 2 years in the nursing home
Goal: To provide sanitary assistance and administer therapies to guests
Problems: She complains the lack of time to carry out all duties. The bureaucracy is too heavy. She would use new technologies.

Name: Maria
Age: 78 years old
Description: She has been in the nursing home for three months and is affected by senile dementia. She has problems with memory and disorientation. She is not under specific monitoring because she have never tried to escape. She can walk though the recent assessment made by the physiotherapist gives some balance problems. She moves by the sustain of the handrails or by using the stick.
Wishes: Maria wants to remain independent even if she is in the nursing home. She would like to be able to move in the centre without the help of operators, see her family more often and do more recreational activities

Name: Carlo
Age: 93 years old

Description: Carlo has been in the nursing home for 1 year. He is suffering from Alzheimer's disease, memory deficits, disorientation in time and space and behavioural problems. He once tried to escape, so operators should give special attention to his movements. He has been aggressive in past; this crisis had been handled promptly by the operators who must appease him by distracting him away from other guests and by means of its interests (e.g., singing).

Wishes: Carlo smokes and would like to stay outside at fresh air. He often complains because he does not like to stay in nursing homes.

Name: Piera

Age: 90 years old

Description: Piera has been in the nursing home for 6 years. She has mobility problems which prevent her from walking. She also has health issues (blood glucose and cardiac problems that require constant monitoring, trauma to the femur). In addition, she is impaired in cognitive deficits: memory and depression. She needs for constant assistance.

Wishes: Piera has problems with depression. The situation leads her to loose motivations. She would like to have a more human relationship with operators, doctors and nurses.

2.3 Scenarios

Scenarios are stories representing people acting in a specific context and supported by technologies. Scenarios make concrete the behavior of a service as experienced by specific, though fictional, users - personas. They help design teams in negotiating a shared representation of the domain and hence a more effective elicitation of requirements. The following four scenarios have been created starting from initial field data and then validated with users and project stakeholders:

Scenario 1: Fall monitoring and prevention. Maria is leaving the restoration room, and the sensor on the door sends a signal to Sabrina's PDA that alerts with a vibration. Sabrina knows that a vibration means Maria is moving out from the room, but she cannot follow her in that moment because she must oversee the room. Whether Maria leaves the room with other guests or with a caregiver, the alarm would not be sent. Maria is going upstairs in order to reach her private room but when she is on the staircase, she falls. The camera identifies the event and sends warning signals to caregivers' PDA. Sabrina's PDA displays an unknown person is fallen down in the staircase between second and third floors. The nurse, Gianna, receives this signal and she is available to go, so she notifies (by PDA) that she is taking the event in account. Also Sabrina decides to go, she imagines that Maria is fallen, so she sends a message to other caregivers that restoration room is currently

not overseen. Renato (that is about to finish his turn) receives the message and suddenly goes to the restoration room where guests are alone. Sabrina reaches Maria and soothe her. Maria is active and she talks and reasons perfectly, she is afraid but she is not in pain for the hit. Gianna rapidly understands that all is OK and she press the orange button on her PDA (emergency is off). Maria is helped to stand and to return in her room. Sabrina comes back to other guests thus Renato is free to go home. At the end of their turn, Sabrina and Gianna have to write the report for the next turn colleagues. They turn on their computer and find an automatic report with all data relative to the event. Cameras, audio and RFID sensors have collaborated to collect data and to compile the report.

Scenario 2: Escape monitoring and prevention. Carlo is in the garden and follows some visitors going through the gate with the intention to run away. Carlo's bracelet sends Carlo's position to the system. The alert signal comes to Sabrina's PDA who reads "Carlo is leaving the institute", thus she decides to go. She communicates by using the PDA that is is taking in account the emergency. Other caregivers receive only a warning message. The camera near the gate activates and: 1) tries to follow Carlo's path 2) automatically locks the gate to prevent the escape Whether Carlo goes through the gate a second RFID sensor sends a message to Sabrina (who takes in account the event) alerting that the emergency is now serious. The camera records all the activities thus to allow caregivers to see what happened. All the events are collected in order to write the report at the end of the turn.
system knows that in last days Carlo is quite, likes to stay in the garden and smokes less.

Scenario 3: Aggressive behaviour. Sabrina has just started her turn. She is alone in the great restoration room where there is a group of Alzheimer people (8-10). Today it is noise and Sabrina cannot oversee everyone. It is summer and a few social workers are in the institute. Piera begins to disquiet and her behaviour becomes aggressive. A camera in the room identifies Piera's state and the system switch on some soft lights around Piera, and plays her preferred song. In the meanwhile the system alerts the nearest caregiver Sabrina about the trouble who decide whether to go, to call help or to ignore it.
At the end of the turn, Sabrina is in her office and validates the automatic report that describes what happened: Piera's behaviour, and the action activated (lights and music) and Piera's response. The report also contains that the room was full and maybe this is the cause of Piera's stress. The system learns something new.

Scenario 4: Night monitoring. Two caretakers are working in couple during the night to oversee and support guests during the night. They must move each guest every three hours. In the institute only a doctor is present. They are in Piera's room and all is OK, thus they continue their work. Suddenly Piera is suffering a heart attack; the t-shirt identifies the event. The PDA soon alerts Sabrina and Manuela (and the nurse and the doctor) with a vibration and the text: heart attack on room... The external light in the room

silently switches on to drive caregivers to the right room. This signal can be switched off manually. In the meanwhile Maria coughs and microphones identify the event. In this case only Sabrina and Manuela receive the warning because Maria's T-shirt estimates a regular breath and ECG (it is not a health emergency). When the nurse and the doctor are in the room, the caretakers can leave the room and continue their work. They can ask the system the last guest they have supported so to avoid to forget someone. The system replies that room 123 is completed but in 124 Ugo must be moved. The health emergency is automatically reported in the health diary.

3 Identifying and Modelling Behaviour Patterns

In order to automate the behaviour patterns identified in the requirement elicitation process, we have transformed the requirement models into two executable models: a context model and a task model.

Following these guidelines, we have identified and modelled the following patterns (see Figure 2):

Controlling Aggressive Behaviour: When a patient starts to behave aggressively, the system alerts the nearest caregivers. Then, the system puts soft lights and plays the preferred song of the patient that is behaving aggressively. Five minutes later, if the patient is still behaving aggressively, the system warns the security officers. Finally, a report is created and sent to the involved staff.

Avoiding Patient Escaping: If it is detected that a patient is leaving the nursing home, the system activates the emergency state, alerts the nearest caregivers and starts to record the patient. Finally, a report is created and sent to the involved staff.

Dealing with a Fall: If it is detected that a patient falls and no one of the caregivers is around, the system activates the emergency state and alerts the nearest caregivers. Finally, a report is created and sent to the involved staff.

Dealing with Health Emergencies: When a health anomaly is detected in a patient, the nurses and the doctor of the patient are alerted. The external emergency light in the room is then switched on. When the doctor and the nurses arrive to the room, the emergency light is switched off. If the situation is controlled, messages are sent to the involved personal staff to inform them about their next tasks. The health emergency is automatically reported in the health diary.

4 Automating and Evolving the Behaviour Patterns

After the specification of the context and task models, we ran the system to check the automation and evolution of the specified behaviour patterns.

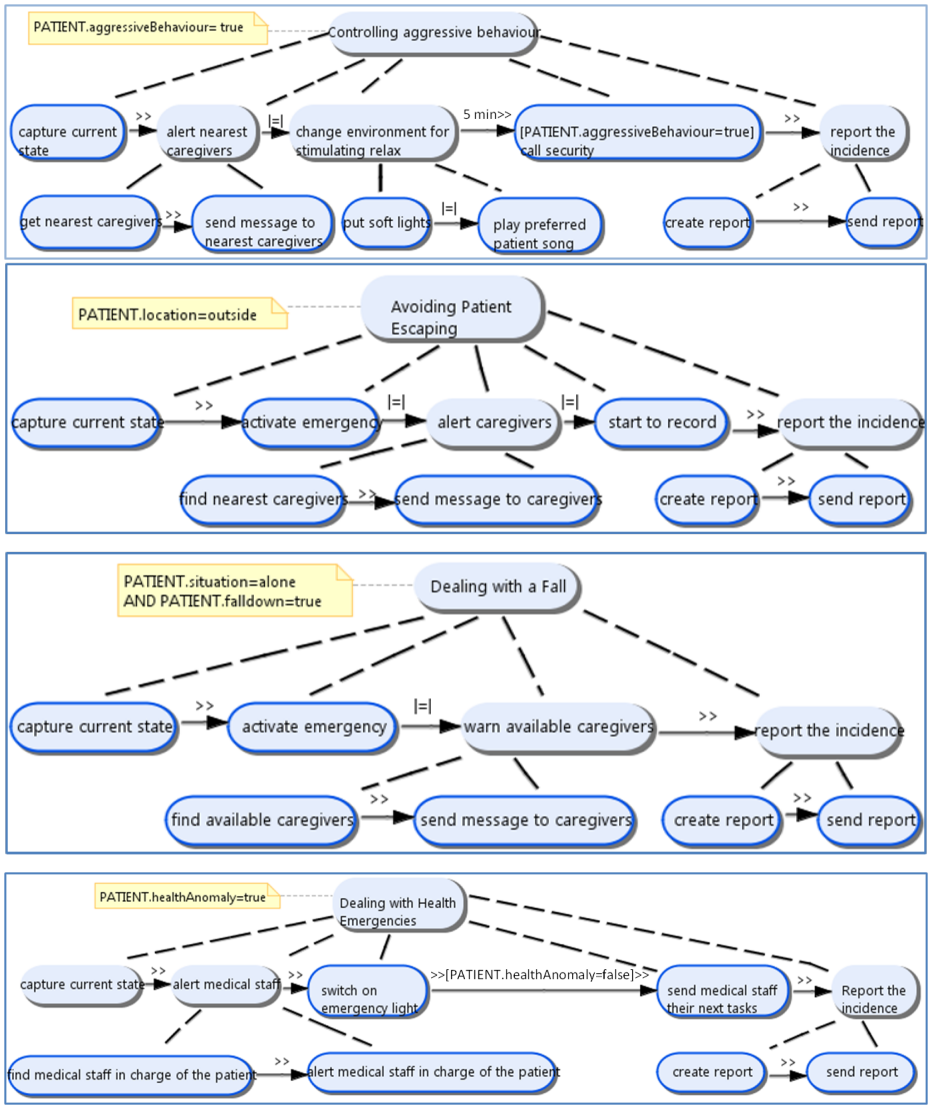

Fig. 2. Specified behaviour patterns in the nursing home case study

To support the functionality needed to execute the system tasks of the patterns, we developed the required services. Some of them, such as lighting or multimedia, were reused from previously developed case studies. The other required services were implemented as simulated services in order to simulate the functionality of the needed devices because we did not have the real technology (t-shirt for monitoring patient health, user position detectors, etc.). Thus, we

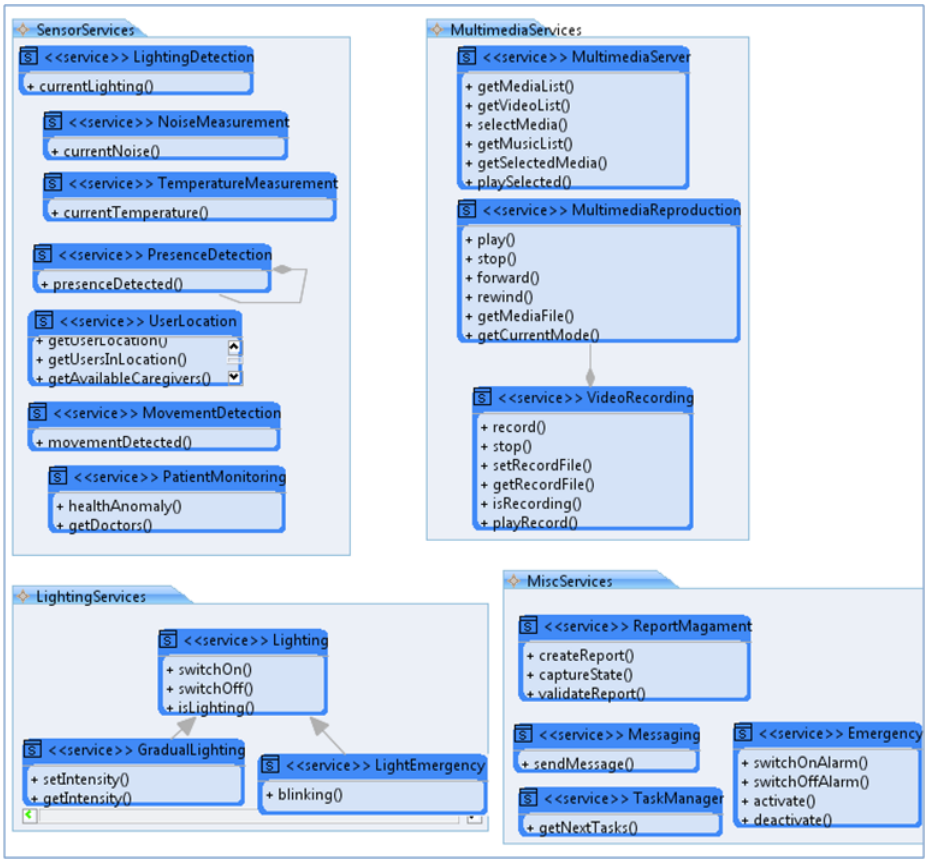

Fig. 3. Services required for the smart home case studies

used a total of 17 different pervasive services that are shown in Figure shown in Figure 3 using a class diagram.

We then put the system into operation. We used a PC with an installed Equinox. To run the system, we use the software infrastructure (which is composed of the MUTate and OCean APIs and the automation engine MAtE) [4]. Thus, we packaged the pervasive services, MAtE, MUTate, OCean and the device simulator (presented in [3]) into bundles, and we installed and started them in Equinox. The models were copied in the folder were Equinox was installed.

Using the running system, we evaluated the feasibility of our approach. To do this, we executed a set of JUnit tests developed to check that the specified behaviour patterns were correctly automated as specified in the models. Since the automation of the behaviour patterns are triggered as a response to context changes, we caused these context changes by changing the state of the sensors using the simulator. We changed the state of the sensors simulating the scenarios of the requirement elicitation phase. For instance, to enable the *Controlling*

aggressive behaviour pattern, we simulate that most of the patients were in the dinning room and one of them start to behave aggressively. This makes the context situation of the behaviour pattern fulfil (see Figure 2).

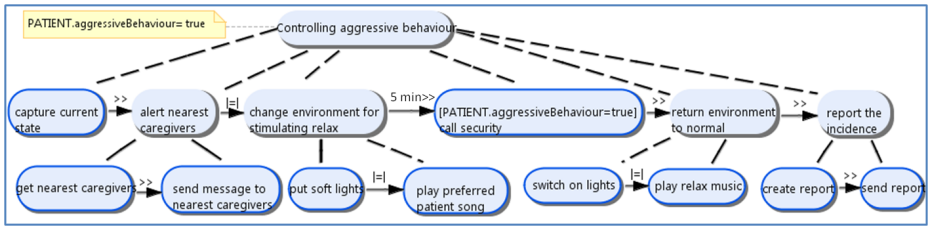

Fig. 4. Example of a behaviour pattern evolution

In the same way, we simulated the rest of the scenarios of the case study and executed the prepared JUnit tests. For all of them, we checked that they were executed as specified in the models.

We also perform some evolutions in the specified behaviour patterns. Figure 4 shows an example of these evolutions. It shows how the *Controlling aggressive behaviour* pattern has been extended to execute two tasks more, which return the environment to a normal state by switching lights on and turning on relax music. For each performed evolution, we applied again the JUnit tests checking that all the behaviour patterns were correctly executed.

5 Conclusions of the Nursing Home Case Study Development

The development of the ACube Nursing Home case study has allowed us to validate the proposed methodology.

In the requirement elicitation process we could identify several behaviour patterns that could improve the medical and assistance staff tasks. Using these requirements and the provided guidelines, we have transformed the captured requirements into the executable models.

In addition, we developed the pervasive services that were needed to automate the patterns. We then ran the case study using these services, the specified models, and the provided software infrastructure. Testing the system in execution, we have validated that the behaviour patterns are automated as they are specified in the models, fulfilling the requirements identified in the requirement elicitation process.

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