Personalized and Intelligent Sleep Lifestyle Reasoner with Web Application for Improving Quality of Sleep Part of AAL Architecture

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Abstract. An average human spends about one third of his life sleeping so quality of sleep is essential for the human being to maintain good physical and emotional health. Sleep disorders may introduce severe physical effects, e.g. cognitive impairments and mental health complications. So being able to measure and evaluate sleep behavior is important for health practitioners and the users themselves. In this paper, we present the implementation of the Sleep Lifestyle Reasoner part of AAL platform which allows detection of minor or major deviations in the sleeping patterns in MCI and COPD patients indicating changes in their health status. The output of the reasoner is fed to the My Sleep Web Application that provides recommendations to improve sleep hygiene and coaches the users into a healthy sleeping behavior, based on their personal rhythms and problems. It also supports the informal caregiver by providing insights on the sleeping behavior of the patient.

Keywords: Intelligent Decision Support System · Sleep quality Sleep monitoring · Context awareness · Ambient Assisted Living

1 Introduction

It is estimated that around twenty five per cent of elderly people worldwide have sleeping disorders [1]. Bad nights of sleep make people feel tired during the day, lose their enthusiasm and get easily irritated. Insufficient sleep is also associated with significant morbidity and increased mortality [2], and with an increased risk of falls [3]. Insomnia becomes a more common problem with age.

Along with the common sleep disorders related to the ageing population, detection of sleep disturbances in elderly suffering from Mild Cognitive Impairments (MCI) may be a predictive marker of the conditions' progression [4]. An irregular sleep–wake pattern can reflect the level of cognitive impairment. As the disease progresses, more severe sleep disturbances develop which affect the continuity of nighttime sleep, alertness during the day and overall wellbeing. The evaluation of sleep disturbances can help toward a proper diagnosis and a better understanding of the cognitive condition of the person with cognitive impairments [5].

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The increasing inclusion of the new technologies in the everyday life of people more precisely the Ambient Assisted Living (AAL) architecture, provides an ecosystem of different types of sensors, computers, mobile devices, wireless networks and software applications for personal healthcare monitoring systems [6]. In recent years a number of smart home projects based on AAL have been developed [7]. In some of these home health-care systems automatic sleep monitoring platforms using different kinds of sensors and data processing are developed [8].

One such AAL cloud-based service-oriented architecture was elaborated during the development of the eWALL project [9]. eWALL is a platform providing dynamic environment for elderly patients with MCI and Chronic Obstructive Pulmonary Disease (COPD) for social interaction and continuous medical surveillance. The system offers personalized services such as daily activity monitoring, exercises, reminders and others.

The main contribution of this paper is the implementation in Sect. 2 of the Sleep Lifestyle Reasoner (SLR) which allows detection of minor or major deviations in the sleeping patterns in MCI patients indicating changes in their health status and being a good indication of the progression of their cognitive impairments. The output of the SLR is fed to the My Sleep Web Application described in Sect. 3. The added value of this personalized application is to support the primary user in the self-management of his condition and also to support the informal caregiver in providing insights on the sleeping behavior of the patient. It also provides recommendations to improve sleep hygiene and coach the users into a healthy sleeping behavior, based on their personal rhythms and problems.

2 Sleep Lifestyle Reasoner Description

A general description of the eWall architecture with all its components is given in [10]. The Lifestyle Reasoners (LR) within the eWALL are components which aim to predict behavior and to detect variations that might indicate a change in the user's health status. To do so, the LRs consume data from multiple sources and derive semantically meaningful patterns. The reasoner determines whether a variation falls within the expected thresholds, or employs more complex statistical methods to determine deviations and outliers.

Figure 1 illustrates the data flow regarding the sleep from sensor data acquisition to the SLR. The sensors existent in the user's room (microphone, accelerometer and bed pressure [11]) provide raw data to the Daily Functioning Service Brick (SB), which perform pre-processing algorithms as filtering. The Sleep Intelligent Decision Support System (IDSS) reasoner [11] then combines the data from the SB retrieved from several service endpoints and infer on the sleep period. The SLR runs once a day and, if new data is detected, creates updated averages of each one of the pre-defined parameters related to the sleeping pattern of the user. Averages are calculated using Linear Weighted Moving Average, giving bigger weight to more recent values. Outliers are filtered and not considered in the calculations.

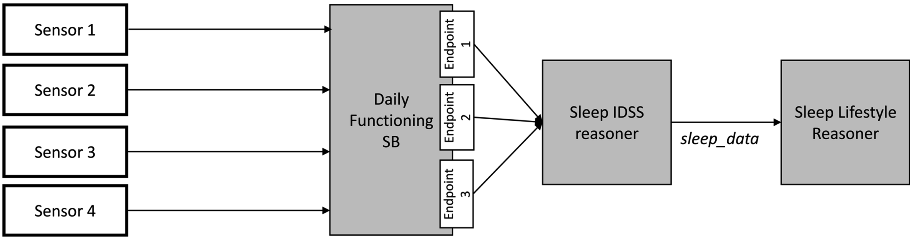


Fig. 1. Conceptualization of data flow from raw data acquired by sensors to *sleep_data* used by the lifestyle reasoner.

Reasoner inputs: The SLR gets data regarding the last night's sleep from the Sleep IDSS reasoner, which uses sleep data from a Fitbit tracker (a third party component, which delivers partially low level, partially high level reasoning - https://www.fitbit.com). Based on the data received, it infers the following parameters part of the *sleep_data*:

- bedOnTime: Time the user went to bed, in minutes since 0:00 of the day preceding the night.
- bedOffTime: Time the user got out of bed, in minutes since 0:00 of the day following the night.
- totalSleepTime: Total duration in minutes that the user was in bed during the night;
- frequencyWakingUp: Number of times that the user woke up during the night;
- sleepEfficiency: The sleep efficiency in percent.

Reasoner outputs: Weighted average in minutes of each parameter of sleep per day of the week till the current moment. The SLR has two JSON (JavaScript Object Notation) end-points. The "lastupdate" endpoint provides the date until which the reasoner has processed data for a specific user, and the "sleepweekpattern" provides the averaged sleep data for each day of the week for a specific user.

Applications served: The SLR generates data that is shown to the users by the following applications:

- My Sleep Application, providing patterns of sleep over time (e.g. usual time of going to sleep or usual sleep location);
- Personal Daily Support Service, whenever a notification should be provided to the user;
- Caregiver Application, whenever the caregiver should be informed about significant changes in the sleeping patterns of the primary user.

The SLR stores intermittent and processed results in the MongoDB database. By detecting deviations from normality, it supports MCI patients in the self-management of their condition. Also, as the sleeping period becomes, for example, more interrupted, the patient is alerted and it might lead him to be directed to a healthcare professional to control his condition. In order to meet the requirements of the MCI and COPD target groups, a set of different modules were defined. For each of these modules an appropriate scenario and their associated requirements are taken into account in the platform.

3 My Sleep Web Application

The “My Sleep” application has the purpose of presenting quantitative and qualitative interpretation of the user’s sleep behavior based on the home sensing. It shows an interpretation of last night sleep data. The application consumes service brick data describing sleep events such as: time the user went to sleep; time the user woke up; the duration of sleep; the sleep efficiency, etc. This data is processed and semantically represented within the interface. Complementary, the SLR is requested to provide patterns of sleep behavior for the user and the information is displayed according to each sleep period described in the interface. These connections are depicted in Fig. 2.

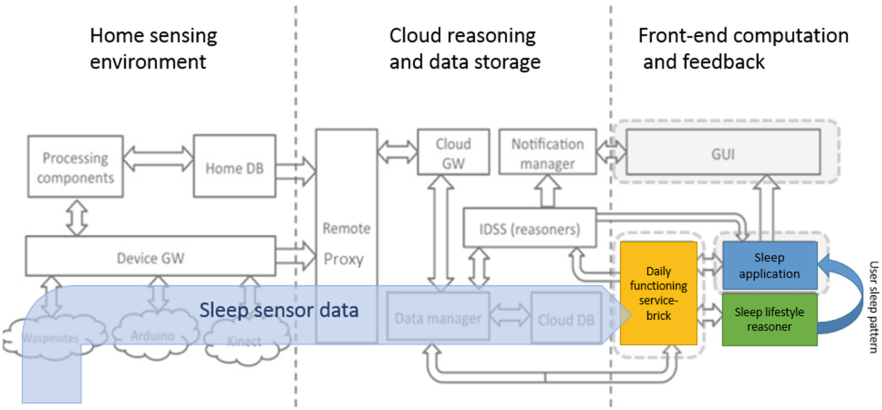


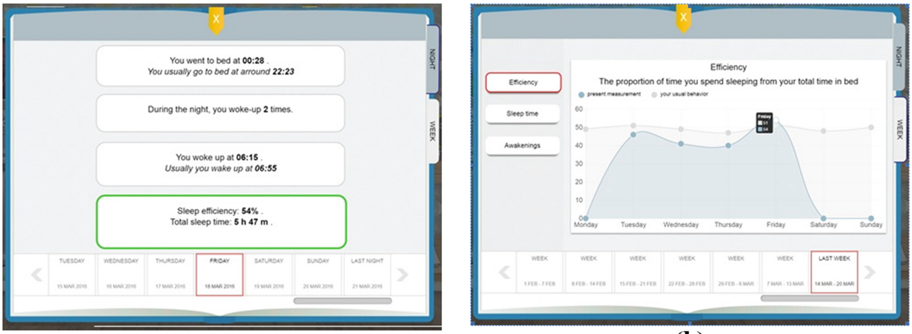
Fig. 2. Connection between the sleep application and the dependent eWALL components

Thus we present the user’s last night behavior in the context of his routine behavior. Additionally, the application computes quality of sleep parameters, taking into account objective parameters according to medical norms in measuring quality of sleep. The sleep data can be visualized for one day at the time, or one week at the time. Figure 3(a) depicts the interface for the sleep application. The GUI was adapted to the recommendations which came out of the target group of eWALL users. On Fig. 3(a) and (b) is illustrated the summary of one night sleep expressed in 4 paragraphs. This implementation reduces considerably the information overload of the interface.

Sleep efficiency counts the proportion of time the user spends in bed with the intention of sleeping and the actual time spent sleeping. This measurement is expressed in percent.

Sleep time counts the total time in minutes the user has been sleeping (Fig. 4(a)). The number of awakenings during the sleep period is also important. The Fig. 4(b) shows the weekly overview of this measurement.

The outcomes from SLR output interpretation are represented through clear text in the daily view and color coded in the weekly view. The text is short and concise, eliminating the perception of “long boring read”.



(a) (b)

Fig. 3. The eWALL sleep application interface based on elderly user and expert user tests. (a) Depicts the daily sleep review. (b) Depicts weekly sleep efficiency view

(a) (b)

Fig. 4. (a) The eWALL sleep interface, depicting the sleep time panel, (b) depicting the awakening panel

4 Conclusion

In this paper we present an implementation of Sleep Lifestyle Reasoner allowing detection of changes in the sleeping patterns in MCI and COPD patients thus indicating changes in their health status. This information is useful for a sleep specialist who wants to check a patient's daily sleep pattern and also supports self-awareness about each individual sleeping patterns and create alerts whenever the sleeping behavior deviates from expected. The presented Web application offers to manage the user's profile and feedback for personalized recommendations on the basis of subject's interests, preferences and behavior. The application provides services according to the user's selected device (i.e., web interface, smartphone or tablet).

The design and implementation of most of eWALL software components including the lifestyle reasoners are operational and currently are in the phase of end-user testing.

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References

1. Ancoli-Israel, S.: Sleep and its disorders in aging populations. Sleep Med. **10**, S7–S11 (2009). https://doi.org/10.1016/j.sleep.2009.07.004
2. Dew, M.A., Hoch, C.C., Buysse, D.J., et al.: Healthy older adults’ sleep predicts all-cause mortality at 4 to 19 years of follow-up. Psychosom. Med. **65**, 63–73 (2003)
3. Brassington, G.S., King, A.C., Bliwise, D.L.: Sleep problems as a risk factor for falls in a sample of community-dwelling adults aged 64–99 years. J. Am. Geriatr. Soc. **48**, 1234–1240 (2000)
4. da Silva, R.: Sleep disturbances and mild cognitive impairment: a review. Sleep Sci. **8**(1), 36–41 (2015). https://doi.org/10.1016/j.slsci.2015.02.001
5. Nikamalfard, H., et al.: A sleep pattern analysis and visualization system to support people with early dementia. In: Proceedings of the 5th ICST Conference on Pervasive Computing Technologies for Healthcare, pp. 510–513 (2011)
6. Universal Open Platform for AAL. http://www.universaal.org/
7. Li, R., Lu, B., McDonald-Maier, D.: Cognitive assisted living ambient system: a survey. Digit. Commun. Netw. **1**, 229–252 (2015)
8. Kitamura, K., Nemoto, T.: Automatic sleep monitoring system for home healthcare. In: IEEE-EMBS International Conference on Biomedical and Health Informatics, pp. 894–897 (2012)
9. Ewall for Active Long Living project. http://ewallproject.eu
10. Koleva, P., Tonchev, K., Balabanov, G., Manolova, A., Poulkov, V.: Challenges in designing and implementation of an effective Ambient Assisted Living system. In: International Conference on Advanced Technologies, Systems and Services in Telecommunications – TELSIKS, Niš, Serbia, pp. 305–308 (2015)
11. Tonchev, K., Koleva, P., Manolova, A., Tsenov, G., Poulkov, V.: Non-intrusive sleep analyzer for real time detection of sleep anomalies. In: 39th International Conference on Telecommunications and Signal Processing (TSP), Vienna, Austria (2016)