Ubiquitous Monitoring & Service Robots for Care

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Abstract. The Ubiquitous Monitoring System (UMS) developed in the framework of Knowledgeable Service Robots for Ageing (KSERA) project is able to trigger unfavourable outdoor and indoor environmental conditions, potentially harmful for patients, especially with chronic respiratory diseases. The authors present a new artificial cognitive tool integrating sensing and decision making for care purposes. Authors showcase how a combination of virtual sensorial components acquiring daily the concentration of very fine Particulate Matter, one data analysis component triggering long lasting polluted periods cooperates with one humanoid robot actuating information delivery about the harmful conditions and risks of disease exacerbation. The use of humanoid robotic interfaces offers better persuasive capabilities and compliancy of care.

1 Introduction

In Europe, life expectancy is increasing. The number of seniors aged 65 and over continues to increase. Patients with Chronic Obstructive Pulmonary Disease (COPD) have an overall gradual decline in their physical functions accompanied by acute periods of exacerbation. For this reason they become vulnerable to the unfavourable environmental conditions. One example is the pollution by very fine Particulate Matter (PM). Depending on the size of fine particles, there are different polluting agents known as PM_{25}, PM_{10}, and $PM_{2.5}$. Among them, the $PM_{2.5}$ particles penetrate deep into lung tissue giving the correlation with COPD exacerbations. It challenges new remote COPD care applications.

Care solutions relying on smart home alone appear to be incomplete. They are stationary and lack attractive interfaces for the elderly requiring them to always go where sensors are. The KSERA Ubiquitous Monitoring System (UMS) processes the information and context. It informs and gives alerts to the person about both the indoor and outdoor conditions (pollution, temperature, humidity). A strong orientation towards human needs as opposed to a pure implementation of the technologically possible is required. Designed according with the User Centred Design (UCD) [1], the system becomes responsive to the context of life of people to which it is addressed and persuasive: an advanced humanoid robotic interface interacts with the user. Nevertheless, the sole presence of a robot is not enough because it needs to interact with the home environment and to provide relevant information that only external devices can provide (e.g., PM_{10} levels, environmental conditions). Thus, a COPD care appli-

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cation which collects historical series of environmental/medical data for the medical assessment [2] before actuating care operations offers better personalized care.

The improved compliance of care depends on an efficient and persuasive communication. In turn, it requires context-sensitivity and capacity to read user intentions. Socially assistive robot (SAR) provides two types of support: functional and social. Functional support includes reminders and instructions. Social support typically aims at reducing social isolation and enhancing well-being in the form of social interaction with users. The robot's physical embodiment and multimodal communication channels allow it to communicate with users verbally and non-verbally in a social manner. As a consequence, users benefit from the interaction, while robot can be perceived as companion. Using SAR [3], it can reduce the feeling of social exclusion and the level of stress, both common problems of aging. Thanks to the social robot, the person can also ask for information when, for example, planning his/her daily activity. According to the data gathered, the system can follow some protocols, patient specific, reminding to perform the measurements of relevant parameters. Cognitive capabilities [4, 5] are used to manage the exacerbation periods through monitoring, collecting data, and applying the rules to discriminate among several real-life situations.

2 Ubiquitous monitoring

The *sensing* is one of the core capabilities of AI systems. The KSERA UMS [3] is able to acquire several parameters coming from indoor, outdoor, and wearable devices. One variant of the system uses web services to acquire at regular basis the specific environmental parameters such as PM_{10} and/or $PM_{2.5}$ values. The main information set (temperature, humidity, and CO levels) comes from physical sensors, while the particle pollution comes from a virtual sensor. The system makes persistent the information flows in the database. After some days the accumulated time series of data about pollution reveal trends. It enables to perform analytical processing of the historical series using data-warehousing algorithms. The persistence of high PM levels for many days is likely to cause exacerbations in patients affected by chronic respiratory diseases. Since 2006, the 24-hour fine particle $PM_{2.5}$ threshold is 35 $\mu g/m^3$, while PM_{10} threshold is 50 $\mu g/m^3$. The aforementioned dataset is useful to set up one interesting care scenario capable to prevent COPD exacerbations in situations in which one plans venturing outdoor. The UMS analyzes the outdoor conditions and trends, while KSERA rule engine triggers the situations in which patient is venturing outdoor for any reason. In such cases the intelligent software delivers appropriate information to patient attempting to prevent the unwanted effects. For these reasons the UMS daily analyses PM levels and counts a number of consecutive days in which PM levels exceed 35 or 50 $\mu g/m^3$ (Fig.1). It gives one simple rule-based reasoning scheme governing the COPD care application, which can be easily extended by additional clauses incrementally. Two simplest triggering rules are: IF (Number_of_days_with_PM_{10}>50 IS 20) OR (Number_of_days_with_$PM_{2.5}$>35 IS 10) THEN Deliver_Feedback ("Reduce outdoor stay").

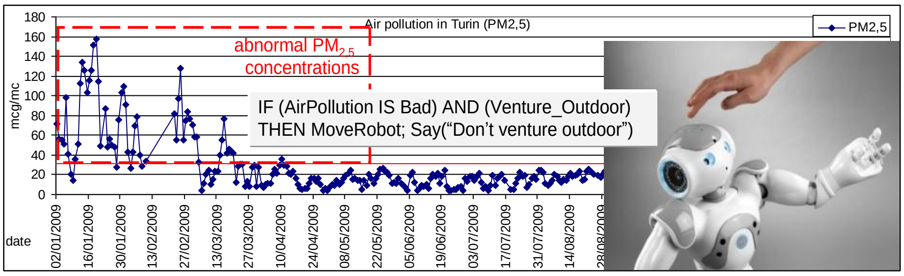

Figure 1. Daily samples of particle pollution make a trend originating the robot's reaction.

The timing of feedback delivery is handled in more sophisticated way. The reasoning might deliver many triggers daily, while their use depends on the user intentions being captured. In the example, KSERA recognizes the patient's intention to *venture outdoor* being expressed and it delivers the useful advice once. Using SARs, a wide range of social and cognitive skills needs to be seamlessly and in a personalized manner integrated to enable them to interact effectively [6]. To do so, we added explicit dialogs with speech recognition features. They are especially effective since recall the natural cues of human interaction.

The novel time management option is embedded in the respective scripts/state machines. In a situation, in which high PM levels persist for more days and human tells about the planned outdoor activities, the anthropomorphic SAR conveys a warning to patient by moving itself *nearby* him/her. This interaction is very complex. To avoid any obstacle, the optimal walking path has to be calculated first. To establish an eye contact with the patient, SAR has to find the user and align the viewpoint by calculating gaze vector. Finally it tells him/her the message in natural language.

In COPD care, the respiratory training programs are adopted to improve the healthy condition of patients because prolonging their wellbeing. The respiratory activity is monitored indirectly through SpO_2 parameter using pulsimetry, which is a non-invasive technique checking the saturation of oxygen in the arterial blood. Since the difficulty levels of exercises depend on SpO_2 thresholds, the aforementioned values have to be acquired by UMS before prompting to undertake the training set in the patient's care protocol. In the absence of the updated values, KSERA prototype invites patient to acquire new measurements by moving the robot in the neighbourhood. The system proposes one personalized respiratory training program based on the robot in the place-of-need then.

3 Complementing the Human Robot interaction

The anthropomorphic robot is the most visible component of the system. It is the major communication interface between the elderly, the smart home, and the external world. It enables natural human-robot interaction, but requires some sophisticated artificial cognition components to interplay system components. We took one off-the-shelf (NAO) robot and modified its behavior based on the laboratory user studies in the Netherlands and Italy and user feedback from field trials in Austria and Israel with elderly COPD patients.

In our vision, the UMS complements the HRI by means of an enriched context sensitiveness that includes the main interaction agents (robot, patient, and their *changing positions*) resulting in their improved reliability and trust. Thus, we integrated robot mobility as a part of the human robot interaction with novel localization and navigation methods. The ceiling-mounted camera gives positions of a person and a robot. The person localization uses a hybrid probabilistic model, while the robot localization is based on particle filter prediction. Navigation uses the position information as input for determining where to move the robot. The robot moves to a specific position in the room according to the status of the interaction with the person and external events. The choice of the target position is made by the rule engine that interprets the environmental parameters and external events and triggers appropriate robotic mobile behaviors. KSERA contains behavior-based navigation providing a smart obstacle-avoidance strategy and map-based navigation which *learns* the spatial knowledge by observing the human's movement in a room.

KSERA provides a mobile assistant to follow and monitor the health and behavior of a senior, video and internet communication services including needed alerts to caregivers and emergency personnel, and a robot integrated with smart household technology to monitor the environment and warn the senior or caregivers of anomalous or dangerous situations. The ubiquitous monitoring of physiological and behavioral data through direct measurements and interaction with household sensors is used in conjunction with human-robot interaction including shared environmental processing, affective technology, and adaptable multimodal interfaces. A single robot, hosting entertainment and communication aids, contributes to the senior’s health and quality of life. At the same time, it provides an assistant that monitors the environment and the senior’s behavior. It uses contextual information and adaptive decision making algorithms to continually update the monitoring and mobile behavior for improved interaction with the senior and to provide information and support at the right time and place.

The mix of quantitative and qualitative metrics is used to evaluate holistically KSERA. Quantitative metrics include Godspeed, WHO QoL, PANAS, ad-hoc questionnaires (Likert-scale based), and system performance metrics. Qualitative metrics include: focus groups, free interviews, user tests and thinking aloud protocol. We tested the embodiment discovering that our participants do like the robot more than smart home interfaces and that they consider it more alive. The reaction time in categorization tasks was slower for the robot than for the smart home. One possible explanation is that the robot used gestures, which caused the participants to wait for them to complete before starting with the categorization task.

4 Conclusions

The KSERA system with several UMS sensors and web services processing the information describing indoor, outdoor, patient mobility and health/living parameters daily gives an example of organic computing. Using historical series of data, we discriminate among different patient conditions and care trends. Using trend monitoring functionality, the system gained the capacity to friendly inform people about the harmful outdoor conditions according with their intentions (venturing outdoor or opening windows during polluted days in example). User tests and field trials showed high acceptance of the UMS, which is able to improve the patient's engagement in disease self-management process [7] through the social robot. As opposed to [5] grounded on RFID to detect the sequences of events and mobility patterns, the present work uses a combination of different classes of sensors. The next intention is not calculated based on temporal constraints, but it is made using speech recognition algorithms and disambiguation (dialogs). Extending the monitoring functions of previous prototype [7], more complex data-warehousing/trend analysis options are used to match the patient's history with the formalized disease management pathway (rule-based). The SpO_2 values were correlated with PM levels to derive a new combined situational indicator of wellbeing. Using the humanoid robot to inform patients about pollution and exacerbation risks appears convincing. The social robot acting inside the house implements ubiquitous monitoring features and makes them acceptable by users through a natural interaction.

Future artificial cognitive systems correlating the collected data with the intentions might implement more communication variants.

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References

1. D. Norman, S. Draper, User-Centered System Design: New Perspectives on Human-Computer Interaction, Lawrence Earlbaum Associates, Hillsdale, NJ (1986).
2. R. Wichert, B. Eberhardt, Ambient Assisted Living - Advanced Technologies and Societal Change, Springer (2011).
3. -, Knowledgeable Service Robotics for Ageing (KSERA) project, http://www.ksera-project.eu
4. E. K. Zavadskas, Multi-criteria decision support system of intelligent ambient-assisted living environment, in proc. of ISARC-2008 conf. (2008).
5. M. Simonov, F. Mazzitelli, Near miss detection in nursing: rules and semantics, in H. Chen, Semantic e-Science Book, Springer (2010).
6. K. Dautenhahn, Socially intelligent robots: dimensions of human-robot interaction. Philosophical Transactions of the Royal Society B: Biological Sciences, 362(1480), 679-704. http://dx.doi.org/ 10.1098/rstb.2006.2004 (2007).
7. M. Simonov, A. Frisiello, M. Bazzani, Using Humanoid Robot In Ambient-Assisted Living with COPD, in proc. of Med-e-Tel'12 conf. (2012).