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睡眠と食事のログデータに基づく生活リズムの定量的評価手法の検討

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A Preliminary Study for Quantitative Assessment of Life Rhythm Based on Sleeping and Dining Log Data

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Abstract　According to numerous researches, life rhythms disturbance leads to some chronic disease. Hence, maintaining a healthy life rhythm is very important for everyone. Recently, although popular of smartphone and IoT devices make recording various life log easy, there are rare works provide service to assess resident's life rhythms. To resolve the problem, we provide a framework, quantitative assessment of life rhythm by analyzing user's daily activity log and self-assessment of QOL(Quality of Life) log. In the framework, we provide a method of measuring the resident's life rhythm by statistic analyzing sleep and dining log data and quantitative assessment models of life rhythm by using regression analysis and normal distribution analysis.

Key words　Life Rhythm, Activities of Daily Living, Data Mining, Assessment of Life Rhythm, One Person Households

1. Introduction

In the world, more and more people are living in OPHs. As global averages and late marriage, considerable variation exists in the incidence of OPHs across countries. Among European countries OPHs of 40% or more are reported in Denmark, Finland, Germany and Norway, in 2015. In Japan, 37.4% of all households will become OPHs in 2030 [1]. However according to [2] [3], people in OPHs easy lose control of life rhythm, and chaos of life rhythm often leads to health deterioration. To support people maintain life rhythm, there are a lot of related works [4] [5] [6]. Most of the works can detect resident's activities log (e.g., sleep, sport, transfer), or recognize the pattern of day (e.g., work day, hospital visit day), but there are rare of works provide a service assess resident's life rhythms. Since assessment of life rhythm is essential to measure appropriateness of life rhythm for people, assessment of life rhythm is promising for people of OPHs. Therefore, we proposed a framework to assess life rhythm. In this paper, we will show some research result of our preliminary study.

In order to build a the framework for assessment of life rhythm, we considered 3 technology problems need to be solved. First one is measuring life rhythm. As life rhythm have huge numbers of features, we cannot get a comprehensive information about it. Therefore, it is challenge to choose features and define a method to represent life rhythm. Second problem is defining scales of assessment for life rhythm. As we all know, the period of cycle of life activities is daily. However, in the biology field, most of assessment of QOL based on week, month or year. It hardly find an assessment scale based on daily. The last one is establishing assessment satisfied with diversity of individual's life rhythm. For life rhythm is diversity, so assessment of life rhythm is also diversity. An appropriate life rhythm of one is hardly appropriate for others. So we cannot defined a common assessment function.

To resolve the 3 problems, we proposed a framework for assessment of life rhythm. About approaches for the problems we will explain it at Section 3. Our research is development work of our previous work [7]. By using statistic tools and correlation analysis, we extract effective features of life rhythm for assessment. And we established 2 assessment mode of life rhythm by using regression analysis and normal

distribution analysis. In Section 4. we will illustrate structure of framework and data process for extracting features of life rhythm and establish assessment model in detailed.

Moreover, some results of the preliminary study will be shown in Section 4. About experiments, the activity log data is obtained from one's 224 daily life and 32 weeks self-assessment of QOL.

2. Preliminary

2.1 Significance of Life Rhythm Assessment

Life Rhythm is a cycle of life activities and biological function, and period of the cycle is almost 1 day [8]. Most of our biological functions (e.g., sleep, awake, hormone) are frequently variation daily. We can feel that our activities are controlled by a clock inside of our body. In field of biological, the phenomenon be called as circadian rhythm (*dian* means day). From the research of Nobel Prize physiology and medicine in 2017, it proved that molecular mechanisms controlling the circadian rhythm. And a chaos of life rhythm often leads to health deterioration. For instance, people circadian rhythm disturbance have a higher risk of cardiovascular disease [9], sleep disturbance to increase the risk of suffering from neutral fat [10]. Hence, maintaining a good life rhythm is very important for people's health and QOL.

However, people of OPHs easily fail to manage life rhythm, since no one else can take care of their living. For example, students living with families were earlier than students living alone in bedding and waking [2]. With total meals and breakfast skipping, the loneliness group have significantly higher rate [10]. Moreover, since life rhythm is a long-term variation and includes too many features, it is very difficult to find optimal life rhythm for a resident without using analysis tools.

Therefore, a framework that minings life rhythms and assesses life rhythm is promising for people of OPHs. The framework are requested two functions, grasp features of life rhythm by analyzing resident's past life rhythm and evaluate quality of life rhythm. Base on the result of assessed life rhythm until now, people can find the most suitable life rhythms for themselves to achieve high QOL.

表 1 Daily Activities Log Data

username	date	startTime	endTime	ADL
niulong	2018/6/1	0:00:00	0:08:59	Others
niulong	2018/6/1	0:08:59	0:19:10	Bath
niulong	2018/6/1	0:19:10	0:33:52	Others
niulong	2018/6/1	0:33:52	8:05:34	Sleep
niulong	2018/6/1	8:05:34	8:12:18	Rise
niulong	2018/6/1	8:12:18	8:26:17	Others
niulong	2018/6/1	8:26:17	8:50:09	Eat
niulong	2018/6/1	8:50:09	9:41:00	Others
niulong	2018/6/1	9:41:00	23:59:59	GoOut
niulong	2018/6/2	0:00:00	18:09:16	GoOut
niulong	2018/6/2	18:09:16	18:52:15	Return

2.2 Research Goal and Technology Problems

In this paper, our research goal is providing an assessment of life rhythm framework, which can provide a quantitative assessment service for user's life rhythm and generate an optimal life rhythm for achieving highest QOL of testee.

To achieve the research goal, there are 3 technology problems need to be solved.

- **P1:** how to detect resident's life rhythm. According to Section 2.1 life rhythm is a cycle time structure based on activity and rest, and it is individual one by one. Nevertheless life rhythm consists of a huge number of features, so we cannot get a comprehensive information of it. Therefore, it is a challenge to choose features (e.g., start time of sleep, period of sleep) and define method of representing life rhythm based on the features.
- **P2:** how to establish assessment model for resident's life rhythm. As mentioned in Section 2.1, the basic repeat period of life rhythm is daily. However, for most resident, since their life rhythm or lifestyle is clearly different between

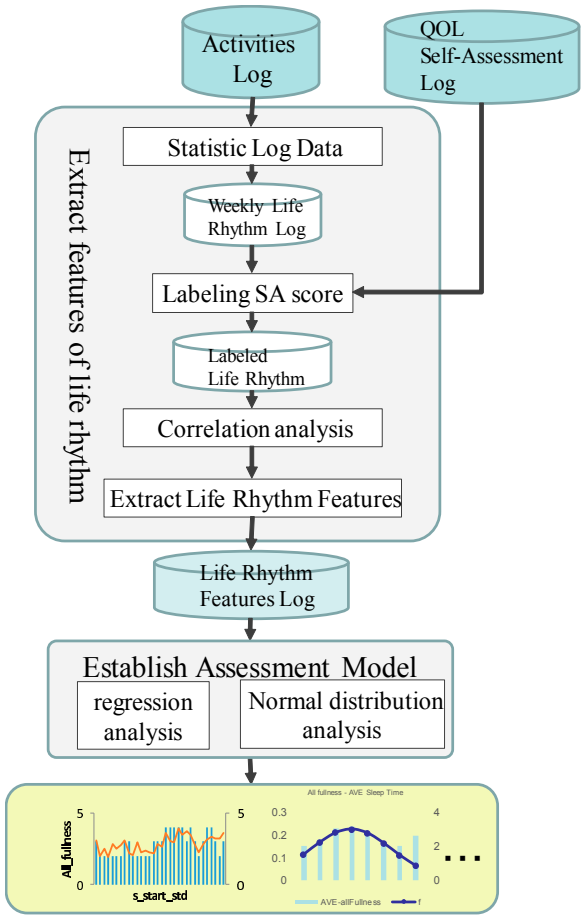

図 1 Architecture of Framework

表 2 Self Assessment Scales for QOL

date	achie	All_full	Res_full	PJob_full	Priv_full
2018/04/23	2	3	2	4	4
2018/05/08	3	2	2	4	4
2018/05/17	2	3	2	4	4
2018/05/28	9	4	4	3	3
2018/06/05	8	4	5	2	5
2018/06/19	7	3	3	2	3

表 3 Evaluation Scales of Fullness

Value	Means
1	inanity
2	little inanity
3	normal
4	little fulfilled
5	very fulfilled

workday and holiday, assessment scales of life rhythm for weekday is not suitable to weekend. Hence, we should defined an appropriate period of time to assess life rhythm during the period.

- **P3:** how to establish assessment models which are satisfied with individual life rhythm for a user. Since life rhythm is diversity and the assessment scale for QOL of each user is also diversity, an adaptable life rhythm for one user is hardly adapt to others. Therefore, we cannot defined a common assessment model for all users' life rhythm.

3. Approach

For the **P1**, there are many related works. In field of biological, many research measure patient's life rhythms by a manual survey. And some approaches detected life rhythm by sensing the biology's features, such as body temperature, the power of gripping. In computer science field, [11] detect resident's daily life pattern by analysis of pyroelectric sensor data. However, those works have some limitations such as, intrusive resident's body, not suit for providing optimal life rhythm (Cause sensing data cannot represent detail information of activities). To minimize those limitations, in our previous work, we proposed an ADL recognition system based on No-intrusive environment sensing devices and beacon technology in our previous work [7]. The system is able to recognize 7 ADLs. Table 1 shows recorded activity log data. As a development research of the previous work, we analysis and assessment of life rhythms based on the ADLs log data. Moreover, according to [9], there are 3 basic factors for life rhythm: sleep, breakfast, and hormone. By adjusting rhythm of the 3 factors, people can effectively adjust his life rhythm. As it is not possible that directly measure hormone rhythm of a resident by using a sensor or wireless sensing technology currently. Hence, we proposed a method that measuring life rhythm based on sleep and eat log data.

For the **P2**, since resident's life rhythm always significantly changes along with the daily schedule. Most of residents' life rhythm can be classified into 2 basic patterns: work day and holiday. Since QOL of the 2 life patterns are always different, we need to define a suitable long cycle for period assess life rhythm includes the 2 life styles. Considering week is the shortest unit of time circle which include work day and holiday, we defined long of period assess life rhythm as week.

For the **P3**, for everyone's scale of evaluate for QOL is diversity, assessment model should assess user's life rhythm based on user's individual scale for assessment of QOL. For instance, for a patient, the evaluate scale of QOL is health status, but a researcher's evaluate scale of QOL is quantity or quality of works have been completed in last week. Therefore, it is clear to know that we can not defined a common scale for assessment of everyone's life rhythm.

In this preliminary study, we proposed some evaluate scales for a resident, who is a graduate student. Table 2 shows the subject's individual scale for assessment of QOL. About meaning information of the table data, column *data* is the first day of week. Column *achievement* means how many percents of tasks or work planed in last be completed in this week. In the scale, value of achievement is defined as an integer, for instance, the value *3* mean 30% of tasks are completed. Column *All Fullness* means level of fullness about all of aspects of life in last week. Column *Research Fullness* means level of fullness about research work in last week. On the analogy of this, *job fullness* is about part-time job, and *private fullness* is about private activity. The assessment scale defined 5 level of fullness for the 4 aspects of life and value of the score is integer in {0, 1, 2, 3, 4, 5}.

4. Proposed Framework for Assessment of Life Rhythms

In this section, We will give a detailed instruction of data process of analysis and illustrate how to assessment of life rhythm by some examples. Figure 1 shows the architecture of the framework.

4. 1 Data Collection

As mentioned at Section 3. we collection of activities log and QOL self-assessment log at first step. For the 2 class of log data, we have detailed explained the data structure and the defined of each evaluate scales for QOL, in Section 3. About data collection, activities log is obtained from recognition ADL system and self-assessment of QOL log is manual recorded by resident in every week.

4. 2 Extract Features of Life Rhythm

As approach for problem *P1*, we should statistic analysis user's weekly life rhythm from the daily activities log

	Achievement	All_fullness	Research_fullness	partJob_fullness	private_fullness
s_end_mean	0.081503545	-0.256741794	0.160209484	-0.270695775	-0.041061413
s_end_std	-0.110343622	-0.046970989	-0.107007606	0.032590173	-0.033097385
s_start_mean	-0.242144352	-0.102617434	-0.255107666	-0.014314429	-0.126324597
s_start_std	-0.263568085	-0.40827074	-0.28103621	0.143160929	-0.220093272
AVE-sleep.period	0.01459312	-0.311529873	0.089419633	-0.28006759	-0.187254745
STD-sleep.period	-0.10966723	-0.083191003	-0.058528694	-0.253880433	-0.062953223
e_end_mean	-0.144438427	-0.422832323	-0.237803351	-0.420376469	-0.488726311
e_end_std	-0.011650558	-0.038780787	-0.015032395	-0.190315633	-0.175506563
e_start_mean	-0.153723952	-0.410194664	-0.242140335	-0.438639084	-0.460622496
e_start_std	-0.0780759	-0.024196275	-0.06495214	-0.214491294	-0.147718547
skipEatCounts	-0.229588216	0.088386956	-0.173127965	-0.121837521	0.105884029

図 2　Correlation coefficient of All Features

data and extracts individual feature of life rhythm that is effectively affect user's QOL, to prepare establish assessment model for life rhythm. For those parts work in the framework, we named as *extract features of life rhythm*, which conducts 4 main data operation.

- Statistic daily activity log data

As approach 2, we need to convert daily activity log into weekly life rhythm log. In this operation, system integrate daily activity log by using some statistic calculate, such as average of wake up time, standard deviation of period time of sleep in each week.

- Labeling weekly life rhythm

According to approach 3, in order to assessment life rhythm based on resident's individual evaluate scales, we labeled life rhythm log with score of self-assessment for QOL in each week.

- Correlation analysis

In this operation, correlation analyzing of labeled log data, calculates *correlation coefficient* of each features of life rhythm with each scales of evaluate for QOL. Correlation coefficient is a measure of the linear correlation between life rhythm features: X and QOL evaluate scales: Y. The formula for is is :

$$\rho(X,Y) = \frac{E[(X - E[X])(Y - E[Y])]}{(E[(X - E[X])^2]E[(Y - E[Y])^2])^{1/2}} \qquad (1)$$

E is the expectation.

Figure 2 shows result of correlation analysis for all features of life rhythm data and all scale of assessment for QOL. From the result, we can see correlation coefficient of **All_fullness** (Fullness of all things) with **s_start_std** (standard deviation of sleep time), **e_end_mean** (average of ending breakfast time) and **e_start_mean** (average of beginning breakfast time) are little less then -4.0, which means that they have somewhat correlated with each other. As the same way, we can also find research fullness have a little week correlated with average sleep time and standard deviation of sleep time.

Moreover, we also need correlation analysis among features of life rhythm, to avoid using some features have high correlation coefficient with each other. For instance, from the table we can find the start time of breakfast and end time of breakfast is similar correlated with all self-assessment scales of QOL, in fact that correlation coefficient of the 2 features is 0.983.

- Extract life rhythm features This step is the final operation of prepare work for establish assessment model. Based on the result of correlation analysis, we extract effective features of life rhythm which has a relatively stronger correlated with special self-assessment scale of QOL.

Similar with the scales of assessment for QOL measure quality from different aspects, assessment of life rhythm is also based on different aspect. For instance, if we establish an assessment model for life rhythm based on fullness in all aspects (All_fullness), then we will extract features that have relatively stronger correlated with All_fullness: *s_start_std*, *AVE.-sleep.period* and *e_end_mean*.

表 4　Regression Statistic

Multiple R	0.676199
R Square	0.457245
Adjusted R Square	0.399093
Standard Error	0.626037
Observation	32

4. 3　Establish Assessment of Life Rhythms Model

In this step, we establish assessment of life rhythms model that quantity assessment of life rhythm. The model can be describe as a function:

$$Y = f(X_1, X_2, ..., X_n) \qquad (2)$$

- Y: quantity assessment of QOL
- X_i: a feature of life rhythm

In this paper, we challenged 2 approaches to establish assessment model, regression analysis and normal distribution

表 5　Detail Result of Regression Analysis

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	6.383265769	0.825160027	7.735791317	1.99359E-08	4.693002078	8.07352946	4.6930020	8.0735294
s_start_std	-0.334647885	0.094947532	-3.524555908	0.001478857	-0.529139087	-0.140156682	-0.5291391	-0.1401567
AVE-sleep.period	-8.1073E-05	2.61944E-05	-3.095051724	0.004434314	-0.00013473	-2.74162E-05	-0.000135	-2.74162E-05
e_end_mean	-0.062287619	0.032537923	-1.914308373	0.065851045	-0.128938533	0.004363295	-0.1289385	0.004363

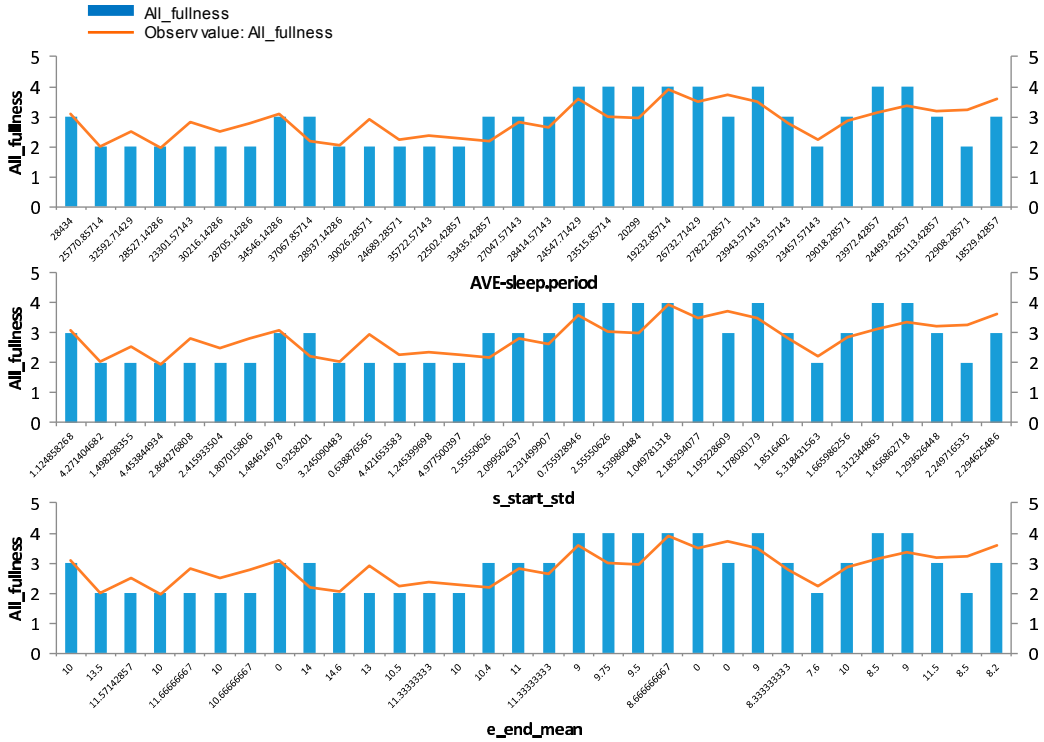

図 3　Observed value Graph

analysis.

4. 3. 1　Regression analysis

In statistical modeling, regression analysis is a set of statistical processes for estimating the relationships among variables. In the section, we will explain the method of building assessment model using regression analysis tools by an instance. Table 4 shown regression statistic of *All_fullness* with *s_start_std, AVE-sleep.period, e_end_mean*. *R Square* is a statistical measure of how close the data are to the fitted regression line. It is also known as the coefficient of determination, or the coefficient of multiple determination for multiple regression. The result of R-Square is about 0.457, which means statistical measure is relatively closer the fitted regression line. And from the analyzed result shown in Table 5, we can establish functions for assessment of life rhythm :

$$Y = a + bX_1 + cX_2 + dX_3 \tag{3}$$

- Y: fullness of all things
- $X1$: standard deviation of sleep time
- $X2$: average of period sleep
- $X3$: average of breakfast end time
- a: 6.3832657 which is coefficient of Intercept
- b: -0.33464785 which is coefficient of s_start_std
- c: -0.000081073 which is coefficient of s_start_std
- d: -0.06228761 which is coefficient of s_start_std

Figure 3 origin color lines shows the observe value of all fullness by each features of life rhythm. We can see it is somewhat close with the actual value.

4. 3. 2　Normal distribution analysis

In probability theory, the normal distribution is a very common continuous probability distribution. Therefore, we challenged to establish assessment model by using normal distribution analysis for life rhythm.

We consider that resident's self_assessment score of QOL in each week is a *Event* (probability theory) and defined a **Probability Space**:

- Sample space **Ω**: all possible scores of QOL
- Events F: evaluated score of all patterns of life rhythm
- Function P: a assignment of probability to *events*

Then, we defined average score of self_assessment of QOL

表 6　Normal distribution analysis

time-zones	AVE-allFullness	f
23.14 - 23.86	2	0.111888496
23.86 - 24.57	2.4	0.164463578
24.57 - 25.29	3	0.206731545
25.29 - 26	3.14	0.222226825
26 - 26.71	2.75	0.204286153
26.71 - 27.43	2	0.160595766
27.43 - 28.14	2	0.107964747
28.14 - 28.86	2.6	0.062070117

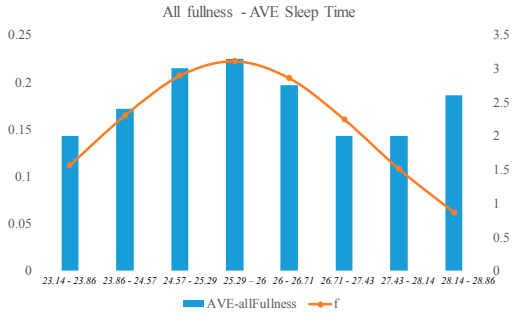

図 4　Assessment Sleep Rhythm by All Fullness Score

for any patterns of life rhythm is random variables x. The *patterns of life rhythm* are dispersed values and are defined based on statistics data of user's life rhythm.

For instance, we defined 8 patterns of life rhythms based on average sleep time in one week. And Table 6 column ťime-zonesśhows the value of 8 patterns life rhythm statistic data. About value of x, if a resident have 3 weeks, during when his average of sleep start time belong *time-zone*, then average of the 3 weeks QOL evaluated score is random variables of event-*[23.14 - 23.86]*.

We supposed the random variables (x) is belong to normal distribution analysis:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \qquad (4)$$

- σ is the mean of x or expectation of the distribution
- μ is the standard deviation of x

By using the function (4), we create Table 6. Column f of Table 6 is *scales of fullness all thing*'s normal distribution based on function (4), when σ is 25.243 and μ is 1.795.

Figure 4 is visual graph for the Table 6. We can see distribution of [fullness all thing]'s scale is somewhat closely approximates normal distribution. From the Figure 4 user can easy find when the average sleep time during 01:13 and 02:00 his all fullness have a high probability high level. However we cannot prove it is normal distribution.

5. Conclusion

In this paper, we proposed an assessment of life rhythm framework by analyzing daily activities log data and self-assessment of QOL. The framework consists of 2 main parts, extract features of life rhythm based on user's sleep and eat log, establish assessment model by using regression analysis and normal distribution analysis, and we also showed the process of establishing 2 assessment models and results of experiment.

As a preliminary study, there are a lot of future works to conduct. We need to do experiments on multi residents and evaluate effectiveness accuracy and other things for the proposed model.

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