Situated agents and humans in social interaction for elderly healthcare: the case of COAALAS

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Abstract. Assistive Technologies (AT) are an application area where several Artificial Intelligence techniques and tools have been successfully applied to support elder or impeded people on their daily activities. However, approaches to AT tend to center in the user-tool interaction, neglecting the user's connection with its social environment (such as caretakers, relatives and health professionals) and the possibility to monitor undesired behaviour providing both adaptation to a dynamic environment and early response to potentially dangerous situations. In previous work we have presented COAALAS, an intelligent social and norm-aware device for elder people that is able to autonomously organize, reorganize and interact with the different actors involved in elder-care, either human actors or other devices. In this paper we put our work into context, by first examining what are the desirable properties of such a system, analysing the state of the art on the relevant topics, and verifying the validity of our proposal.

1 Introduction

Population ageing is becoming a global problem in the world, as older population (aged 60 years or over) is estimated to grow from the current 11% to 22% by 2050 [16]. Moreover, the cost of supporting an elder is greater than the cost of supporting a child in a ratio of five to three [15], most of this cost being caused by higher health expenses. In the coming years this situation (together with other economic factors) will put great pressure on the national healthcare budgets, mainly because therapies for managing chronic diseases (*e.g.*, diabetes, Parkinson, *etc*) are performed away from the institutional care setting, typically at home. This distributed approach to daily care requires that elders be capable of autonomously taking several different medications at different time intervals over extended periods of time. This can easily lead to forgetfulness or confusion when following the prescribed treatment, specially when the patient is suffering multiple pathologies that require a treatment with a cocktail of drugs. This gets worsened when elders suffer a cognitive impairment. Medication compliance is a critical component in the success of any medical treatment.

In this context, AT have been able to provide successful solutions on the support of daily healthcare for elder people, mainly focused on the interaction between the patient and the electronic devices. However, the distributed approach that such kind of healthcare has to follow in the current socio-economical setting requires more complex AT designs that go further than the interaction with a tool and are able to focus on the relationship between the user and their social environment: caretakers, relatives, health professionals.

In previous work, we presented the COAALAS project (COmpanion for Ambient Assisted Living on *ALIVE*-Share-*it* platforms) [8], a framework for multi-agent systems that combine organisational and normative theories with Ambient Assisted Living (AAL) technologies. The project aims to create a society of organisational aware devices (typically sensors and actuators) that are able to adapt to a wide range of AAL situations. COAALAS models the device network around the user as a society, including the set of behavioural patterns the devices are expected to follow. COAALAS effectively supports smart assistive tools that integrate human actors with the surrounding devices, contributing to the state-of-the-art in semi-autonomous and intelligent devices for elder people by allowing the devices to be both social- and norm-aware.

The mid-term objective of COAALAS is to integrate a wide range of sensors and actuators in a domotic setting, in order to transparently assist the user in their daily activities, while keeping all the participants of the healthcare workflow involved. The first design and implementation of such a sensor/actuator is the social electronic reminder for pills [7], which tackles the supply of the required stock of medicines to a user with difficulties to leave their house, while supervising that he follows the medical treatment prescribed by his doctor, not missing any dose due to forgetfulness or taking it at the wrong time due to confusion.

The focus of our previous published work with respect to COAALAS has been the description of the architecture framework and technical design of the social electronic reminder. In this paper we present the high level motivations of the research being done in the project (§2), and we present proposals existing in the state of the art that have properties common to COAALAS (§3). Our proposal is then put into context with both our research purposes and the state of the art (§4). Finally, in §6, conclusions are drawn.

2 Resarch Questions

As stated in §1, COAALAS focuses on scenarios where the elder user, physically or cognitively impaired, has to comply with the medication prescribed by a doctor. Such scenarios can get especially complex due to a high and uncountable number of potentially probable circumstances, *e.g.*, the combination of several treatments that impose a temporal order on the doses, lack of user's discipline on taking the medicines during the correct interval, delays on the delivery of the medicines, lack of communication between the user and the doctor, and so on.

In such scenarios, the primary goal of our approach is to provide enough support to enable a change in the users' (including elders, doctors, health professionals among other stakeholders) non-compliant behaviors by engaging them in the drug intake task. With this purpose in mind we introduce the design and proposed implementation of a social-norm aware pill dispenser. The dispenser, based on the concepts developed by COAALAS [8], will support the elderly or disabled people to manage their daily doses of medication while presenting the following three properties:

– *Social awareness*: The device is connected with other assistive devices and with relevant actors (such as doctors, caretakers and other health professionals, relatives, *etc*) for helping the elder take his daily doses of medication.
– *Autonomy*: The device can react to changes in the physical or social environment without requiring human intervention. Furthermore, it should be able to react to simple changes in the scenario autonomously (*e.g.*, a change in the scenario implies the pill dispenser is not filled by the patient any more, but by a care giver).
– *Normative awareness*: The device performs its task while following a set of specified behavioural patterns. However, due to its autonomy, the device has the option of breaking the patterns, provided it considers it will be in the benefit of the society (*e.g.*, if an incoming stock break is detected).

In particular, the three research questions addressed in this paper are:

1. Can a social-norm aware pill dispenser help elders adhere to their medication prescription? (*i.e.* daily take all the doses)
2. Can a social-norm aware pill dispenser help elders adhere to their medication regime? (*i.e.* daily take all the doses at the prescribed time and with the correct order)
3. Can a social-norm aware pill dispenser help the other users involved in the treatment workflow take care of unexpected events?

3 State of the art

This section presents a short survey on the existing work in the area of Ambient Intelligence for supporting independent living, with special emphasis on the works focused on facilitating activities of daily living (ADL). In this paper we specially focus in those related with the intake of a prescribed medication. Special attention is put on COAALAS that has been selected as basis for the work presented in this paper.

3.1 Medication prescription and regimentation

AT can be effectively used for guiding elders with their prescribed treatments, avoiding major problems such as non-compliance with the treatment and adverse drug reaction. Several devices are available for helping patients manage their

daily doses of medication. They range from simple pill containers with multiple compartments that can hold a month's supply to intelligent pill dispensers[10] with an alarm function which can detect when the patient takes the pill, and that can be telematically programmed in case the treatment changes. However, these kinds of devices tend to have a static encoding of their functions, and are unable to react to changes in the environment (*e.g.*, they will keep on dispensing the pills even if the patient is on holidays away from home) and autonomously react to potentially dangerous situations (*e.g.*, the dispenser is about to run out of supply for a given pill). Furthermore, to the best of our knowledge none of these devices takes in consideration the important role that third parties may have in the activity. For instance, the prescribing doctor scheduling a visit with the patient when the treatment finishes, a delivery company refilling the dispenser when it is about to run out of medication, or the patient's personal computer displaying reminders when it is time to take a given medication. Nor they reflect the social constraints that apply in the relation between the user and the other actors. For instance, forbidding the delivery company employee from entering the user's home if the doctor considers the user capable of autonomously refilling the dispenser.

3.2 Agent-based healthcare systems

In [3] ECA (Event-Condition-Action) rules are used for Smart Homes that support assisted living for the elderly. A basic interpretation of the ECA rules is that, on detecting certain events, if certain pre-conditions are satisfied, then a given set of actions are to be enacted. By using rule-based systems and other Artificial Intelligence (AI from now on) techniques, devices and hardware-oriented technologies for Smart Homes can be augmented and enriched. With that goal in mind, authors propose connecting the devices to a central monitoring facility that performs all the reasoning. This approach differs from the rest in the sense that devices show a complete lack of intelligence, leaving all the reasoning to a central component, effectively preventing coordination and cooperation among the agents representing the different devices.

A similar work [14] proposes using abductive logic programs for the reasoning process. Abductive logic programs provide active behaviour, just like the ECA rules, but they also provide added declarative semantics and a extensive background knowledge available via the logic programming. For instance, this approach allows for easily applying preferences to the reminders issued to the user. Both works present a higher system adaptability, allowing even for a customization that adapts the system to the preferences of the user. However they lack the coordination among different agents that would allow the system to autonomously recover from a failure if one of the agents stops working.

Robocare Robocare [4] is a project deployed on a domestic test-bed environment that combines a tracking component for people and robots and a task execution-supervision-monitoring component. The system is composed of several software and hardware agents, each providing a set of services, and an event

manager that processes requests to the different services and directs them to the appropriate agents. The system also includes a monitoring agent, with knowledge of the assisted person's usual schedule. In order to coordinate all the agents and monitor user's behaviour heavy computational processes take place, limiting the tested scenarios to non-crowded environments, where only 2-3 persons and only a small portion of the domestic environment are monitored. What is more, the expected schedule is non dynamic and small justified deviations (*e.g.*, relatives visiting the user) are currently detected and corrected.

Independent LifeStyle Assistant The AHRI (Aware Home Research Initiative) [6] is a residential laboratory for interdisciplinary research where several projects have been evaluated. The most relevant one is the ISLA (Independent LifeStyle Assistant) project [9], that passively monitors the behaviours of the inhabitants of the residential laboratory, alerting relatives in case of potentially dangerous situations (*e.g.*, the user falls). The ISLA project presents two main innovations with regards to the Robocare project:

– Agents autonomously interact within them in order to achieve their goals, without the need of an event manager agent that coordinates them. However, in order to transform context-free perceptions provided by the agents into context-aware perceptions, a centralized coordinating agent is used.
– Agents are able to learn schedules based on the daily tasks performed by the inhabitants. Models are built, reflecting which devices are triggered as a result of the performance of which activities, and alerts are raised whenever an unlikely activity takes place. Therefore, instead of using generic static schedules for the users, the schedules are built dynamically based on user's detected behaviour. However, once a schedule has been learned, the user is not able to deviate from it without raising an alarm.

  Evaluation of the ISLA project presents two main conclusions:

– The need for coordination of the agents and centralized control outweights the benefits of the distribution and independence of components agents architectures provide.
– Partial observability of actions performed by the inhabitants is a problem, specially when plans are abandoned due to forgetfulness and reminders need to be issued. Inhabitants do not tend to be in favour of having every of their moves observed.

MINAmI In the scope of the MINAmI project[13] a qualitative study of three ambient intelligence scenarios is reported, being the most relevant one a scenario that deals with monitoring the taking of medication. In the scenario users are given a smart pillbox, with a cap that counts the number of opening and closing events and a clock. The pillbox can communicate with a mobile phone, that displays the timed record of cap openings and closings. If the users forgets to take

his medication for a prolonged period of time, the pillbox sends a notification to a care center. During the evaluation of the scenario, users felt it was too intrusive on their privacy, arguing the data should not be reported to their doctors. They considered relying on such devices for the reminders could weaken people's cognitive abilities, and that such a system would not be suitable for users taking a cocktail of medication rather than just a single medicament, as several pillboxes should be provided. The scenario presented seems to be mainly theoretical, lacking an implementation, and does not provide a fully integration of the pillbox with the rest of the devices in the Smart Home (*e.g.*, the system can notify that the user forgot to take his medication even when the rest of the devices are showing that the user has not been at home on the last 3 weeks, for instance, because he is on holidays).

SPiDer *SPiDer* focuses in the specific problem elderly face when trying to follow a complex schedule of medications (*i.e.*, the low compliance with complex prescribed medication schedules) and aims to partially solve the aforementioned problems through the use of AT and AI tools [11]. The system developed by *SPiDer* has three main components: the Smart Pill Dispenser (SPD) which allows to perform the dispense tasks and the sensing of the environment, the Identification Access Management (IAM) which allows to monitor and manage the entrance and exit of the house, and the MAS which integrates both the SPD and the IAM components and adds new features as communicative tools between the system and the outside world. There is a physical implementation of the SPD.

4 COAALAS

COAALAS builds on the results of two European funded projects: EU-Share-*it* [2] and EU-*ALIVE* [1]. By combining several state-of-the-art AI techniques (such as Autonomy, Proactivity, Social Behaviour and Adaptability) COAALAS provides a multi-agent platform able to integrate software agents embedded in the AAL devices and human actors. This allows for making AAL devices intelligent enough to organize, reorganize and interact with other actors. The agents embedded in the devices have an awareness of their social role in the system – their commitments and responsibilities – and are capable of taking over other roles if there are unexpected events or failures. COAALAS creates a society of physically organisational-aware devices able to adapt to a wide range of AAL situations that could have an impact on the user's well-being.

COAALAS builds on top of the *ALIVE* framework, a multi-level architecture (as seen in *Figure* 1 it is divided in an organisation level, a coordination level and a service level) that provides support for *live*, open and flexible service-oriented systems. The *ALIVE* framework presents normative structures that allow for easily expressing both expected behavioural patterns and the actions to be taken when the actors involved in the scenario do not comply with these
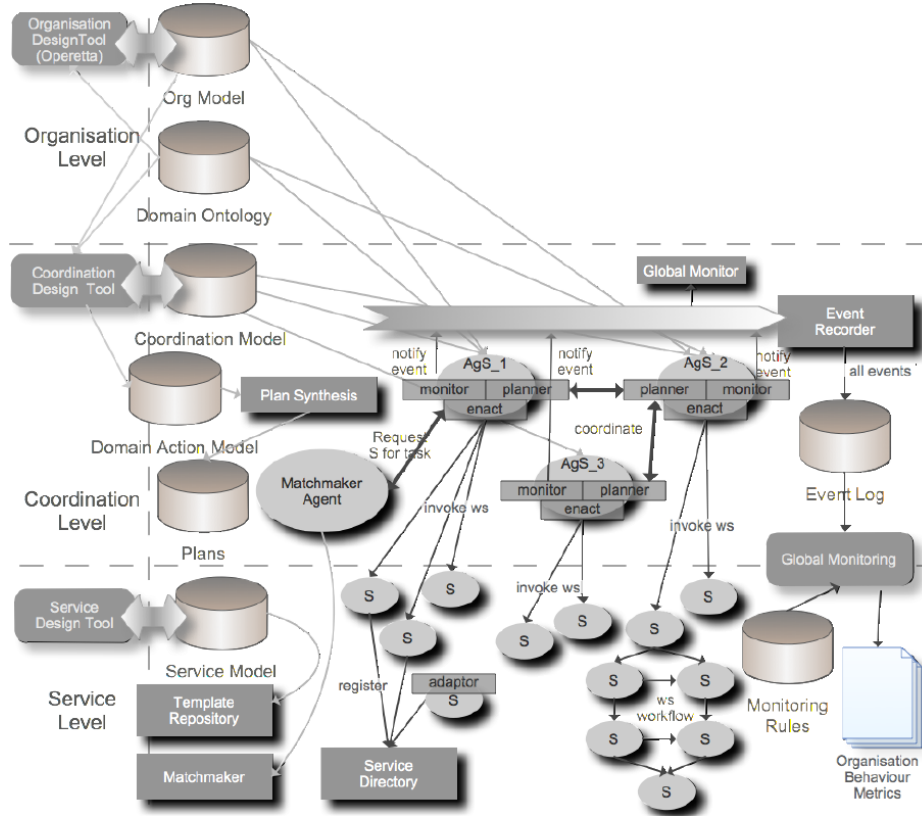
Fig. 1. ALIVE architecture (S stands for Service)

patterns. For achieving this functionality, *ALIVE* relies on substantive norms that define commitments agreed upon actors and are expected to be enforced by authoritative agents, imposing repair actions and sanctions if the system reaches invalid states (*i.e.*, states that are outside of the expected behavioural patterns). Substantive norms allow the system to be flexible, by giving actors (human or computer-controlled) the choice to cause a violation if this decision is beneficial from an individual or collective perspective.

The Organisational level in *ALIVE* contains organizational structures inspired in the *Opera* methodology [5] by using the following concepts:

– Objective, states of the world pursued by the system and the actors in the system (*i.e.*, daily take the prescribed medication dose).
– Role, Groups of activity types played by the different actors in the system (*e.g.*, patient, caretaker, doctor, *etc.*). The set of roles and the relationships among them form the *Social Structure*.

Property	Value
Activation Condition	*atom* isActive(Provide_medication)
Deadline	
Expiration Condition	*atom* isFullfilled(check_best_before_date)
Maintenance Condition	¬ ~isFullfilled(Provide_medication)
Norm ID	o_check_best_before_date_before_Provide_medication

Property	Value
Activation Condition	*atom* isViolated(O_check_best_before_date_before_fill_dispenser)
Deadline	
Expiration Condition	*atom* isFullfilled(Apply_generic_sanction)
Maintenance Condition	
Norm ID	o_Apply_Generic_Sanction_fill_dispenser

Fig. 2. Example of norms of the use case

– Landmark, represent states of the world that are relevant for the achievement
of goals (*i.e.*, a medication dose has been provided).

The organisation level supports the definition of substantive norms (see *Figure
2* for an example of an ALIVE norm), adding a normative structure to the social
and interaction structures. The norms contain the following main components,
expressed using Partial State Descriptions of the world:

– *Activation Condition*: when the world reaches the state specified in this
condition, the norm starts to be checked.
– *Expiration Condition*: when the world reaches the state specified in this
condition, the norm stops to be checked, and has not been violated.
– *Maintenance Condition*: when the world reaches the negation of the state
specified in this condition, the norm stops to be checked, and has been vio-
lated.

ALIVE provides coordination structures (basically a repository of coordi-
nation plans automatically generated from the elements in the Organisational
level) that provides actor's patterns of interaction, effectively allowing the sys-
tem to move between relevant states (*e.g.,* the pill dispenser needs to be refilled,
the pill dispenser has been refilled, etc.). The coordination structures are formed
by tasks containing both pre and post conditions (*i.e.*, the state of the world
before and after the task has been executed respectively) and the permissions
required for executing the tasks (associated to the different roles in the scenario).
A set of organizational aware intelligent agents select a role according to their
capabilities and start enacting the plans associated to that role as requested.

Finally, *ALIVE* also includes a service level that maps actions in the environ-
ment to abstract tasks. Non-organizational aware agents in the system register
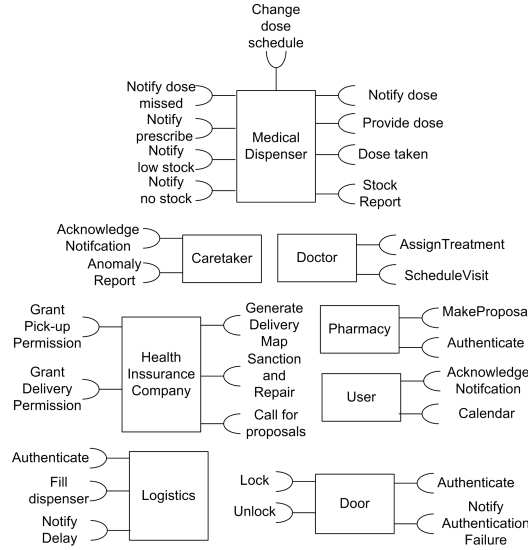their capabilities (e.g., tasks they can perform) via a white pages system and are

Fig. 3. Capabilities of the different actors

coordinated by the organizational aware agents to execute the tasks required for enacting the different plans. *Figure* 3 provides an example of actor's capabilities in a scenario inspired in an intelligent pill dispenser.

5 Related work

The following table presents a summary of the analysis of the state of the art performed in *Section* 3 and puts in contrast existing AT w.r.t. COAALAS.

The uBox is a palm-sized pill dispenser that reminds a patient when it is time to take medication and records when he takes a pill from the dispenser. It is also able to track accesses to the box by other users (typically a health professional refilling the box) via RFID keys. The project is able to ensure patient adheres to his medication prescription. However, it is hard to see how it would manage multiple medication doses, ensuring every dose is taken at a particular time and in a particular order. What's more, the project is not social aware nor able to react to unexpected deviations from patients schedule.

The Robocare project provides coordination between the different actors in the scenario via an event manager, that processes requests for the different services and redirects them to the appropriate agents. As the system also includes a monitoring agent that is aware of the patient's expected schedule, it can be effectively used to ensure the patient adheres to his medication prescription and regime. However, the expected schedule is not dynamic, and only minor deviations can be detected and corrected.

Name	Deployment	Social Aware	Prescription	Regime	Adaptive
COAALAS	Smart device integration platform	✓	✓	✓	✓
uBox	Programmable pill dispenser	×	✓	×	×
Robocare	Tracking of people and robots	✓	✓	✓	×
ISLA	Passive monitoring and schedule learning	✓	×	×	×
MINAmI	Network-connected pillbox	×	✓	×	×
Smart Homes	ECA rules	×	✓	✓	×
SPiDer	Smart pill dispenser	✓	✓	✓	×

Table 1: Comparison of existing solutions

The ISLA project aims at passively monitoring the behaviour of the patient, alerting relatives in case of potentially dangerous situations. Agents in ISLA are able to learn patient's schedule, building a user model as the patient interacts with the different devices. Therefore, instead of using generic static schedules for the patients, the schedules are built dynamically based on detected behaviour, and the resulting schedule is perfectly tailored for every patient. However, once a schedule has been learned, the patient is not able to deviate from it without raising an alarm. The ISLA project is not Social Aware it can detect some unexpected situations, but is unable to coordinate the different actors in the system for solving them. The project can not be used to ensure patient adheres to a medication prescription and regime, because the behavioural pattern the system learns might not be aligned with them (*e.g.*, the learned expected behaviour is for the user to miss every medication dose).

The MINAmI project presents a smart pillbox, with a cap that counts the number of opening and closing events and a clock. The pillbox can communicate with a mobile phone, that displays the timed record of cap openings and closings. If the users forgets to take his medication for a prolonged period of time, the pillbox sends a notification to a care center. The project can be used to ensure patient adheres to a medication prescription, and is able to detect unexpected situations and alert about them. However, it is not able to coordinate the different actors in order to deal with the unexpected situation. MINAmI is not suitable for ensuring patient adheres to a medication regime (specially if a very complex combination of different medications is used) and does not present any social capabilities.

The Smart Homes project proposes connecting the different AT devices to a central reasoning component that is able to issue particular actions when certain events and conditions are met. The project can be effectively used to monitor user's behaviour ensuring he adheres to a medication prescription and regime. However, as all the intelligence in the system is focused on a central component, the project presents no social awareness and it's adaptation capabilities are very limited.

SPiDer connects a smart pill dispenser and an access management system with a multi-agent system to control and coordinate both components. The project can be effectively used to monitor user's behaviour ensuring he adheres to a medication prescription and regime. However, The *SPiDer* project is not Social Aware in its current status of development. It can detect some unexpected situations, but is unable to coordinate the different actors in the system for solving them.

COAALAS applied to a pill dispenser device provides a social context, help patients adhere to their medication prescription and regime and is able to react to unexpected events at the same time. COAALAS provides a social structure that allows the pill dispenser to coordinate with other devices in order to ensure the patient takes his daily medical dose. For instance, the pill dispenser can coordinate with a device taking care of the patient's schedule to find out if the patient will be away from home when it is time to take his medication. If it is the case (and the medication dose does not require any special conservation procedures) the pill dispenser can dispense a pill before the patient leaves home, and issue a reminder asking the patient to take the pill with him. When it is time to take the medication dose, a reminder will alert the patient, who can take his medication dose even though he is away from the dispenser. In case the patient deviates slightly from the expected schedule (*e.g.*, misses a non vital medication dose), COAALAS will detect the deviation and the pill dispenser can coordinate with other actors (including doctors if required) to re-schedule future medication doses, so the patient complies with his medication regime. What's more, in case the patient deviates heavily from the expected schedule (*e.g.*, misses one important medication dose or several medication doses), COAALAS allows for detecting the deviation and can help the different actors involved in the treatment workflow take care of the situation. COAALAS will not only be able to detect the deviation but will also be able to identify which are the most appropriate actors for taking care of the unexpected event, coordinating them to return the system to an acceptable (*i.e.*, expected) state.

6   Conclusions

Via the *ALIVE* framework COAALAS provides a flexible multi-level architecture able to model the complex interactions among different actors involved in the AAL tasks, where a set of heterogeneous actors have different responsibilities and offer or consume different services. Thanks to *ALIVE*'s multi-level approach, COAALAS supports introducing changes at a high level (*e.g.*, introducing a new actor, a new objective for the system or a new expected pattern of behaviour) without performing any modification to the lower levels (*i.e.*, reprogramming the agents in the different smart devices) because changes at higher levels automatically trigger changes at the lower levels. COAALAS provides AT devices with a high level layer, easy to use and understand by non-technological experts. By using this layer, AT devices can be easily adapted to introduce a new medication

regime or to include a new actor (*e.g.*, patient's relative as a caretaker) in the system.

Also via the *ALIVE* framework, COAALAS allows for monitoring the different actions performed by the set of actors in order to fulfil the AAL tasks. Deviations from the expected patterns of behaviour can be detected, and sanctions or repair actions applied. Therefore, COAALAS provides support for dealing with unexpected events (*e.g.*, sending a doctor, or an urgent shipment of medications to the patient when the pill dispenser device runs out of pills).

Finally, the *ALIVE* framework provides COAALAS with a set of intelligent agents that support both exception handling and organisational normative awareness capabilities. Exception handling is common in other service-oriented architectures, however, most approaches tend to focus on low-level (*i.e.*, services provided by the actors) exception handling. The ALIVE approach enables managing of exceptions at multiple levels ranging from substituting services (*i.e.,* low level exception handling) to looking for alternative ways to achieve a particular goal (*i.e.,* high level exception handling). Regarding organisational normative awareness, making normative agents reason about their tasks before performing them, and discarding the ones that do not comply with the expected patterns of behaviour, adds organisational awareness to the execution of the different tasks.

AT are applied to support people in their daily life. Most approaches focus solely on the direct interaction between users and the assistive tool. AI has the potential to provide innovative mechanisms and methods capable of taking into account more complex interactions. For instance, the important role that third parties may have in user activities, and explicitly reflect the social constraints that apply in the relationship between device and patient. For instance, a simple reminder system can be implemented using a smart-phone's calendar and alarm systems. However, it would lack the autonomy, social awareness and normative awareness our proposal provides. A simple alarm system is not able to adapt reminders to user's calendar (it will keep reminding the user to take a medication dose even if his calendar indicates he will be away from home when it is time to take his medication, rather than adapting the reminder to user's schedule) nor is able to alert caretakers if potentially dangerous deviations from user's routine are detected.

COAALAS focuses on making devices intelligent enough to organize, reorganize and interact with other actors providing smart devices with an awareness of their social role in the system (including commitments and responsibilities). This way, smart devices are capable of reacting to deviations from the expected patterns of behaviour, effectively adapting to a wide range of AAL situations that could have an impact on the well-being of the user.

The particularities of each elder's disabilities makes any custom solution difficulty exportable to a whole population of elders. Furthermore, if the characteristics of a particular elder's disability change over time (*e.g.*, the disability is degenerative) the applicability of a custom solution is also limited in time. In order to tackle these issues, we present COAALAS a system based on an adaptable and extensible architecture. By using COAALAS elder-care experts can easily

adapt the system capabilities to the patient's current state. What's more the extensibility of Coaalas (through the addition of more agents and services) provides a virtually endless amount of tools for elder's support.

The ideas presented in this paper combined with qualitative research conducted *in situ* with real users might serve designers in better addressing computing challenges for elders. It is clear that the research questions §2 should deal with the issue of *Different elders, different disabilities* to satisfy elders actual needs. The resulting system will need of a multimodal interaction with supporting agents that are norm-aware and socially active.

Fig. 4. The Smart Pill Dispenser of the *SPiDer* project

7 Future Work

Once COAALAS has been properly designed and its features analysed, the next step is to use it for implementing a working system where we can verify the theoretical assumptions of our approach. In that regard we have decided to addapt the project *SPiDer* to the COAALAS architecture. We decided to use *SPiDer* as basis because, to the best of our knowledge, it is the most appropriate project for this task, as seen in *Section* 5. While COAALAS provides the theoretical framework upon which complex MAS can be built, *SPiDer* provides a working implementation of a MAS which could benefit from high-level organizational properties[12]. The main component of *SPiDer* , the Smart Pill Dispenser, can be seen in Figure 4.

To obtain a complete integration of both projects, we will start by analysing the capabilities provided by the existing agents and services within the *SPiDer* project. From those we will obtain the roles, norms and landmarks which will allow us to define the high-level features of COAALAS at the organizational level. Once the organizational level is completed, we can proceed down the COAALAS hierarchy, defining at the coordination level the plans and tasks that will allow the system to navigate between states of the world. We will finish by defining the agents of the system at the service level as well as the services that they provide. At that point, with the integration of both projects completed, we expect to obtain a fully operational system with all the extended features provided by COAALAS .

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