Social Robot and Sensor Network in Support of Activity of Daily Living for People with Dementia

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Abstract. In this paper, an eHealth system is described to improve the lifestyle of people with dementia and their caregivers. In the eWare project, a social robot is integrated with a sensor network to measure ADLs with the goal to provide context relevant suggestions to the person with dementia and reduce the caregiver burden. Furthermore, the context relevant messages can remind people with dementia to perform the activities that they want and need to perform, but forgot due to a decline of brain. The developments are based on iterative co-design and in-situ evaluations with people with dementia and their (in)formal carers. The architecture configuration of eWare was tested in laboratory experimental tests to provide a final ecosystem that will be further evaluated during the pilot cases of the project.

Keywords: Dementia · Social robot · Measurements

1 Introduction

The estimated number of people living with dementia in the world is about 46.8 million with a person diagnosed every 3.2 s [1]. In prospective, this number is going to double every 20 years reaching about 75 million in 2030. Typically, people with dementia have a lifestyle which is not different from other people, and have similar daily needs in respect to well-being and health. Daily needs that are increasingly more difficult to fulfill with the support of care professionals due to shortages and budget cuts. Furthermore, informal carers are already overburdened. ICT solutions can support people

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with dementia in improving their quality of life, and staying independent and active [2, 3]. This work is focused on an eHealth system, based on a social robot to support people with dementia in the mild to middle stage of dementia - who live alone at home - in their daily activities, and to be independent. The social robot has the potential to improve their wellbeing and reduce care-related stress among their caregivers. The system is characterized by the integration of a lifestyle monitoring technology (Passive Infra-Red and door contact sensors) and social support robotics, providing people with dementia context-relevant reminders based on predefined goals such as taking breakfast or going to bed within a certain time interval. In Fig. 1 is shown the specification of utilities for the project. Carers are informed via an app whenever goals have been met or not. The work has been performed within the framework of the eWare project [4] AAL-2016-071, financed by European Commission, National Ministries (The Netherlands, Italy and Switzerland) and National Funding Agencies (Norway).

Fig. 1. Specification of utilities

2 System Architecture and Methodology

The innovative aspect of eWare is the integration of sensors - to monitor the Activities of Daily Living (ADLs) of the older adult at home [5, 6] - and a small social robot to provide context-relevant suggestions to the user. Feedback is sent through a web-app to the caregiver to provide information about the older adults at home. In particular, the robot interacts to the person with dementia in achieving their Activity of Daily Living (ADL) goals. Goals such as having breakfast within a pre-defined time frame, eating dinner, leaving the house for activities, or going to bed. People with dementia often have difficulties in initiating activities and the day-night rhythm can shift.

To design an eHealth solution that supports people with dementia and their carers, active iterative involvement of these users is preferred in design to ensure compatibility with preferences, needs, and abilities. Currently, there is an increasing effort in actively involving people with dementia in the design of supportive technologies [7]. In particular for the design of navigation aids and social robotics.

The eWare system for people with dementia is realized combining two eHealth solutions already existing on the market. Life-style monitoring represents the newest category of monitoring system for application in elderly care. Passive Infrared sensors (PIR) combined with door contact sensors are used to monitor the activities of daily living of older people living alone at home [8, 9]. The innovative idea of this system is to combine the elaborated information coming from the life-style sensors network to give feedback to the user through a social robot. Introducing to people with dementia a social robot to provide suggestions and feedback regarding their daily goals is becoming an new way people with dementia in improving their quality of life and caregivers in reducing stress burden.

In the upcoming sections, we describe the technical development of the eWare system and a first experimental test with actual end-users.

2.1 Lifestyle Monitoring

A commercial sensor network of PIR sensors has been selected (Sensara Lifestyle monitoring system; https://sensara.eu/) for the purpose of the eWare project. The lifestyle system configuration is characterized by five wireless sensors (3 Passive Infrared (PIR) sensors and 2 doors contact sensors), which are installed in the home of the customer. The sensors are battery operated and need to be attached to the wall at about 1.40 m height. PIR sensors are installed in toilets/bathroom, kitchen, exit door(s), hall and the living room. Door contact sensors (On/Off sensors) are installed in the kitchen, for example in frequently used drawer or on the door of the fridge, etc. Sensors communicate with software in the cloud using a wireless receiver with a connection range sufficient to cover the monitored apartment. This receiver requires a wired power source and an internet connection.

Due to a self-learning algorithm, the lifestyle monitoring system supports different customer lifestyles. The algorithm collects data and can learn a baseline lifestyle pattern during the first two weeks of use (learned behavior period). Special filtering functions are implemented in order to make the system robust to interfering inputs such as visitors, holidays, pets, false sensor messages, etc. Based on the self-learning algorithm, this system configuration can provide useful information about the lifestyle of the users, e.g. level of activity, going inside/outside, in or out of bed, kitchen and toilet activity, walking speed. The end-user is the owner of the data and can invite (in)formal carers to follow its lifestyle. If the end-user is not able to perform this task, then a responsible family member can invite others. An associated privacy wizard allows for controlling access to the provided information.

2.2 Tessa Social Robot

For the purpose of the eWare project, Tinybot's Tessa is used, which is a small talking conversation robot [1] (https://www.tinybots.nl/). The definition of Social Robot is continuously debated, as reported also in [10]. The authors, in particular, have defined a social robot as an autonomous or semi-autonomous robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact. The high degree of personalization of the interaction represents the kernel of the Tessa robot social capability. Despite this, of course, there are several improvements that can be made, regarding for instance the social interaction capability and the social presence of Tessa, but, taking into account the peculiarity of the target group involved in the project, it was decided to provide a low-complex and easy to use robot, that has been specifically designed for- and with people with dementia. Tessa has been developed to provide social support and agenda functionalities for individuals with dementia and their informal caregiver. Tessa consists of a stationary social robot that provides a stimulus for individuals with dementia by delivering spoken verbal reminders, friendly suggestions, and playing personal music. Both formal and informal caregivers can personalize Tessa through an easy-to-use app, as well as add their own reminders, suggestions, and music.

3 Method and Results

3.1 Preliminary Pilot

Active involvement of people with dementia, their informal and formal carers was to ensure a match with the individual end-user goals and needs of the eWare eco-system in iterative test-retest procedures. Insights from different sessions and focus groups, a persona profile and the structure of the services were developed. In this paper is reported, the preliminary studies with the end-users, with aim of understanding the interaction features of the robot and of the UI, taking into account the peculiarities of the communication modalities of people with dementia (see Fig. 2).

Fig. 2. Active involvement of end users.

Following the national guidelines of the country involved, the Ethical approvals were collected for the evaluations and informed consents were collected. During the sessions people with dementia (primary end-users), (in)formal carers (secondary end-users) and (location) managers (tertiary end-users) were involved. The initial participatory sessions took place in three countries, Italy, Switzerland and The Netherlands, involving the future primary-, secondary- and tertiary end-users of eWare. The results from active involvement of the end users iteratively lead to improvements of the eWare eco-system. From the active involvement sessions, needs were gathered for the person with dementia in respect to support in ADLs and these were translated into system requirements (Table 1) for creating ADL goals with the eWare system.

Table 1. System requirements.

	Tessa	Movement sensor	Door sensor	Bed sensor	Other sensors
Activity Guidance	v	v	v		
Activity Level Monitoring	v	v	v	–	–
Reminders & Simulation	v				
Provide Daily Information	v				
Inactivity Detection	v	v	v	Optional	
Monitoring Mood	Optional				
Wandering		v	v	Optional	
Activating Cognition	v				
Sleep Quality Monitoring	Optional	v		v	
Safety Monitoring	Optional				v
Real-time Tele-monitoring	Optional				v

After the active involvement sessions, rich qualitative and quantitative insight was gathered in multiple in-situ evaluations with nine older people with early to middle stage dementia, four informal caregivers, and one formal caregiver. Life-style monitoring sensors and Tessa were placed inside the home of older people with mild to moderate dementia for three weeks. All participants were interviewed, except for one due to personal circumstances. The in-situ evaluation used a Wizard-of-Oz test set-up, in which the participants interacting with the robot believe it is fully autonomous, but which is actually operated by an unseen human being [11] and had a twofold purpose to the eWare project. First, the intention was to gain rich insights in the actual services that people with dementia would like to use in the eWare system and to see how they would respond to the interaction with the Tessa. Second, a Wizard-of-Oz experiment was also intended to see whether the sensor system would give enough information about the lifestyle for the AI to evoke meaningful insights for the robot to respond to. The experiment lasted for three weeks at four different households. People with dementia and their informal carers provided relevant input for functionalities and improvements of eWare as a response after trying out this Wizard-of-Oz version. The main results of the sessions in-situ evaluations were:

- Personalisation was considered important by all participants, but more so on the level of ‘when’ and ‘how’, rather than ‘what.’ For example, such as using the name of the person (“Good morning, Jane. Would you like some breakfast?”)

ADL tasks chosen were very similar, but timing and messages differed.

- The Tinybot's voice was universally liked, and its appearance was considered adequate. Participants focused on its appearance more in the participatory sessions than the field study participants. "Sure. It is fine. I think it is a nice little egg." – one of the participants with dementia in our in-situ evaluation study.
- The Tinybot was considered less suited for care receivers leading an unstructured life, and for houses with multiple inhabitants and multiple floors. This was confirmed in the field study.
- Field study participants wanted and expected more interaction between care receiver and Tinybot. This element did not come forward as prominently in the participatory sessions.

3.2 Further Developments

Results of the pilot are necessary to define the final architecture of the system. From the initial configuration, the final architecture is characterized by:

- Lifestyle monitoring Adapter –It is based on the public API called "Customer-API", which allows retrieval of the lifestyle information of the users of the system, which use LAN (gateway and PIR and door sensors). This information includes information about the attached users, their ADLs.
- Robot Adapter –It is based on an API which allows firing various actions (i.e. playing messages, asking questions, playing music) and receiving feedback from the end-users (residents/ elderly).
- System Database – it is the central data storage for the whole system and combines data received from the Lifestyle monitoring system, the robot and some system operating data.
- System Web UI – This component allows users (caregivers) to access all relevant configuration and user data, including the list of users of the system, the lifestyle information for the active user of the system, the list of active Tessa's and the associated social robot general configuration, the list of campaigns for all active social robots and the configurations of these campaigns, log files for the executed campaigns, including the received response from the end-users (residents).
- System Main Application – This software module is responsible for the overall orchestration and administration tasks within the system, like for example system startup and scheduling the system activities.
- System Artificial Intelligent (AI) Module – This software component implements the added "intelligence" of the system.

3.3 Goals Setting for People with Dementia

Based on the final architecture, the main aspect of the developed system is the setting of the goals for the resident. Goals are the combination of ADL events (sensor events of the life-style monitoring system) and reminder messages from the social robot. Together with the person with dementia, the informal and formal caregiver, the goals are set. Cards to guide this discussion are developed in the project. Next, the caregiver can set goals for the resident through the web-app. For example, having regular breakfast, or going outside more often for a walk. The system uses the sensor data to send relevant suggestions and motivating compliments via social robot. Goals are set within a time window (a minimum and maximum time). For example, a goal can be set for having regular breakfast between 7am and 11am. The caregiver can write these messages directly in the system app when planning a goal.

To give relevant suggestions through the social robot, the caregiver can write three different messages for each goal. Tessa will say these messages under certain conditions whether a goal has or has not been achieved yet within the set time. A message in a green font represents the success message. The robot will say this message when the goal has been achieved. A message in a yellow font represents a reminder: the robot will say this reminder halfway if a goal has not been achieved yet. A reminder in a red font represents a more urgent reminder if a goal still has not been achieved yet after the yellow reminder.

4 Discussion and Conclusion

The final functional system of eWare is designed to support people with dementia in achieving their Activity of Daily Living (ADL) goals. Goals such as having breakfast on time every day, eating dinner at appropriate times, leaving the house for activities, or going to bed at the right time. Individuals with cognitive disabilities such as dementia often have difficulties in initiating activities. Caregivers can promote healthy behaviour patterns for the person at home, fixing goals for the week and knowing the ADLs of the days. Using this protocol, the caregiver can monitor which ADLs have been triggered and which reminders Tessa has spoken. So based on this information, the caregiver can decide whether to change the goals or change something in the environment of the person with dementia. This always happens in close communication with the person with dementia themselves. The goals cannot be enforced, but with better information the caregiver can provide better support to make sure the older user achieves goals.

From the literature, it is evident the advantage in using social robots to take care of people with dementia [12] but, integrating the social robot with a sensor network may provide a more powerful system in helping people with dementia and their caregivers. People with dementia can benefit from this integrated system thanks to the advices received from the social robot, but funded on the measurement of ADLs, they are encouraged in maintaining their independence and intrinsic capacity receiving support and reminding for their daily activities, as reported in (Organization 2015). This way they won't get blunt reminders that do not comply with what actually happens in their homes.

The integrated system was realized based on in-situ evaluations and interactive sessions with people with dementia and their (in)formal carers. The eWare system has been tested through regression-tests: after every change functional and non-functional tests were re-run to ensure that previously developed and tested software still performed. Regression tests provided the complete functionality of the system ensuring that the architecture is functioning; this allows us to hypothesize the feasible application of the eWare system on people with dementia.

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References

1. Bouwhuis, D.G., Human Technology Interaction: Current use and possibilities of robots in care (2016)
2. Chen, K., Chan, A.H.S.: A review of technology acceptance by older adults. Gerontechnology **10**, 1–12 (2011). https://doi.org/10.4017/gt.2011.10.01.006.00
3. Kamphof, I.: Seeing again. Dementia, personhood and technology. In: Ageing and Technology (2016)
4. eWare – Early Warning Accompanies Robotics Excellence. https://aal-eware.eu/wp/. Accessed 12 Dec 2018
5. Monteriù, A., Prist, M.R., Frontoni, E., et al.: A smart sensing architecture for domestic monitoring: methodological approach and experimental validation. Sensors **18**, 2310 (2018). https://doi.org/10.3390/s18072310
6. Pietroni, F., Casaccia, S., Revel, G.M., et al.: Smart monitoring of user and home environment: the Health@Home acquisition framework. In: Casiddu, N., Porfirione, C., Monteriù, A., Cavallo, F. (eds.) Ambient Assisted Living, pp. 23–37. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-04672-9_2
7. Suijkerbuijk, S., Nap, H.H., Cornelisse, L., et al.: Active involvement of people with dementia: a systematic review of studies developing supportive technologies. J. Alzheimer's Dis. **69**, 1041–1065 (2019). https://doi.org/10.3233/JAD-190050
8. Casaccia, S., Pietroni, F., Scalise, L., et al.: Health@Home: pilot cases and preliminary results : Integrated residential sensor network to promote the active aging of real users. In: 2018 IEEE International Symposium on Medical Measurements and Applications (MeMeA), pp. 1– (2018)6
9. Gochoo, M., Tan, T., Liu, S., et al.: Unobtrusive activity recognition of elderly people living alone using anonymous binary sensors and DCNN. IEEE J. Biomed. Health Inform. 1 (2018). https://doi.org/10.1109/JBHI.2018.2833618
10. Bartneck, C., Forlizzi, J.: A design-centred framework for social human-robot interaction. In: RO-MAN 2004. In: 13th IEEE International Workshop on Robot and Human Interactive Communication (IEEE Catalog No. 04TH8759). pp. 591–594 (2004)
11. Martin, B., Hanington, B.M.: Universal Methods of Design: 100 Ways to Research Complex Problems, Develop Innovative Ideas, and Design Effective Solutions. Rockport Publishers, Beverly (2012)
12. Mordoch, E., Osterreicher, A., Guse, L., et al.: Use of social commitment robots in the care of elderly people with dementia: a literature review. Maturitas **74**, 14–20 (2013). https://doi.org/10.1016/j.maturitas.2012.10.015