Towards a Care Support System that Can Guess the Way Aged Persons Feel

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Abstract
This paper explores a care support system that can guess the way aged persons feel and evaluates it from the viewpoint of sleep in care houses. For this purpose, this paper focuses on the daily activities (e.g., meal and rehabilitation) of the care plan (i.e., rough schedules in a day) for an aged person, and analyzes some activities which derive a deep and stable sleep before the great east Japan earthquake on 11th March 2011 and derive a light and unstable sleep after the earthquake. The human subject experiments in the actual care house have revealed that our proposed system has a great potential of guessing the change of the way the aged woman feels, i.e., it could guess that she became to lose much of her appetite but became to do as much rehabilitation exercise as she can for struggling with her diabetes. To investigate the reason of such a change of the way the aged woman feels, this study interviewed her and confirmed that she became to change the way she feels by hearing the news of the death of many people by the earthquake.

1. Introduction
The great east Japan earthquake occurred on 11th March 2011 killed many people by Tsunami, and damaged a mind of all Japanese people. Such disastrous news also affected the aged persons who live in care houses. For example, some persons became to lose much of their appetites or other persons became to wake up at the midnight due to a light and unstable sleep. Even if such a situation occurs, the care plans (i.e., rough schedules in a day) in care houses does not change, which prevents from a comfortable and healthy life for aged persons. This is because it is difficult for care workers to precisely know the change of the way aged persons feel by the earthquake. In particular, it hardly guesses the feeling of dementia persons or aged men who did not often communicate with other persons.

From this fact, this paper explores a care support system that can guess the way aged person feel and aims at investigating its effectiveness through the human subject experiments in the actual care house. For this purpose, this paper focuses on the daily activities (e.g., meal and rehabilitation) of the care plan for an aged person, and analyzes some activities which derive a deep and stable sleep before the great east Japan earthquake on 11th March 2011 and derive a light and unstable sleep after the earthquake.

This paper is organized as follows. The next section explains the sleep stage estimation and its system, and Section 3 describes the relationship between the care plan and sleep. Section 4 proposes the care support system that can guess the way aged persons feel. The experimental results are analyzed in Section 5 and the proposed system is discussed from the viewpoint of data driven wellness in Section 6. Finally, the conclusion is given in Section 7.

2. Sleep stage estimation and its system

Sleep stage
To evaluate care plans in the actual care house, our previous research (Takadama 2012) investigated the sleep of aged persons from the viewpoint of the sleep stage 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, 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 deep and 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 light and 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 such differences, the care plans are evaluated from the following criteria, which indicate that aged
persons 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.

Fig 1. Sleep stage

- **Deep & stable sleep**: Total time of the sleep stages 3 and 4
- **Light & unstable 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 the care house 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 et al. 2004) succeeded to estimate the sleep stage from the heartbeat data measured by the pneumatic approach using the air mattress in a bed, 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 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 young human subjects, which may not be effective in 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 by adapting 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 measured by the pneumatic approach as the same as Watanabe’s method, this study employs 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 Emfit sensor and the Ethernet cable for transmitting the heartbeat data to the server PC as shown in Fig 2 (c).

Fig 2. Emfit sensor under the bed in care house

3. Care plan and sleep

Tradeoff between desires of care workers and aged persons

Our previous research (Takadama 2012) succeeded to illustration of a tradeoff relationship between care worker and aged persons as shown in Fig. 3 (a), where the vertical and horizontal axes respectively indicate a request degree of care workers (f1) and aged persons (f2). Concretely, the care plans that care workers desire (i.e., the same and fixed schedule plan) are not comfortable and not happy for aged persons (which area is shown in the left-up blue oval). For example, the aged persons should go to bed and wake up at the pre-determined time, which is the same in all aged persons. On the other hand, the care plans that aged persons desire (i.e., the individual and flexible schedule plan) are hard for care workers to execute (which area is shown in the right-down blue oval). For example, care workers limit
to care aged persons if aged persons want to eat their meals in their desire time (i.e., the different time).

To tackle the tradeoff relationship between desires of care workers and aged person, our previous research explored the care plans shown in the light purple area in Fig. 3 (a), which are basically based on the current care plans (i.e., the same and fixed schedule plan) but change a small part of a schedule as an aged persons desires (which area is shown in the right-side of the current care plans). Note that such care plans are the mostly same as the current care plans, which can be executed as usual, but they include a part of requests of aged persons, which can contribute to providing a good sleep of aged persons. Towards such potential care plans shown in the light purple area, our previous research explored them and found that the care plans in the blue area derive a light and unstable sleep while those in the light purple area derive a deep and stable sleep. Fig. 3(b) shows the enlarged drawing of Fig. 3(a), where the red dots indicate the lower 10 care plans that derive a light and unstable sleep while the blue ones indicate the upper 10 care plans that derive a deep and stable sleep.

Fig 3. Tradeoff between care worker and aged persons

Scoring activities in care plans

In order to plot the several care plans in the 2D map shown in Fig 3, our previous research (Takadama 2012) proposed the score of the activities in care plans. Such activities are composed of the followings events:

1. meal (breakfast, lunch, and dinner) including liquid
2. snack (between breakfast and lunch, between lunch and dinner) including liquid
3. wake up time and bedtime
4. exercise or rehabilitation
5. bath
6. gardening
7. reading newspapers
8. others

The vertical and horizontal value of care plans in the 2D map is determined as follows, where \( n \) indicates the total number of activities and \( activity(i) \) indicates the \( i \)-th activity shown in above.

\[
y = \sum_{i=1}^{n} \text{score of activity (i) of care worker} \\
x = \sum_{i=1}^{n} \text{score of activity (i) of aged person}
\]

The score of activity of care worker and aged person is determined as follows. When focusing on dinner, for example, the care workers want to have aged persons eat all dinner. From this request, the score (ranged from 0 to 100) of the care workers is set to 0 score when the aged person eat nothing, a little amount of a meal, or less than a middle amount of a meal, 20 score when eating a middle amount of a meal, 50 score when eating less than a proper amount of a meal, 100 score when eating a proper amount of a meal, and 0 score when eating more than a proper amount of a meal as shown in Fig 4 (a). The score (ranged from 0 to 100) of the aged person, on the other hand, is set to 100 score when eating more than a proper amount of a meal and is set to less values when eating less than a proper amount of a meal if the aged person wants to eat to more than a proper amount of a meal.

When focusing on water as the another example as shown in Fig 4 (b), the care workers does not want to allow aged persons to drink more than 1000cc because the aged person is limited to drink due to a diabetes, which sets 100 score of care workers when the age person drink around 1000cc (i.e., a proper amount of water), 50 score when drinking around 750cc or 1250cc, and 0 score when drinking less than 500cc or more than 1500cc. The score of the aged person who wants to drink more than a proper amount of water, on the other hand, is set to 100 score when drinking around 1500cc (which is quite larger than a proper

Fig 4. Score of activities in care plans
amount of water), 50 score when drinking around 1250cc or 1750cc, and 20 score when drinking around 1000cc, and 0 score when drinking less than 750cc.

These scores are determined via an interview with care workers in care house. Note that the scores of the care works can be easily determined by talking with them, while those of the aged persons is hardly to be determined because some persons do not want tell their preference or dementia patients are difficult to properly answer the questions on their preference. From such a difficulty, the scores of aged persons are determined by care workers who care them (i.e., the score of an aged person A is determined by a care worker who cares an aged person A).

4. Guessing the way aged persons feel

The human subject experiments in the actual care house found that the area of a deep and stable sleep (i.e., blue dots) of an aged woman and that of a light and unstable sleep (i.e., red dots) are mostly separated before the earthquake as shown in Fig. 5 (a) but they are mixed after the earthquake as shown in Fig. 5 (b). Such a change occurred because the way she feels changed (i.e., the $f_1$ values changed). Since the blue and red dots are plotted by the requests of aged persons (and care worker), a change of the way she feels may be understood by changing the $f_1$ values to divide these dots clearly as shown in Fig. 5 (c). In other words, there is a possibility of understanding how the way she feels change by investigating how such $f_1$ values change. Recalling Fig.3 (a) that roughly suggests that aged persons tend to have a deep and stable sleep when their requests are satisfied as much as possible, the area of a deep and stable sleep is plotted in the right-side as show in Fig. 5(c) in high possibility.

To investigate how the $f_1$ values change, this paper proposes the care support system that guesses the way aged persons feel. This system is based on evolutionary algorithm (EA) using the support vector machine (SVM) technique (Vapnik 1998) (Cristianini 2000). As shown in Fig. 6, the algorithm of the proposed system is summarized as follows.

1. Creating the $N$ numbers of individuals at random, each of which is represented by a sequence of the score of the activities in care plans as described in Section 3.
2. After plotting the blue dots represent a deep and stable sleep and the red dots that represent a light and unstable sleep, SVM classifies these two types of dots and calculates the percentage of the correctly classified dots as a fitness value, e.g., 80 means that 80% of dots are correctly classified.
3. After selecting two parents by the tournament selection according to the fitness value, two children are created from the parents by the crossover and mutation operations. In Fig. 6, the individuals which have 70% or 80% fitness value are selected as the parents and two children (child1 and child2) are created from the parents.
4. Adding the two created children by deleting two individuals which have the lowest and second lowest fitness value. Return to 2 until the solutions converge.

5. Experimental result and its validation

Our experiments focused on the care plan of three aged persons (i.e., 82 aged diabetes person, 89 aged dementia and emotional illness person, and 107 aged healthy person), and analyzed the score of the daily activities (e.g., meal and rehabilitation) of the care plan from the viewpoint of a sleep. Fig. 7 shows the result of 82 aged diabetes person
among three persons as the representative result. In detail, Fig. 7 (a) shows the scores of breakfast, i.e., the request for breakfast of the care worker \( (f_2 \text{ values}) \), aged person \( (f_1 \text{ values}) \), and our system \( (f_1 \text{ values}) \) that estimates the request of the aged person, while Fig. 7 (b) shows their scores of rehabilitation, i.e., the request for rehabilitation. Note that the scores of the care worker and aged person are determined before the earthquake while the scores of our system are calculated after the earthquake.

![Fig 7. Score of breakfast and rehabilitation](image)

When focusing on the score of aged person, Fig. 7 suggests that she sleeps well when she eats mostly full-breakfast and does not rehabilitation exercise because her big appetite (the score of less than proper or a proper amount of breakfast \( 95.08146 \text{ or } 84.03362 \)) is higher than others) and her avoiding rehabilitation exercise (the score of none of rehabilitation \( 50 \)) is higher than others) are satisfied. 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 sleeps well when she has a small appetite for a breakfast or did rehabilitation exercise in A.M. because her small appetite (the score of less than middle amount of breakfast \( 99.00000 \)) is highest) and her willing rehabilitation exercise (the score of rehabilitation in A.M. \( 50 \)) is higher than others) are satisfied.

To summarize the above state, she slept well when she had a small appetite for a breakfast or did rehabilitation exercise in A.M. after the earthquake, even though she had a big appetite (and never left anything) and disliked rehabilitation exercise before the earthquake. This indicates that she changed her feeling to have a small appetite 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 appetite 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.

6. Discussion

Finally, this section discusses our approach from the viewpoint of the data driven wellness which aims at understanding, keeping, and improving own health according to the data collected by self-tracking technologies. One of typical examples of the data driven wellness is the health control by walking with a pedometer.

A new type of self-tracking technology as a breakthrough of data driven wellness

Our approach that can guess of the way a person feels can be considered as a new type of the self-tracking technology. This can be easy understood by comparing the conventional self-tracking technology (such as a pedometer or a calories calculation by a smart phone) with our approach, i.e., the former one mainly focuses on the data of a physical aspect (e.g., heartbeat) while the latter one focuses on the data of a mental aspect (e.g., the way a person feels). Since such a difference is a significant to understand our health, our approach has a potential of a breaking through of the data driven wellness by providing the mental aspect information in addition to the physical aspect information. From the sleep viewpoint, for example, the current self-tracking technology can provide an information on whether a person has a deep sleep or not but cannot tell us the way a person feels, and thus an integration with our approach enables us to understand our health from the viewpoint of not only physical aspects but also mental aspects.

Towards social activities on health improvement

Social activities on health improvement can be created by utilizing the data collected by the self-tracking technologies. One of good examples includes 23andME. The users of 23andME start to send their saliva samples, and then know their genetic data of over 100 traits and diseases as well as DNA ancestry by the self-tracking technologies of 23andME. Interestingly, after knowing their genetic data, some of them develop a community as social activities to discuss the same diseases (such as diabetes) for their good health. In contrast, our approach can promote not only care workers but also families of aged persons to develop a community for sharing the information on how to derive a good sleep for aged persons. Such a collective knowledge shared in a community contributes to improving a health of aged persons.
7. Conclusion
This paper explored a care support system that can guess the way aged persons feel and evaluates it from the viewpoint of sleep in care houses. For this purpose, this paper focused on the daily activities of the care plan (i.e., rough schedules in a day) for an aged person, and analyzes some activities (e.g., meal and rehabilitation) which derive a deep and stable sleep before the earthquake and derive a light and unstable sleep after the earthquake. The human subject experiments in the actual care house have revealed that our proposed system has a great potential of guessing the change of the way the aged woman feels, i.e., it could guess that she became to lose much of her appetite but became to do as much rehabilitation exercise as she can for struggling with her diabetes. To investigate the reason of such a change of the way the aged woman feels, this study interviewed her and confirmed that she became to change the way she feels by hearing the news of the death of many people by the earthquake.

Since this project is ongoing, a lot of issues including further careful qualifications and justifications, such as human subject experiments with other 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) an validation of the score of both the aged person and care workers; and (2) an extraction of the activities of deriving a deep and stable sleep which is scheduled in the care plan.

References