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

Long Niu
Kobe University, Rokkodai 1–1, Nada, Kobe, Hyogo, 657–8501 Japan
longniu@ws.cs.kobe-u.ac.jp

Sachio Saiki
Kobe University, Rokkodai 1–1, Nada, Kobe, Hyogo, 657–8501 Japan
sachio@carp.kobe-u.ac.jp

Masahide Nakamura
Kobe University, Rokkodai 1–1, Nada, Kobe, Hyogo, 657–8501 Japan
Riken AIP, Nihon-bashi 1–4–1, Chuo, Tokyo 103–0027 Japan
masa-n@cs.kobe-u.ac.jp

ABSTRACT
It is known that the disturbance of daily life rhythm leads to chronic disease. Hence, it is important for everyone to keep a healthy rhythm. Owing to emerging technologies of smart phones and IoT, many studies and products recognizing personal daily activities exist. However, there is little research to evaluate if the life rhythm, characterized by the daily activities, is good or bad for the person. As a result, it is hard for individuals to understand what to be their own healthy life rhythms, and how to improve the current situation. To cope with the problem, we are developing a system that quantitatively assesses user’s life rhythm based on the daily activity log and the self-assessment of QoL (Quality of Life). In this paper, we present a method of measuring user’s life rhythm by analyzing sleep and eating log data. We then construct a personalized quantitative assessment model of life rhythm using regression analysis. We conduct a preliminary experiment in an actual apartment. Based on the derived model, we find personalized advice on daily activities to maintain healthy life rhythm of the resident.

CCS CONCEPTS
• Computing methodologies → Model development and analysis;
  • Applied computing → Health care information systems;
  • Human-centered computing → HCI theory, concepts and models;

KEYWORDS
Data Mining, Life Rhythms, Assessment Model of Life Rhythm, Daily Activities

1 INTRODUCTION
In the world, more and more people are living in one-person households (OPHs, for short). Due to the global aging and the late/less marriage, the number of OPH grows rapidly 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 [5].

According to health studies [14] [2] [4], people in OPHs have a significantly high risk of suffering cardiovascular disease. The reason is that people in OPHs easily lose control of daily life rhythm, compared with those living with family or others. Moreover, the chaos of life rhythm often leads to the health deterioration [16]. The research of the life rhythm and circadian rhythm (dian means day) show that a key factor for achieving good health-related quality of life (HRQoL) is to maintain a healthy life rhythm.

Recently, due to the spread of smart phones and IoT technologies, there are a lot of studies and applications (e.g., [1] [11] [3]), which aim to support user’s health by recording daily activity log (e.g., sleep, sport, transfer), or recognizing the pattern of a day (e.g., workday, hospital visit day). These are quite promising for health management of people in OPH. However, most of them just provide features of recording and visualizing the activity logs, whereas the interpretation and assessment of the achievement are left to users.

As a result, it is not easy for individuals to understand what the healthy life rhythm should be, and how they improve the current situations.

To cope with the limitation, we are developing a system that quantitatively assesses one’s life rhythm, based on the daily activity logs and the self-assessment of quality of life (QoL). The proposed system tries to find correlations between the activities and user’s QoL, and then establishes a personalized model that explains the QoL by the daily activities. Using the model, the user can easily understand how good (or bad) the current life rhythm is, and how to improve the habits to achieve his/her own healthy life rhythm. We eventually consider to integrate the proposed system with life monitoring system, so that the system automatically intervenes in OPH to encourage the user maintaining healthy life rhythm.

In this paper, we present a preliminary study: proposing a method that derives the personalized assessment model. The method consists of the following three steps:

Step 1: Characterize one’s life rhythm by activities
Step 2: Measure and record user’s QoL
Step 3: Establish an assessment model that maps the life rhythm onto the QoL
To implement the above steps, we need to address the corresponding technology challenges. The first challenge is to collect activity data and to extract appropriate features to represent individual life rhythms. For this, we use the sleep and eating log data collected by a daily activity recognition system, developed in our previous work [8] [9]. From the log data, we calculate some statistical features.

The second challenge is how to measure QoL. By its nature, the scale of QoL varies among individuals, and thus a healthy life rhythm for a person is not necessarily healthy for another person. For example, for a patient, the scale is the health of his body. For a researcher, his scale may be quantity and quality of achievements. For this, we develop a system that asks each user a weekly survey. In the survey, the user evaluates the fulfillment of daily living in last week. The degree of fulfillment is given by a numerical value.

The third challenge is how to derive the model of the personal life rhythms. For this, we extract effective features from the statistics of daily activity logs, and derive a regression model that explains QoL values by the statistics.

We conduct a preliminary experiment in an actual apartment, where activity logs of 224 days, and self-assessment QoL logs of 32 weeks are collected. Based on the experimental results, we interpret the assessment model personalized for the resident, and find appropriate habits for maintaining high QoL.

2 PRELIMINARY

2.1 Life Rhythm

The life rhythm is a cycle of life activities and biological functions, whose period is almost one day [18]. Most of our biological functions (e.g., sleep, awake, hormone) has periodic variations on a daily basis. We can feel that our activities are controlled by a clock inside of our body. In the field of biology, the phenomenon is called circadian rhythm (dian means day). In the research of Nobel Prize physiology and medicine in 2017, it was proven that molecular mechanisms are controlling the circadian rhythm.

According to [10], the life rhythm is characterized by the following three properties:

(1) Two basic states: The period of one day is comprised of activities in daytime and sleep in nighttime.
(2) Daily cycle: The two states are repeated periodically every day.
(3) Diversity: The cycle is different among individuals. It adapts to biology, environment, living society, individuality, and variability.

2.2 Keeping Healthy Life Rhythm in OPH

A chaos of life rhythm often leads to health deterioration. For instance, people with circadian rhythm disturbance have a higher risk of cardiovascular disease [4]. The sleep disturbance increases the risk of suffering from neutral fat [17]. Hence, maintaining one’s good life rhythm is very important for individuals.

However, people living in OPHs easily fail to manage life rhythm, since no one else can take care of the daily living. For example, students living with families get up and go to beds earlier than those living alone [14]. As for the total meals and breakfast skipping, people in OPH have a significantly higher rate [17]. Thus, it is more difficult for OPH to keep healthy life rhythm.

The life rhythm is a long-term variation consisting of many activities. Even manually recording the daily activities every day requires strong motivation. Thus, it is challenging to find an optimal life rhythm for a person without any technology assistance. Hence, providing personalized assessment models of life rhythm is quite promising, since the model can explain how good or bad the current life rhythm is. The user is able to easily find appropriate life rhythm, and to understand how to improve his/her daily habit.

2.3 Related Work

There are many existing studies addressing the issue of healthy life rhythm. Based on the type of approaches, we explain them by the following three categories:

(1) Manual survey: A study in the field of biology measured life rhythms of patients with manual medical survey [6]. They found life rhythm by physiological metrics including body temperature, the power of gripping. However, this approach cannot be applied in general households.

(2) Activity detection: Many technologies are being studied to recognize human daily activities at home. They are expected to be used in real-life and human-centric applications such as elderly care and health care. Some approaches (e.g., [1] [11]) try to directly capture daily living using camera, or microphone. Other approaches use state-change sensors, and/or positioning systems to detect activities (e.g., [7] [12]). However, most of these systems just provide features of recording and visualizing the activities. The interpretation and assessment are left for individual users. Thus, it is not easy for the user to understand which patterns of activities leads to a healthy life rhythm.

(3) Life pattern recognition: Studies in [15] [3] tried to detect resident’s daily life pattern by analyzing data of pyroelectric motion sensors. However, the result cannot show the optimal life rhythm, since the pattern is characterized only by the motions. It cannot contain more detailed but essential information of life rhythm including sleeping and eating.

3 RESEARCH GOAL AND APPROACH

3.1 Scope of This Paper

Our long-term goal is to implement a life rhythm assessment system, which quantitatively evaluates the quality of the life. The system is eventually integrated with an activity recognition system, which automatically recognizes and records user’s daily activities.

In this paper, we focus on the most essential part of the system, considering how to construct the personalized assessment model. To construct the model, we follow the three steps below:

- **Step 1**: Characterize individual life rhythms by activities
- **Step 2**: Measure and record user’s quality of life (QoL)
- **Step 3**: Establish an assessment model that maps the life rhythm onto the QoL.
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## 3.2 Challenges and Approaches

To implement the three steps, there are technology challenges to be addressed. In the following, we explain each challenge and our approach to overcome.

**A1: By what is the life rhythm characterized?**

According to Section 2.1, the life rhythm is a cycle based on activities and sleep, and the cycle varies among individuals. Nevertheless, the life rhythm is constructed by a huge number of factors. Hence, we cannot reach the universal definition. It is thus challenging how to represent the life rhythm by what features. Promising features include the time to go to bed, the period (duration) of sleep, and the time of meal. It is also challenging how to collect such data of daily activities.

For this challenge, we use a daily activity recognition system [8], previously developed in our laboratory. Exploiting environment sensing IoT (called SensorBox [13]) and indoor positioning beacons, the system is able to recognize seven kinds of daily activities (cook, eat, clean, bath, sleep, go out, return). Table 1 shows log data of daily activities recorded in an actual apartment.

We make full use of this log data to represent one’s life rhythm. According to [4], there are three relevant factors for the life rhythm: sleep, breakfast, and hormone. Managing these three factors, everyone can effectively adjust his/her life rhythm. By the current technology, however, it is impossible to measure the hormone of a resident. Hence, we decide to use the log data related to sleep and eating. To represent the life rhythm, we aggregate the log data in a certain period of days, and obtain relevant statistics. The statistics include the average time of rising for a week, the number of days with breakfast skipping. In the proposed method, we call these statistics *features of life rhythm*.

**A2: By what is the life rhythm assessed?**

The quality of the life rhythm should be justified by the quality of life (QoL) of the user. However, the sense of value for QoL varies among individuals. Therefore, we consider that the assessment model should be built based on the user’s subjective scale of QoL. To collect the subjective scales, the proposed method requires each user to conduct a self-assessment of QoL and record it.

**A3: How is the assessment model established?**

The life rhythm varies among individuals, and the assessment scale of QoL is also different from one user to another. Therefore, it is unrealistic to define a common assessment model that fits all users. Therefore, our idea is to build a personalized model that can explain the personal value of QoL from the personal features of life rhythm. To build the personalized model, we first apply correlation analysis to identify strong features correlated to the QoL. Then, using the strong features, we conduct regression analysis to derive equations that maps the life rhythm features onto the value of QoL.

### 4 PROPOSED METHOD

#### 4.1 Overview

In this section, we explain the details of the proposed method. Figure 1 shows an overview of the proposed system. As mentioned in Section 3.1, the proposed method includes three steps. Step 1 represents the life rhythm using statistical values of sleep and eating log data. Then, Step 2 collects the values of QoL by self-assessment, asking the user the fulfillment of daily living. Step 3 creates labeled life rhythm data by joining the life rhythm data and the QoL data, and then derives a regression model that maps features of life rhythm onto the value of QoL.

#### 4.2 Step 1: Representing Life Rhythm

In this step, we assume that our previous system [8] continuously collects and records the daily activities of the user. The system is...
able to recognize seven types of activities (sleep, rise, sleep, eat, bath, go out, return). For each activity recognized, the system records the activity in log data, as shown in Table 1. Each row represents a recognized daily activity, specified by username, date of occurrence, start time, end time, and the type of activity.

In A1 of Section 3.2, we saw that sleep and breakfast are relevant factors for the life rhythm. Hence, we extract sleep and eating activities from the log data, and aggregate the data by week. The reason of the data aggregation by week is that one week is a reasonable unit in which we observe the variation of life rhythm.

For the sleep activities, we calculate the following statistics as relevant features of the life rhythm:

- **s_start_mean** (Average of start time of Sleep): Characterizes about what time the user went to bed during the week.
- **s_start_std** (Standard deviation of start time of Sleep): Characterizes how regularly the user went to bed during the week.
- **s_end_mean** (Average of end time of Sleep): Characterizes about what time the user woke up during the week.
- **s_end_std** (Standard deviation of end time of Sleep): Characterizes how regularly the user got up during the week.
- **s_length_mean** (Average of length of Sleep): Characterizes about how long the user slept every day during the week.
- **s_length_std** (Standard deviation of length of Sleep): Characterizes about how regularly the user secured sleeping time.

For the eating activities, we focus only the first occurrence of the day to capture the breakfast activities. Then, we calculate the following statistics:

- **e_start_mean** (Average of start time of Eating Breakfast): Characterizes about what time the user started eating breakfast during the week.
- **e_start_std** (Standard deviation of start time of Eating Breakfast): Characterizes how regularly the user started eating breakfast during the week.
- **e_end_mean** (Average of end time of Eating Breakfast): Characterizes about what time the user finished eating breakfast during the week.
- **e_end_std** (Standard deviation of end time of Eating Breakfast): Characterizes how regularly the user got up during the week.
- **e_skip_count** (Number of days with breakfast skipping): Characterizes how many days the user skipped breakfast during the week.

Table 2 shows instances of [s_start_mean, s_start_std, e_start_mean] of an actual user calculated for four weeks, where each value is specified by an hour. For example, in Week27 (from May 17th to 23rd, 2018), the user went to bed around 1:17 a.m. (≈25:285) with the deviation of 1 h 40 min (≈1.666). The user ate breakfast around 9:30 am. Thus, we can observe a life rhythm of the user from a certain perspective. Note in Table 2 that the date between the weeks is not consecutive, since the user was out of home and the data was missing for some days.

Table 3: Evaluation Scales of Fulfillment

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>not fulfilled at all</td>
</tr>
<tr>
<td>2</td>
<td>little fulfilled</td>
</tr>
<tr>
<td>3</td>
<td>fulfilled</td>
</tr>
<tr>
<td>4</td>
<td>very fulfilled</td>
</tr>
<tr>
<td>5</td>
<td>perfectly fulfilled</td>
</tr>
</tbody>
</table>

Table 4: A Part of Results of QoL Assessment

<table>
<thead>
<tr>
<th>WeekID (Period)</th>
<th>General</th>
<th>Research</th>
<th>PT-Job</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week26 (2018/05/08-14)</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Week27 (2018/05/17-23)</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Week28 (2018/05/28-6/3)</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Week29 (2018/06/05-11)</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

4.3 Step2: Measuring Quality of Life (QoL)

In this step, the proposed method asks the user to do self-assessment of QoL every week. The value of assessment is required to specify a numerical value, which can be either discrete or continuous.

As mentioned in A2 of Section 3.2, the QoL is assessed by the fulfillment of daily living from user’s perspective. In this preliminary study, we ask the user every week to answer the following four questions:

1. How was your last week in general?
2. How was your research work last week?
3. How was your part-time job last week?
4. How was your private time last week?

For each question, the user is instructed to answer the degree of fulfillment by 5-level scale, as shown in Table 3.

Table 4 shows examples of the self-assessment of QoL. The columns General, Research, PT-Job and Private represent the answers for the above four questions (1)-(4), respectively. Each assessment was done in the last day of the week. For instance, the user felt that Week 27 (from May 17th to 23rd, 2018) was marginally fulfilled in general, little for research work, and very fulfilled for the part-time job and the private time.

4.4 Step3: Deriving Life-Rhythm Assessment Model

In this step, the proposed method joins the features of life rhythm and the value of the QoL Assessment, and then establish an assessment model through data mining. The data mining process is divided into two sub-steps.
**Step 3-1: Extract relevant features of life rhythm**

In this sub-step, we identify which features of life rhythms are relevant to the QoL value of the user. For this, we apply correlation analysis to the joined data, and obtain correlation coefficient between any pair of feature and QoL value.

Let \( X \) be a series of any feature of the life rhythm defined in Step 1 (See Section 4.2), and let \( Y \) be a series of any QoL value defined in Step 2 (See Section 4.3). Then, a correlation coefficient \( \rho(X, Y) \) is defined by:

\[
\rho(X, Y) = \frac{E((X - E[X])(Y - E[Y]))}{\sqrt{E[(X - E[X])^2]E[(Y - E[Y])^2]}}
\]

where \( E \) represent the mean operation.

When the absolute value of \( \rho(X, Y) \) is large, it means that the feature \( X \) well contributes to predicting the QoL \( Y \). Therefore, through this correlation analysis, we only pick up features where \( |\rho(X, Y)| \) is larger than a certain threshold \( r \).

The above correlation analysis is performed between the feature \( X \) and the QoL value \( Y \). However, we also apply the correlation analysis among features. When two features \( X_1 \) and \( X_2 \) are highly correlated, choosing both \( X_1 \) and \( X_2 \) results in decreasing the performance of the model. For instance, \( s_{\text{start}} \_\_\text{mean} \) and \( e_{\text{end}} \_\_\text{mean} \) are highly correlated, since the time of ending breakfast strongly depends on the time of starting breakfast. In such a case, we drop either \( X_1 \) or \( X_2 \) from the feature selection, even if \( |\rho(X_1, Y)| \) and \( |\rho(X_2, Y)| \) are large.

Based on the above analysis, we select only relevant features of the life rhythm, which have relatively stronger correlation with the QoL value of the user.

**Step 3-2: Derive assessment model**

In this sub-step, we establish a personalized model of the life rhythm assessment, which explains (predicts) user’s QoL value from given features of life rhythm. Let \( X_i \) (\( i = 1, 2, ..., n \)) be a series of i-th relevant features, and let \( Y \) be the series of target QoL values. Then, the model is defined by a function \( f \) such that

\[
Y = f(X_1, X_2, ..., X_n)
\]

where \( f \) maps n-tuples of feature values \( x_1, x_2, ..., x_n \) onto a QoL value \( y \). In this preliminary study, we adopt the linear regression model to derive \( f \).

\[
Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + ... + \beta_nX_n
\]

The regression analysis is a set of statistical processes that estimates values of \( \beta_i \)’s for given \( n \) relevant features. In Section 5, we will explain how to build the assessment model using regression analysis tools.

**5 CASE STUDY**

**5.1 Experiment**

We have conducted a preliminary experiment to establish an assessment model of an actual user living in an OPH. The subject is a PhD course student in a university, and is living alone in an apartment. He usually studies in the university, however, he has to work at a part-time job to make a living. In his apartment, our previous system has been already installed.

In Step 1, we collected his daily activity log since May 1st, 2016 until June 31, 2018, and retrieve valid data of 32 weeks from the period. In Step 2, we collected the QoL self-assessment log data for the same 32 weeks. Since the details of Step 1 and Step 2 were already explained in Sections 4.2 and 4.3, respectively, we here concentrate on the explanation of Step 3.

First, we identify relevant features of the life rhythms based on the correlation analysis. Table 5 shows the result of the analysis between the features and the four kinds of QoL values. As we focus General (the degree of QoL in general), we can see that the correlations coefficient of \( s\_\text{start}\_\text{std} \) (standard deviation of the time to go to bed), \( s\_\text{length}\_\text{mean} \) (average of sleeping time length), \( e\_\text{end}\_\text{mean} \) (average of the time of ending breakfast), \( e\_\text{start}\_\text{mean} \) (average of the time of beginning breakfast) are significant, which

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1The data used for the experiment is available at http://ws.cs.kobe-u.ac.jp/~longniu/data/iiwas2018/
Table 6: Detailed Results of Regression Analysis

<table>
<thead>
<tr>
<th></th>
<th>Coefficients</th>
<th>Standard Error</th>
<th>t Stat</th>
<th>P-value</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
<th>Lower 90.0%</th>
<th>Upper 90.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.38265769</td>
<td>0.825</td>
<td>7.735</td>
<td>1.993E-08</td>
<td>4.693</td>
<td>8.073</td>
<td>4.693</td>
<td>8.073</td>
</tr>
<tr>
<td>s_start_std</td>
<td>-0.33467885</td>
<td>0.095</td>
<td>-3.524</td>
<td>0.001</td>
<td>-0.529</td>
<td>-0.14</td>
<td>-0.529</td>
<td>-0.14</td>
</tr>
<tr>
<td>s_length_mean</td>
<td>-8.1073E-05</td>
<td>2.6E-05</td>
<td>-3.095</td>
<td>0.004</td>
<td>-0.0001</td>
<td>-2.7E-05</td>
<td>-0.0001</td>
<td>-2.7E-05</td>
</tr>
<tr>
<td>e_end_mean</td>
<td>-0.06287619</td>
<td>0.032</td>
<td>-1.914</td>
<td>0.066</td>
<td>-0.129</td>
<td>0.004</td>
<td>-0.129</td>
<td>0.004</td>
</tr>
</tbody>
</table>

Table 7: Regression Statistics

<table>
<thead>
<tr>
<th></th>
<th>Multiple R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Standard Error</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.676199</td>
<td>0.457245</td>
<td>0.399093</td>
<td>0.626037</td>
<td>32</td>
</tr>
</tbody>
</table>

means that these features significantly contribute to the degree of General.

Since we found that e_end_mean and e_start_mean are strongly correlated with each other (i.e., \( r(e_{end\_mean}, e_{start\_mean}) = 0.983 \)), we dropped e_start_mean from the feature selection. As a result, we identified three features of s_start_std, s_length_mean, and e_end_mean for the regression model of General.

Then, we establish an assessment model by a regression analysis with the three features, predicting the value of QoL (General). Table 6 shows the detailed results of the regression analysis. The coefficients correspond to \( \beta_i (i = 0, 1, 2, 3) \) for the formula (2). From the analyzed result, we can derive a function of the assessment model of life rhythm:

\[
Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3
\]  

(3)

where

- \( Y \): general fulfillment in daily living
- \( X_1 \): s_start_std, the standard deviation of the time to go to bed
- \( X_2 \): s_length_mean, the average of the sleeping time length
- \( X_3 \): e_end_mean, the average of the time to ending breakfast
- \( \beta_0 \): 6.3826575 which is the constant called Y-Intercept
- \( \beta_1 \): -0.3346785 which is coefficient of s_start_std
- \( \beta_2 \): -8.1073E-05 which is coefficient of s_length_mean
- \( \beta_3 \): -0.06287619 which is coefficient of e_end_mean

Table 7 shows the overall statistics of the regression analysis of General with s_start_std, s_length_mean, e_end_mean. R Square is the coefficient of determination, representing a statistical measure of how close the data are to the fitted regression line. The result of R Square is about 0.457, which means the statistic measure is relatively close to the fitted regression line.

5.2 Interpreting Assessment Model

We here try to interpret the derived assessment model. By assigning the obtained values in the model (3), we have the following formula:

\[
\text{QoL(General)} = 6.38 - 0.33 \cdot s_{\text{start\_std}} - 8.1 \times 10^{-5} \cdot s_{\text{length\_mean}} - 0.062 \cdot e_{\text{end\_mean}}
\]  

(4)

First, we visualize how the model (4) is able to predict the actual values of QoL. Figure 2 depicts the actual QoL values (General) recorded by the self-assessment of the subject, and the predicted QoL values by the model (4). In the figure, the horizontal axis represents weeks, whereas the vertical axis represents the value of degree of general fulfillment. The solid blue line shows the actual value, and the shaded orange line shows the predicted value. We can see in the results that the model is able to predict the actual values to a certain extent.

Next, we interpret the semantics of the model (4). The units of s_start_std, s_length_mean, and e_end_mean are hour, second, and hour, respectively. With respect to the life rhythm of the subject, the model (4) tells the following facts:

- If the deviation of the time to go to bed increases by 1 hour, the QoL value of the subject decreases by 0.33 points.
- If the sleep time increases by 1 hour (\( \approx 3,600 \) seconds), the QoL value of the subject decreases by 0.29 points.
- If the time of breakfast is delayed for 1 hour, the QoL value decreases by 0.062 points.

Therefore, for this subject, keeping the time to go to bed regularly, sleeping not too much, and no late breakfast are good habits to maintain the good QoL values.

5.3 Finding Personal Advice for Maintaining Healthy Life

The derived model tells the statistical correlation between the relevant features of the life rhythm and the QoL values. However, the user of the proposed method would like to know more detailed personal advice on the daily activities. To find such personal advice, we apply the regression analysis to each of the relevant features.

More specifically, for each of s_start_std, s_length_mean, and e_end_mean, we reconstruct a regression model for QoL(General). Figure 3 shows three scattered plots between QoL(General) and s_start_std, s_length_mean, or e_end_mean, respectively. In each sub-figure, the vertical axis represents the value of QoL(General), the horizontal axis represents the corresponding feature. The dotted line shows the regression line fitting the samples.

Suppose now that the subject wants personal advice for maintaining the QoL value more than or equal to 3.0 (marginally fulfilled). Using Figure 3, we can find three advice.

First, from Figure 3(a), we can see that the regression of QoL by s_start_std (depicted by a dotted line) is defined by:

\[
\text{QoL(General)} = 3.44 - 0.26 \cdot s_{\text{start\_std}}
\]  

(5)

From the line, we know the value of s_start_std should be smaller than 1.7 to achieve the value of the QoL higher than 3.0. Based on this assessment, if the subject is able to control s_start_std to
be less than 1.7, the QoL is likely to be more than 3.0. Thus, we find a personal advice that "the subject should keep the deviation of the time to go to bed within 1 hour 35 minutes, in order to be marginally or more fulfilled". Second, from Figure 3(b), we can see that the regression of QoL by $s_{\text{length\_mean}}$ (depicted by a dotted line) is defined by:

$$QoL(\text{General}) = 4.33 - 6 \times 10^{-5} \cdot s_{\text{length\_mean}}$$ (6)

From the line, we know that the value of $s_{\text{length\_mean}}$ should be between 185,000 and 22,000 to achieve the value of the QoL higher than 3.0. Thus, we find the second personal advice that "the subject should control the sleeping time between 5 hours 10 minutes and 6 hours 10 minutes, in order to be marginally or more fulfilled".

Finally, from Figure 3(c), we can see that the regression of QoL by $e_{\text{end\_mean}}$ (depicted by a dotted line) is defined by:

$$QoL(\text{General}) = 4.6 - 0.17 \cdot e_{\text{end\_mean}}$$ (7)

From the line, we know that the value of $s_{\text{length\_mean}}$ should be less than 9.41 to achieve the value of the QoL higher than 3.0. Thus, we find the third personal advice that "the subject should control finish the breakfast before 9:25 every day, in order to be marginally or more fulfilled".

If the subject is able to obey the above three advice, he will maintain fulfilled daily living with great probability.

6 CONCLUSION

In this paper, we proposed a method that constructs a personalized assessment model of life rhythm. In the proposed method, we characterize individual life rhythms by features related to sleep and eating, which are extracted from the daily activity log. We also collect the data of user’s QoL by the self-assessment survey. Using these data, the proposed method derives the assessment model by using the regression analysis. We conducted a case study with an actual subject. The proposed method was able to derive his personal assessment model based on the time to go to bed, the sleeping time length, and the time to finish the breakfast. Using the model we also derive personal advise to maintain the subject life marginally or more fulfilled.

In our future work, we plan to evaluate the proposed method through elaborated experiments with more subjects. It is also interesting to investigate algorithms other than the linear regression.
ACKNOWLEDGMENTS

This research was partially supported by the Japan Ministry of Education, Science, Sports, and Culture [Grant-in-Aid for Scientific Research (B) (16H02908, 18H03242, 18H03342), Grant-in-Aid for Scientific Research (A) (17H00731)], and Tateishi Science and Technology Foundation (C) (No.2177004).

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