Concierge-Based Care Support System for Designing Your Own Lifestyle

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Abstract
This paper focuses on a care support of aged persons in a super aging society and proposes the concierge-based care support system that designs the appropriate lifestyle of each aged person for a comfortable and healthy life. For this purpose, this paper proposes the three types of agents, i.e., the sleep monitoring agent, the care plan design agent, and the care worker support agent. To provide the comfortable and healthy life for aged persons, the proposed system estimates the sleep stage of aged persons to evaluate it from the viewpoint of the deep and stable sleep. Such a daily evaluation can be done by storing dairy personal data as a big data and by converting them into meaningful knowledge (e.g., the heartbeat and body movement data of the personal big data are converted into the sleep stage in our system). The human subject experiments of our system set up in the care house have revealed the following implications: (1) the sleep monitoring agent succeeds to estimate the sleep stage without connecting any devices to human's body and its estimation accuracy is higher than 90% by allowing one stage difference; (2) the care plan design agent can design care plans (i.e., rough schedules in a day) that provide nine years younger sleep in the healthy aged persons and seven years younger sleep in dementia persons; and (3) the care worker support agent has a great potential of guessing the way aged persons feel.

1. Introduction
Which do you want to stay, an exclusive hotel or a care house? Most of persons select an exclusive hotel because it can provide a high added value such as a comfortable space, relaxed room, a luxurious time, and so on. From this viewpoint, what kind of an added value is required to select a care house rather than an exclusive hotel? It is very difficult to answer this question, which derives the serious situation because there is no attractive value for aged persons who stay in care houses. Since such persons may be hard to live a meaningful life and the number of aged persons increases every year (i.e., the percentage of the people aged 65 or over currently exceeds 20 of the total population (about 25 million people) in Japan (IPSS 2002), (MIC 2000)), it is quite important to find an added value for aged persons who stay in care houses.

Although there is no clear answer to find such value, our project claims an importance of an appropriate lifestyle design for aged persons. For example, aged persons have a comfortable and healthy life if care houses can provide their good appetite and proper rehabilitation for their healthy bodies, and possibly their long life. To provide such a kind of the added value in care houses for aged persons, this paper proposes the concierge-based care support system that supports aged persons by providing their own agents that design their own appropriate care plans (i.e., rough schedules in a day) for a comfortable and healthy life. For this purpose, our system estimates the sleep stage of aged persons to evaluate whether they have a comfortable and healthy life from the viewpoint of the deep and stable sleep. Such an evaluation can be done by storing dairy personal data as a big data and by converting them into meaningful knowledge (e.g., the heartbeat and body movement data of the personal big data are converted into the sleep stage in our system). This indicates that the personal big data becomes meaningful knowledge for better health, wellness, and well-being of aged persons.

This paper is organized as follows. The next section explains the sleep stage and its estimation without connecting any devices to human bodies, and Section 3 proposes the concierge-based care support system. The experimental results and their analysis are described in Section 4. Finally, the conclusion is given in Section 5.

2. Sleep stage and its estimation

Sleep stage
To evaluate comfortable and healthy life from the viewpoint of the sleep of aged persons, our previous research (Takadama et al. 2010) proposed the method that can estimate their sleep stage without connecting any devices to human's body as shown in Fig. 1. In this figure,
the horizontal axis indicates the sleep time in a bed, while the vertical axis indicates the sleep stage divided into six stages, \textit{i.e.}, the wake stage, REM sleep stage, stages 1, 2, 3, and 4 represented by W, R, 1, 2, 3, and 4, respectively. Note that the stage 4, in particular, has the deepest sleep, while the wake stage has the lightest sleep. When aged persons take the \textit{deep} and \textit{stable sleep}, the area of the sleep stage (represented by the orange area) generally becomes large and the sleep stage does not often change as shown in Fig. 1 (a). When aged persons take the \textit{light} and \textit{unstable sleep}, on the other hand, the area of the sleep stage generally becomes small and it often changes as shown in Fig. 1 (b).

By focusing on these differences, the sleep of aged persons can be evaluated from the following criteria, which indicate that they have a deep and stable sleep when the total time of the sleep stages 3 and 4 is large, while they have a light and unstable sleep when the total time of the wake and REM sleep stages is large.

- **Degree of deep sleep**: Total time of the sleep stages 3 and 4
- **Degree of light sleep**: Total time of the wake and REM sleep stages

Sleep stage estimation without connecting devices
Although the sleep stage can be calculated from the brain wave of humans by the R&K method (Rechtschaffen et al. 1968), this approach is not realistic for the aged persons in care houses due to the direct connection of devices to their heads. In particular, such connections prevent from the deep and stable sleep of the aged persons by restricting their behaviors.

To overcome this problem, Watanabe succeeded to estimate the sleep stage from the heartbeat data measured by the pneumatic approach using the air mattress in a bed (Watanabe et al. 2004), which means that its stage can be estimated without connecting any devices to human's body. This method is based on the results of the several articles suggested that the heartbeat data has the strong relation to the sleep stage (Harper et al. 1987) (Otsuka et al. 1991) (Shimohira et al. 1998). However, this method is developed according to the actual data of the \textit{young} human subjects, which may not be effective in \textit{aged} persons because the ratio of sleep stage changes as age increases.

To tackle this problem, our previous research (Takadama et al. 2010) proposed the novel method that can estimate the sleep stage without connecting any devices to human's body through an adaptation to each person, and showed that the accuracy of the sleep stage in our method is better than that in the Watanabe's method. Since our method can estimate the sleep stage by adapting to each person, it does not have to matter whether young or aged person.

Sleep stage estimation system
To estimate the sleep stage according to the heartbeat data as the same as Watanabe's method, this study employs \textit{Emfit sensor} (developed by VTT Technical Research Center of Finland) which can measure the heartbeat data by just laying on the bed. Since its sensor is set under the bed as shown in Fig. 2 (b), the aged persons can stay their rooms as usual. This indicates that the bed is usual as shown in Fig 2 (a), except for the AC adapter for battery of \textit{Emfit sensor} and the Ethernet cable for transmitting the heartbeat data to the server PC as shown in Fig 2 (c).

Fig 1. Sleep stage

3. Concierge-based care support system
Fig. 3 shows the overview of our concierge-based care support system that employs the following three types of
agents: (1) the sleep monitoring agent, (2) the care plan design agent, and (3) the care worker support agent. The detailed of these agents are summarized as follows.

● Sleep monitoring agent
To evaluate whether aged persons have good sleep, the sleep monitoring agents (installed in the smart phone which can be substituted for a pad or personal computer) in each room shown in Fig. 3 are provided for each aged person and automatically estimates his sleep stage. In addition to evaluate the sleep stage of aged persons, the agent can recognize that an aged person wander at midnight by sensing the time for an absent in the bed and then send an e-mail to the PDA (personal digital assistant), which is carried by care workers, via Ethernet and WiFi network as shown in the lower right side in Fig. 3.

● Care plan design agent
As shown in Fig. 3, aged persons have their own room and make a living according to the schedule determined by the care plan (i.e., a rough schedule in a day), which includes the meal, medicine, health check, exercise or rehabilitation, excretion, and sleep. What should be noted here is that (1) the care plan is a common for all aged persons, which means that it may not be effective for a certain person; and (2) the current care plan is created according to the experience of the care planner, which means that it has not yet fully optimized. From these facts, the care plan design agents (installed in the smart phone which can be substituted for a pad or personal computer) in each room shown in Fig. 3) are provided for each aged person and create an appropriate care plan of each person for the comfortable and healthy life.

● Care worker support agent
Since all staffs in the care house including the care workers, care planners, and a care manager support aged persons according to their own experience, the training of the staffs is very important to keep high and fair care quality. To tackle this issue, the care worker support agent (installed in the computer shown in lower center in Fig. 3) try to guess the way aged person feel and tell it to support beginner staffs to provide an appropriate care for the specific person. Such support also contributes to increasing the care quality of care workers.

4. Experimental results and their analysis

● Sleep monitoring agent
An improved method of our sleep stage estimation (Takadama 2010) is investigated by comparing its correctness with that of PSG (Polysonomography), which is the standard method of calculating the sleep stage by medical specialists using data such as Electroencephalogram (EEG), Electro-myogram (EMG), and Electro-oculogram (EOG) of humans. This approach is based on R&K method (Rechtschaffen et al. 1968) as described in Section 2 and can estimate the sleep stage with high accuracy.

Fig. 4 shows these results. In this figure, the horizontal axis indicates time (i.e., hour) in a bed, while the vertical axis indicates the sleep stage. In the graph, the blue and red lines indicate the estimated sleep stages of PSG and our method, respectively. This graph indicates that the sleep stage of PSG oscillates frequently in some stages (e.g., the stage 2 and 3) while that of our method does not oscillate frequently, but the overall tendency is mostly the same,
which derived the 91.8% correctness of our method by allowing the one stage difference. Note that the very high correspondence of the sleep stage is not required in our system because we want to roughly investigate where aged persons have deep or light sleep. From this viewpoint, the 91.8% correctness of our method by allowing the one stage difference is enough for our purpose.

Fig. 4. Sleep stage estimation

**Care plan design agent**

Our previous research (Takadama 2012) explores the appropriate care plan for each aged person to derive a deep sleep. For this purpose, we develop the novel data mining method to extract essential daily activities (e.g., meal and rehabilitation) that contribute to deriving a deep/light sleep of aged persons. Note that the daily activities that derive a light sleep are also important to be specified because the possibility of having a deep sleep increases by removing the activities that derive a light sleep. To investigate the effectiveness of our method, we conducted the human subject experiments including the 82 aged diabetes person, 89 aged dementia and emotional illness person, and 107 aged healthy person.

Fig. 5 indicates some of the extracted knowledge for a deep and light sleep. This figure shows that this aged person has a good (deep) sleep when taking a bath or none of rehabilitation exercise and bath, while the same person has a bad (light) sleep when doing rehabilitation exercise without taking a bath. To understand this relationship, we interviewed the person and find that she always takes care of her body clean and she is willing to take a bath especially when doing rehabilitation exercise. From this interview, she can keep her body clean when taking a bath or not doing rehabilitation exercise, which promotes her to have a comfortable sleep. In contrast, she cannot keep her body clean when doing rehabilitation exercise, which promotes her to have an uncomfortable sleep.

Next, we compare the sleep in the current care plan which is conducted in the care house with that in the proposed care plan which includes the daily activities that derive a deep sleep and excludes the daily activities that derive a light sleep found by our data mining method. Fig. 6 shows the depthness of the sleep, where the vertical and horizontal axes indicate the ratio of the sleep stages 3 & 4 and care plans, respectively. Note that the ratio of the sleep stages 3 & 4 increases in the case of a deep sleep while the ratio decreases in the case a light sleep. In this figure, the red and blue bars indicate the current and proposed care plans, respectively. In detail, the two bars from the left side indicate the results of the healthy aged persons (i.e. non-dementia aged person), while the two bars from the right side indicate the results of the dementia persons who are hard to have a deep sleep in comparison with non-dementia persons.

This figure shows that the ratio of the sleep stages 3 & 4 in the proposed care plan is higher than that in the current plan in both healthy (non-dementia) and dementia aged persons, which means that the proposed care plan can provide a deep sleep in comparison with the current care plan. This is very important in care houses because such a deep sleep contributes to decreasing a frequency of wandering in midnight. From the viewpoint of the sleep age estimated from the ratio of sleep stages 3 & 4 averaged...
from a lot of aged persons (The Japanese Society of Sleep Research, 2010), the proposed care plans can provide nine years younger sleep in the healthy aged persons and seven years younger sleep in dementia persons in this experiment. What should be noted here is that the proposed care plans have a great potential of providing younger sleep even in dementia persons, although they are generally difficult to have a deep sleep.

● Care worker support agent

Our previous experiments (Takadama 2013) focused on the care plan of 82 aged diabetes person, and analyzed the daily activities that contribute to deriving a deep sleep by comparing her sleep before and after the great east Japan earthquake occurred on 11th March 2011, which killed many people by Tsunami. To guess the way aged person feel, we proposed the score of the daily activities that indicates the desire of these activities. For example, the score of a proper amount of breakfast is higher than others when the aged person wants to eat a proper amount of breakfast, while the score of rehabilitation exercise in A.M. is higher than others when s/he wants to do rehabilitation exercise in A.M. (50) is higher than others). She sleep well when she ate full-breakfast without rehabilitation exercise. This is true before the earthquake, but not after the earthquake. When focusing on the score of our system, on the other hand, our system estimates that she want to have a small appettite for a breakfast or do rehabilitation exercise in A.M. because of her small appetitite (the score of less than middle amount of breakfast (99.000000) is highest) and her willing rehabilitation exercise (the score of rehabilitation in A.M. (50) is highest than others).

To summarize the above state, she slept well when she had a small appetitite for a breakfast or did rehabilitation exercise in A.M. after the earthquake, even though she had a big appetitite (and never left anything) and disliked rehabilitation exercise before the earthquake. This indicates that she changed her feeling to have a small appetitite from a big one and to do exercise from no exercise. To validate such a change of her feeling, this study interviewed her and understood that she became (1) not to be willing to eat a big appetitite due to grieve for the death of many people by the earthquake and (2) to be willing to do rehabilitation exercise for struggling with her diabetes in order not to die like the killed people by the earthquake. From this interview, our proposed system has a great potential of guessing the change of the way an aged person feels.

5. Conclusion

This paper focused on the care support of aged persons in a super aging society and proposed the concierge-based care support system that designs the appropriate lifestyle of each aged person for a comfortable and healthy life. For this purpose, this paper proposed the three types of agents, i.e., the sleep monitoring agent, the care plan design agent, and the care worker support agent. To provide the comfortable and healthy life for aged persons, the proposed system estimates the sleep stage of aged persons to evaluate it from the viewpoint of the deep and stable sleep. Such a daily evaluation can be done by storing dairy personal data as a big data and by converting them into meaningful knowledge. The human subject experiments of our system set up in the care house have revealed the following implications: (1) the sleep monitoring agent succeeds to estimate the sleep stage without connecting any devices to human’s body and its estimation accuracy is higher than 90% by allowing one stage difference; (2) the care plan design agent can design the care plans that provide nine years younger sleep in the healthy aged persons and seven years younger sleep in dementia persons; and (3) the care worker support agent has a great potential of guessing the way aged persons feel, i.e., it can guess that one of aged persons became to lose much of her appetitite due to grieve for the death of many people by the
earthquake but became to do as much rehabilitation exercise for struggling with her diabetes in order not to die like the killed people by the earthquake.

What should be noted here is that the above implications have only been obtained from data of small number of aged persons in the care house. This suggests that further careful qualifications and justifications by increasing the number of aged persons are needed to generalize our results. Such important directions must be pursued in the near future in addition to the following future research: (1) extending our care support system to home care support, which supports aged persons who live in their house by caring them through a cooperation among the hospital, care house, and care house via a concierge service network; (2) establishing the standardization and de facto standard of the care support system because most of the system in care house does not come into wide use due to the experience-based system by the care staffs; and (3) exploring the life style improvement technology, which is difficult in comparison with the medical treatment (e.g., metabolic syndrome is not self-awakened).

References


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