Context-aware support for people with dementia and their families

Kontextabhängige Unterstützung von Menschen mit Demenz und ihren Angehörigen

Yehya Mohamad[1], Henrike Gappa[1], Jaroslav Pullmann[1], Gaby Nordbrock[1], Carlos Velasco[1], Marcus Handte[2], Stephan Wagner[2] , Marcel Schweda[3]
[1]Fraunhofer FIT, 53757 Sankt Augustin, Germany, firstname.lastname@fit.fraunhofer.de
[2] Universität Duisburg-Essen, Duisburg, Germany, marcus.handte@uni-due.de, stephan.j.wagner@uni-due.de
[3]Assion Electronic GmbH, D-53859 Niederkassel, Germany, schweda@assion-electronic.de

Kurzfassung

Die häusliche Pflege von an Demenz Erkrankten stellt für Angehörige eine große Herausforderung dar. Webbasierte Dienste können Angehörige darin unterstützen und helfen Überforderungssituationen zu vermeiden. Daher wurde ein Aktionsplaner als RFID-basierter Dienst und Teil eines AAL-Assistenzsystems zur kontextabhängigen Unterstützung von Menschen mit Demenz und ihren Angehörigen entwickelt.
Der Aktionsplaner erlaubt den Angehörigen Regeln zu erfassen, die beim Eintritt hier definierter Ereignisse entweder dem erkrankten Menschen Unterstützung anbieten, z.B. durch Erinnerung ans Trinken, oder Angehörigen eine Nachricht zukommen lassen wie z.B. bei Unruhesituationen. Die Besonderheit des Dienstes liegt in der Kontextangemessenheit der festgelegten Aktionen, die durch zeitliche und räumliche Bedingungen bestimmt wird wie beispielsweise eine Benachrichtigung per SMS bei nächtlichem Umherwandern zwischen Schlafzimmer und Flur. Die Position des Nutzers wird dabei durch ein eigens entwickeltes Lokalisierungssystem auf Basis aktiver RFID Technik bestimmt. Die Art der Aktion und die Raum-Zeit-Bedingungen zu deren Auslösung können durch Angehörige in einem Regeleditor definiert werden. Ein erster Prototyp des Systems wurde unter Laborbedingungen evaluiert. Auf Basis der Ergebnisse der technischen Tests und der Nutzertests des Regeleditors wird derzeit ein zweiter Prototyp entwickelt, der u.a. um Algorithmen zur Mustererkennung erweitert wird, die die Zuverlässigkeit erkannter Bewegungsmuster in der Wohnung erhöhen sollen.

Abstract

Caring for people with dementia in their home environment is a challenging task for family carers. Through web-based services family carers can be supported in fulfilling this task also helping to avoid feelings of being overburdened. Therefore a RFID-based service called Action Planner was developed as part of an AAL-assistant system to provide context-aware assistance for people with dementia and their family carers.
The Action Planner allows family carers to describe rules that offer support either for the elderly person who is e.g. reminded to drink or the family carer who receives for example a text message in case a predefined event applies. The service operates context-aware which can be considered as its distinct feature. It is customizable by time- and localization-based rules. For instance, it is possible to configure the service in such a way that a text message is sent when constant wandering between bedroom and corridor is detected at night. The Action Planner relies on a custom indoor localization system that uses active RFID technology. The type of action and the time- and localization-based rules that need to be true in order to initiate an action can be specified using a rule editor. A first prototype of the Action Planner was evaluated in a lab test. Based on the results of the technical tests and the user study investigating usability issues of the rule editor, a second prototype is currently under development. The second prototype will enhance the Action Planer by algorithms for pattern recognition to improve reliability of identified movement patterns in the home environment.

1 Introduction

Dementia is a serious loss of cognitive abilities in a previously unimpaired person, beyond what might be expected from normal aging. Usually loss of memory skills is the most obvious symptom in the beginning stage later on leading to disorientation and general restlessness. As a result people with dementia cannot manage their everyday life anymore and need personal care.
In order to support seniors with mild up to moderate dementia in living at home independently, the BMBF-funded project WebDA develops a range of web-based services that strive to accommodate for the deteriorating cognitive skills of this user group. Since people caring for a family member with dementia quite often feel overwhelmed with this task, assistance of care givers is a primary focus of WebDA.

1.1 Goals of WebDA

According to the acronym's meaning (WebDA: „Webbasierte Dienste für ältere Menschen und Angehörige", i.e. "web-based services for the elderly and their families”) the service portfolio aims at supporting a variety of use cases. These include:

- Locating misplaced objects (Object Locator)
- Scheduling and reminding of appointments (Organizer)
- Interactive support of biography work (Biography Software)
- Training of communication and memory skills (Mental Fitness Trainer)
- Web-based emergency call and audio-video communication unit (HNR)
- Web information portal summarizing regional care providers and contact addresses
- Handling of critical situations such as counteracting restlessness, contextualized delivery of reminders and notifications (Action Planner)

In this paper, the Action Planner subsystem will be presented in more detail. The Action Planner empowers the care giving party to express rules used to evaluate the spatio-temporal context of the affected user and to react accordingly. The end user will for example be presented with a drinking or medication reminder when entailed by the time and location conditions.

The remainder of the paper is structured as follows. To put the Action Planner into context, we briefly outline the overall architecture of WebDA. Thereafter, we discuss the software and user-interface layers of the action planner. Then, we describe the localization subsystem, as localization is one the cornerstones of framework's context awareness. Finally, we outline the preliminary results of our on-going evaluations.

2 WebDA Architecture

The design of the WebDA platform is motivated by several requirements:

- functional coverage configurable in respect to user needs and a flexible business model
- accurate localization while reducing costs for material, installation and maintenance
- ensuring acceptance by a user-centred design
- easy to use and adaptive user interfaces

From an architectural perspective, WebDA consists of a number of modular, extensible services that interact with each other through well-defined interfaces. To accommodate the requirements, the WebDA platform is built on top of the following technologies: We use OSGi[1] as a middleware technology for integration, execution and remote exposure of services. A GlassFish Server[2] mediates services via resource injection into J2EE components. The web-based user interfaces are built using the J2EE technology stack (JSF 2, Managed- and Enterprise Java Beans). Consequently, they are highy interactive while easy to use thanks to features like dynamic forms, input validation and custom UI components. Hierarchical templates and shared resource sets (UI components, style sheets, icons etc.) ensure their visual consistency. The user interfaces are adaptive in respect to user profiles and properties of the target device.

3 WebDA Action Planner

The Action Planner subsystem aims at supporting the various user types by context-aware activation of predefined actions. Depending on the action type the Action Planner reminds the end user suffering from dementia or notifies their family carers and care-givers. The latter group defines the action(s) and configures corresponding activation rules through a web-interface. The particular challenge here is to mediate the definition of adequately complex rules by end users with no or little computer experience. Context information acquired from a variety of sensor services is continuously matched by probabilistic algorithms against these rules and a system action is invoked, when the rule conditions apply. From a high-level perspective, this closely mimics the current state of the art in the area of AAL as there are existing systems and prototypes with similar targets in related areas. Some examples are SOPRANO[3] “Service-Oriented Programmable Smart Environments for Older Europeans” funded by the European Commission or SmartSenior funded by the German Ministry for Research BMBF[4]. However, in contrast to WebDA, the existing systems are focusing on complex and thus, costly sensor systems whereas WebDA is deliberately limited to low-cost solutions in order to be suitable for elderly people with beginning dementia.

3.1 User interface considerations

User interfaces play a crucial rule for the acceptance and an adequate usage of the overall system. In order to aid the user in configuring the Action Planner rules, we split the complex interface up into dedicated tabs. Each tab captures information about one aspect of the rule model: general information (rule activation, name etc.), type and parameters of the intended system actions, the temporal and spatial pattern determining rule's activation. It does so through a series of dynamic forms, that adapt according to the users’ previous inputs.

Figure 1: Action Planner Editor Dialog

[1] http://www.osgi.org/Release4
[2] http://glassfish.java.net
[3] http://www.soprano-ip.org
[4] http://www1.smart-senior.de

The wording and arrangement of form items were carefully selected to express a self-evident “statement” readable from up-left to bottom-right corner.
The perception and orientation are further supported by a dynamically generated natural language summary, that renders the given as well as points to missing information and error conditions across all the input tabs.
This is a unique approach which would allow to literally writing ambient rules, context conditions and actions down in a restricted natural language. Similar approaches have been prototyped in projects like OpenAAL[5] and in UniversAAL[6], unfortunately the developed rules were neither readable by humans nor in natural language.

4 Localization

To evaluate the location-based expressions contained in the rules of the Action Planner, it is necessary to monitor the location of the elderly within the home environment continuously at runtime. To do this, WebDA makes use of custom indoor localization system. In the following, we describe this system in detail. Thereby, we start with the specific requirements on the system, followed by a technical description of the hard- and software. Thereafter, we evaluate the current solution along the requirements and identify directions for future improvements.

4.1 Localization Requirements

The primary application area of the localization system is real-time tracking of persons to support the evaluation of location-based expressions contained within the rules of the Action Planner. From this we can derive the following requirements:
Low cost: To be suitable for many elderly people, the localization system must be inexpensive to deploy and operate. Beyond the cost of the hardware, this also includes factors such as installation cost, the configuration cost as well as the cost for maintaining both, the hard- and the software configuration over an extended period of time.
High precision: The localization system must deliver a high precision Due to the structure of typical home environments achieving a room level precision will not be sufficient for many homes. As a simple example, consider that many living rooms contain a dining table as well as a resting area that includes a couch.
High reliability: Last but not least, the localization system must also be reliable. On the one hand, this includes reliability with respect to the localization results. On the other hand, this means a sufficiently high robustness with respect to short-term changes in the environment.

4.2 Localization Hardware

The localization system for the Action Planner is based on active RFID technology. The reason for this is threefold. First and foremost, the technology is readily available and in contrast to optical [1] or sound-based systems [2], RF-based localization scales well to typical sizes of home environments. Second, when compared with existing high precision localization systems that require special wiring and exact calibration [3], the deployment cost and time can be reduced significantly. Third, by using appropriate localization software, it is possible to achieve a sufficiently high precision.

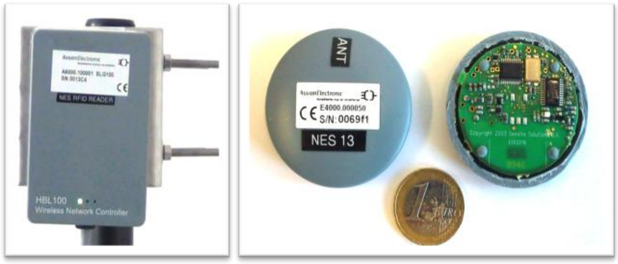

Figure 2: LogiSphere RFID Reader and Tags

We chose the LogiSphere system from Sensite Solution [4] which consists of several readers (HBL100) and tags (BN208) depicted in Figure 2. The system operates at a frequency of 868 MHz which provides coverage for a typical home environment with more than 100m² easily. Given the overall cost of the system components as well as the range that can be covered by each reader, we expect that a typical installation can consist of four readers. The readers can automatically form a wireless multi-hop network which drastically reduces the deployment cost and time since only one RFID reader must be connected via RS-232 to a PC. The remaining readers solely need to be connected to power. Besides from identifying individual tags, the readers are also able to estimate the power of the received signal broadcasted periodically by the tags whereby the periodicity can be flexibly configured.

4.3 Localization Software

RF-based indoor localization is a complicated problem that has been studied by many researchers. Existing approaches can be broadly classified into localization by proximity analysis, by angulation or lateration and by scene analysis [5]. To provide a sufficiently high precision, proximity analysis requires a comparatively dense deployment of several readers consequently it cannot be considered cost effective. Angulation requires specifically designed antennas that are able to determine the angle of arrival of a signal and thus, it cannot be realized with off-the-shelf hardware. Lateration approaches such as TOA, TDOA or RTOF typically require high precise synchronization or time measurements. Usually, this results in expensive hardware setups due to special wiring. To avoid such costs, lateration can also be done on the basis of RSSI. However, due to multi-path effects in indoor environments, lateration on the basis of RSSI does not result in a sufficiently high accuracy. To demonstrate this, Figure 3 depicts RSSI measurements of a RFID tag at different distances in a corridor. Despite the overall correlation between RSSI value

5 http://openaal.org
6 http://www.universaal.org

and distance indicated by the fitting function, distance computations based on RSSI lead to high error rates.

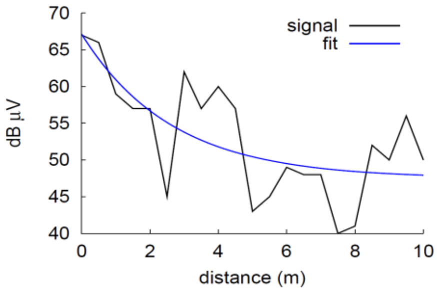

Figure 3: LogiSphere Reported RSSI vs. Distance

To avoid both, the increased cost of lateration approaches as well as the error caused by distance estimation, the localization system used by WebDA relies on scene analysis. We use a fingerprinting technique that is similar to RADAR [6]. Each person is equipped with four RFID tags. The beacons of the tags are then captured over a period of several seconds to generate an aggregated multi-fingerprint. To perform precise localization despite multipath effects, we first perform a series of measurements during the installation of the system and second use this data to train the System. In the following, we describe both phases in more detail.

4.3.1 Localization Software Setup

As a first step during setup, we create a map of the target site. The map consists of the layout and position of geometrical areas or zones that are relevant for the rules used by the Action Planner. Such areas typically exhibit at least room level granularity. However, sub-room level may be needed, depending on the layout of the home. Relevant sub-room areas may include the sleeping area, the dining or the TV area in a living room, etc. To simplify the map creation, the WebDA localization system encompasses import modules that allow the use of free off-the-shelf modeling tools such as Google Sketchup. From such a 3D model the import modules then extract information including the names of areas, coordinates and geometric relations as shown in Figure 4. This allows hierarchical rendering which simplifies the construction of rules.

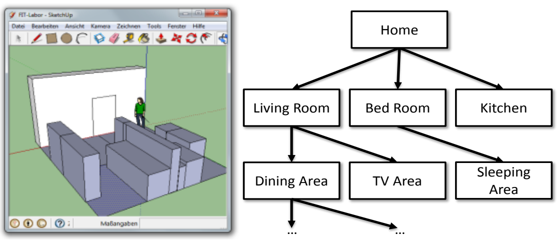

Figure 4: Location Modelling with Google Sketchup

Once a map has been imported, we perform on-site measurements which we associate with the areas of the map. Thereby, we attach 4 RFID tags on a person (two in the front and two in the back) and capture the signal strength of the tags over a period of 20 seconds. In order to mitigate signal effects, we measure 8 directions which results in an overall setup duration of approximately 3 minutes per area. Given these efforts for the initial measurements, we estimate that the overall setup duration for a typical home with less than 20 relevant areas remains under an hour.

Using the measurements, we then generate 8 reference multi-fingerprints per area (one for each direction). To do this, we aggregate the RSSI values received by each reader for each tag into a vector R_i^k where *i* denotes one of the four tags and *k* denotes one of the readers. Thereby, we chose R_i^k as the 80th percentile of readings of tag *i* at reader *k* over the 20 second period. Using a number of experiments with the LogiSphere system, we determined that this results in a representative value, since it eliminates outliers that occur due to imprecise RSSI measurements.

4.3.2 Localization Software Execution

Given the resulting reference fingerprints and the associated mapping of fingerprints to areas, we can easily perform localization at runtime. To do this, we capture a series of beacon signals from the tags mounted to the person's belt. Then, we compute an aggregated multi-fingerprint F_i^k as described previously. Finally, we compute the distance between all pairs of R_i^k and F_i^k as the root square sum over r_i^k-f_i^k and we chose the location of R_i^k with the smallest distance as the result.

4.4 Localization Results

To test the localization system under realistic conditions, we installed it in the WebCC lab room at the Fraunhofer-Institute FIT serving also as test site for the user tests. In the corners of the room, we deployed 4 readers and we divided the lab in four areas inside which we augmented with one area for outside as depicted in Figure 5.

Figure 5: Lab Room for Testing

For each of the 5 areas, we captured 8 directional multi-fingerprints by sampling for 20 seconds per direction. Thereafter, we captured additional fingerprints at different locations for testing. Figure 6 shows the resulting accuracy increases drastically from approximately 50 to 83 percent by adding 3 tags. Using this setup, the WebDA localization system can be used safely within the Action Planner. The remaining 20 percent of failures can be reduced further by aggregation. While the scene analysis approach to localization taken by WebDA is able to fulfill the goals with respect to precision and cost, we are currently studying its suitability with respect to long-term reliability. During our lab tests, we were able to localize different persons over several weeks without recalibration.

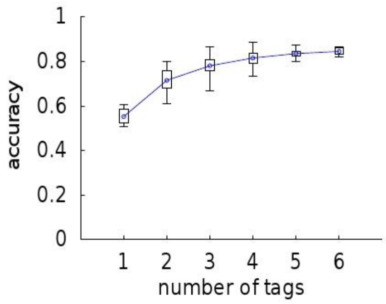

Figure 6: Localization Accuracy vs. Number of Tags

However, due to the use of static reference fingerprints, the accuracy is likely impacted by drastic changes to the environment. Such changes include the moving of furniture or the presence of larger groups of people. In order to compensate this, we are currently working on an extension which will enable the dynamic recalibration of the system without manual measurements.

5 User Study

When designing the rule editor of the Action Planner the guiding principle was to design a user interface that allows users to develop rules according to how they would word them, because this was assumed to be most intuitive. For instance in case a relative shall be reminded to drink some water, this rule can be created with the editor so it sums up to for instance: The intended action of the rule is a notification “Mom, please drink some water” which will be displayed and read out loud. The rule applies daily from 10:00 am up to 9:00 pm and will be activated every two hours. The notification will only be triggered when the person is located at the chair at the living-room table.

The test sample of the user study was comprised of 24 test participants all caring for or having a close relationship to a person affected by dementia. Since it was to suspect that users above 65 years might face more problems when using the Action Planner due to less computer experience, half of the test sample belonged to this age group.

As it is an established standard for usability testing a usage scenario including tasks users will typically perform when using the Action Planner was developed [8]. So the test participants were asked to create a rule that reminds a person to drink every 2 hours when sitting in a chair next to the living-room table, and secondly a rule to be informed via SMS in case of restlessness. For data collection, mainly structured questionnaires and observational protocols were used.

Test results showed that test participants above age 65 encountered more obstacles when working with the Action Planner e.g. due to having more difficulties with wordings and the approach of presenting information subdivided in tabs. Some of the test participants were unfamiliar with this work method. However the underlying design principle of the rule editor to shape the work flow in accordance to how a rule could be worded appears to be appropriate to the older test participants as well (mean value of medians for the cluster suitability for the task as captured in the questionnaires was 2.2 for both test groups where 1 was the most positive and 7 the most negative value). Both test groups considered it also very helpful that in the Action Planner, there is always a rule summary present that also reflects immediately the impact of the selection of a certain rule option.

6 Conclusions

In this paper, we motivated and described the WebDA Action Planner which enables the definition and runtime evaluation of time- and location-aware rules to support activities of people with dementia and their family care takers. The preliminary results from laboratory testing the technical (see section 4.4) as well as the usability tests with a target user group (see section 5) show the feasibility of the developed current approach, using active RFID technology mounted in the laboratory and a combination of rules created by the family carers to react appropriately to the current user’s status. This is the first step in the development of the intended future product which needs to be efficient, affordable and easy installable.

We are currently improving the user interfaces especially the rule editor to increase its usability and accessibility for the target user group of WebDA. The improvement and refinement of the system is an on-going iterative process based on the data collected so far from the user trials and from on-going evaluations.

7 References

[1] Masaki Maeda, Takefumi Ogawa, Kisyoshi Kiyokawa, Haruo Takemura,Tracking of User Position and Orientation by Stereo Measurement of Infrared Markers and Orientation Sensing, Proc. Int. Symp. on Wearable Computers (ISWC), pp. 77-84, Nov. 2004.

[2] Andy Ward, Alan Jones, Andy Hopper, A new location techique for the active office, IEEE Personal Communications, Vol. 4, No. 5, pp 42-47, October 1997

[3] Pete Steggles and Stephan Gschwind, The Ubisense Smart Space Platform, Advances in Pervasive-Computing, Adjunct Proceedings of the Third International Conference on Pervasive Computing. Vol. 191, 2005

[4] Hui Liu, Houshang Darabi, Pat Banerjee, Jing Liu, Survey of wireless indoor positioning techniques and systems, IEEE Transactions on Systems, Man and Cybernetics, Vol 37, No. 6, November 2007

[5] Sensite Solutions, LogiSphere RFID System, http://www.sensite-solutions.com/, August 2011

[6] P. Bahl and V. Padmanabhan, RADAR: an in-building RF-based user location and tracking system. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies, Vol. 2, 2000

[7] Fadil, H., Borazanci, A., Haddou, E. A. B.,Yahyaoui, M., Korniychuk, E., Jaffe, S. L., Minagar, A. (2009). "Early Onset Dementia". International Review of eurobiology 84: 245-262. doi:10.1016/S0074-7742(09)00413-9

[8] J. Nielsen; Usability Testing, in G. Salvendy (ed.), Handbook of Human Factors and Ergonomics, Second Edition, John Wiley & Sons, New York, 1997.