

Walking Route Recommender for Supporting a Walk as Health Promotion*

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SUMMARY This paper proposes a walking route recommender system aiming at continuously supporting a user to take a walk as means for health promotion. In recent years, taking a walk becomes popular with not only the elderly, but also those from all ages as one of the easiest ways for health promotion. From the viewpoint of health promotion, it is desirable to take a walk as daily exercise. However, walking is very simple activity, which makes it difficult for people to maintain their motivation. Although using an activity monitor is expected to improve the motivation for taking a walk as daily exercise, it forces users to manage their activities by themselves. The proposed system solves such a problem by recommending a walking route that can consume target calories. When a system is to be used for long period of time for supporting user's daily exercise, it should consider the case when a user will not follow the recommended route. It would cause a gap between consumed and target calories. We think this problem becomes serious when a user gradually gets bored with taking a walk during a long period of time. In order to solve the problem, the proposed method implicitly manages calories on monthly basis and recommends walking routes that could keep a user from getting bored. The effectiveness of the recommendation algorithm is evaluated with agent simulation. As another important factor for walking support, this paper also proposes a navigation interface that presents direction to the next visiting point without using a map. As users do not have to continuously focus on the interface, it is not only useful for their safety, but also gives them room to enjoy the landscape. The interface is evaluated by an experiment with test participants.

key words: route recommendation, health promotion, smartphone, navigation interface, agent simulation

1. Introduction

This paper proposes a Web-based system that recommends a walking route for continuously supporting a user to take a walk as means for health promotion. Health promotion is one of the most serious issues for many countries. It is said health is not the objective of living, but a resource for everyday life [29]. In order to promote health, having moderate exercise in everyday life is expected to be effective, and taking a walk is popular as one of the easiest exercises. Its advantage is that those from all ages including the elderly can enjoy it.

As taking a walk is easy to do, it is desirable to be

done as daily exercise. However, walking is so simple that it is difficult for people to maintain their motivation. In order to improve the motivation, various activity monitors including wearable devices and smartphone applications have been available recently. Such devices are expected to be effective for maintaining the motivation for taking exercise. However, some people would not like such an explicit approach because it forces users to manage their activities by themselves.

In order to help people take a walk as daily exercise, this paper employs an implicit approach. That is, it proposes a system that recommends a walking route considering users' target calories they want to consume by taking a walk. By following a route recommended by the system, users can consume their target calories without managing consumed calories by themselves.

As the system is designed to support a user to take a walk as everyday exercise, it is supposed to be used for long period of time, such as over months. When the system is used for a long period of time, users would gradually get bored with taking a walk. The more a user gets bored, the more s/he would not follow the recommended route. This would lead to errors between consumed and target calories.

In order to solve the problem, 3 extensions are introduced to a basic route recommendation algorithm. One is to implicitly manage calories on monthly basis, by updating target calories day by day based on the accumulated errors of consumed calories. Second is to recommend routes that can keep a user from getting bored, and the last is to recommend robust routes in case a user does not follow a recommendation.

When navigating a user during walking according to a recommended route, it is dangerous for users to focus on the screen of a navigation interface too much. Therefore, this paper also proposes a map-free navigation interface, which presents direction to the next visiting point without using a map. The timing when to check the interface is notified to users with vibration. Users do not have to continuously focus on the interface, which is not only useful for their safety, but also gives them room to enjoy the landscape.

The proposed system is developed using the road information collected from the Open Street Map (OSM) Japan**, which is converted into RDF (resource description framework) store. The effectiveness of the proposed system is

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**<http://openstreetmap.jp>

evaluated by separating it into the recommendation algorithm and the map-free navigation interface. The algorithm is evaluated with an agent simulation considering the degree of getting bored, of which the result shows it can achieve stable consumption of target calories. The effectiveness of the navigation interface is shown through experiments with test participants.

2. Related Works

2.1 Route Recommendation for Pedestrians

Current major applications of route recommendation targeting pedestrians are evacuation guidance [10], [26] and traveling support [16], [19], [31]. Regarding evacuation, Inoue et al. have proposed a system for indoor evacuation using mobile devices [10]. For traveling support, location information such as GPS (Global Positioning System) log [31] and geotag information [16], [19] is the most important resource to find famous spots and typical routes for sightseeing. Zheng et al. have applied clustering to GPS logs of many people in order to extract sightseeing spots in which many people are interested as well as common travel sequences [31].

Lu et al. have proposed a system that recommends a travel route considering the order and sojourn time of sightseeing spots [19]. Information used for the recommendation is obtained by mining online photos with geotag information. Katayama et al. have proposed a system for navigating users in an event space [12]. It has a route planning algorithm, which recommends a route so that it can satisfy the objectives of an event manager.

While main concern of route recommendation for sightseeing is to include a spot of interest in a recommended route, route recommender systems for other purposes tend to consider preference or individual factors on a road. Kitamura et al. have proposed a system for supporting the rehabilitation of patients by promoting community participation [14]. The system has a function for recommending walking routes considering the patient's physical condition. Sasaki et al. have proposed a SAW criteria: safety, amenity, and walkability [24]. Safety corresponds to car traffic, existence of traffic signal, etc., and amenity corresponds to good view and existence of facilities. Walkability corresponds to the existence of steps, slopes, etc. A route is determined based on the weight for each criterion, which is given by a user.

Although the system proposed by Nakajima et al. [21] is a car navigation system, it recommends a route considering a driver's intent. When a driver deviates from a recommended route, the system estimates his/her intent behind the decision, based on which a new route is recommended.

When a recommender system is used in our daily life, such as walking route recommendation, one of important individual factors to be considered is tiresomeness [17]. That is, how to keep a user from getting bored is a key issue for developing a system. Although diversity-based recommen-

dation [30], [32] relates with this matter to some extent, to the best of our knowledge, less effort has been paid to consider tiresomeness in route recommender systems.

2.2 Navigation Interface for Pedestrians

When designing a navigation interface that is to be used for pedestrians, different factors from car navigation systems should be considered. Kubota et al. classified the challenges of navigation for pedestrians into 3 sub problems: how to obtain user's location, how to obtain user's direction, and how to display a recommended path [15]. As a pedestrian can walk indoor space or narrow roads, more precise location should be obtained than car navigation systems. It is also mentioned that navigation interface should be developed as small and light-weight device for portability.

Currently, the most popular ways to obtain a user's location is to use GPS. As for other methods that are used especially when GPS is not available such as indoor environments, M-CubITS [13] uses a marker that is installed on a road as a braille block. By detecting the marker with a user's camera, his/her position is obtained. The Katayama's system as mentioned in Sect. 2.1 also employs a method for obtaining user's location by using a camera [12]. When a user arrives at a spot, s/he reads QR code attached to the spot, and the obtained information is used to recognize the user's location. The pedestrian navigation system [4] uses RFID tags to obtain user's location. A user carries an RFID receiver for obtaining ID of RFID tags distributed in target area.

Regarding the display of a recommended route, it is important to precisely inform a user of the spatial relationship between the current location and destination [5]. It is said that showing the current location and direction to the destination is effective for a user to recognize a recommended route [18].

Iwata et al. focused on a landmark used for navigation [11]. They investigated the location where a landmark should be placed, which were classified into 4 places: where a user has to turn, where a user will arrive when taking a wrong path, where a user will arrive when taking a correct path, and regular interval on the route to be followed. Shinjo et al. compared a guidance method using landmarks (rivers, bridges, buildings, etc.) and that using distance (e.g. "GO 5m and turn left.") for the purpose of evacuation guidance with PDA [26].

Although map-based navigation is the majority of navigation systems, other approaches have been also studied. Chittaro et al. compared an interface using map only, that using map and photographs, and that using photographs and arrows to show direction [3]. The result shows arrows and photographs are enough to be alternatives for navigating pedestrians in terms of traveling time and errors. Although our map-free navigation interface also uses an arrow for showing direction to follow, we evaluate it from different viewpoint. That is, we do not only evaluate the map-free navigation interface with traveling time and error but also

the frequency of checking the screen of the interface.

Using different modalities than vision has been also studied. Tsukada et al. have proposed a navigation interface using vibration [28]. A user wears a belt-style interface, to which several vibration devices are attached. When a user is walking, a vibration device directed to the destination oscillates at regular interval. The interval becomes shorter when a user is getting close to the destination. Although we also use vibration function of a smartphone, we use it just for letting a user notice when to check the interface.

2.3 Mobile Applications for Health Promotion

Smart phones have been popular in modern society, and majority of people are carrying a smartphone around in their daily lives. As a smartphone is equipped with many sensors, camera, microphones, it can monitor a user's activity continuously. Furthermore, it can provide users with information and alert in timely manner. Making use of these characteristics, mobile applications for health promotion have been studied and developed.

Identification of user's state in real time is one of important technologies for supporting health promotion using smartphones. Chiang et al. proposed a method for recognizing user's activity pattern based on data obtained by smartphones [2]. Using acceleration data, GPS data, and time, several activity patterns such as sitting, walking, running, riding a bicycle, and driving a car, were identified. Sano et al. examined the possibility of recognizing user's stress level using wearable sensors and mobile phones [23]. In addition to some questionnaires, three-axis accelerometer data and skin conductance data, both of which were obtained from wearable sensors, and mobile phone usage data such as call, SMS (short message service), location, screen on/off, were collected. By evaluating the performance of classifiers (SVM, k-nearest neighbor, PCM, etc.) with features calculated from above-mentioned data, they found that high / low perceived stress level were classified with 75% of accuracy using the combination of mobile phone usage and sensor data. Gu et al. classified users' sleep stage into 4 stages based on data obtained by smartphones, such as sound, illuminance, and acceleration data [8]. Aiming at realizing a walking support application, which suggests users to adjust their walking speed, Sumida et al. proposed a method to estimate user's heart rate during walking based on sensor logs obtained by smart phones, such as acceleration amplitude, walking speed, and gradient calculated by GPS data [27].

Regarding mobile applications for health promotion, Chiang et al. [2] visualized activity patterns identified by the above-mentioned method as personal chart journal, which assigns time on horizontal axis and activity on vertical axis. It also provides advises for improving daily physical activity level. Hamper et al. employed Delphi technique to summarize 30 mobile health & fitness applications obtained from ideas by domain experts [9]. The applications are grouped into 5 categories in terms of how to support users' behavior change: risk and fitness assessments, rewarding, progress

monitoring, social & competition, and coaching & advice. The effect of each category was examined based on theoretical models of behavior change. For example, risk assessment applications were said to be highly suitable when users are inactive or get aware of the risk. On the other hand, progress monitoring applications were said to be get more important the more active a user is. Although it does not use smartphones, an interactive jogging system was proposed [22], which selects and plays a tune based on jogging pitch measured by an accelerometer. It tries to induce a user to jog at a certain pitch by selecting a tune with appropriate tempo.

3. Walking Recommendation System

3.1 System Overview

The proposed system consists of recommendation engine, navigation interface, and database (RDF store). A recommendation engine receives the current position of a navigation interface and returns information about a recommended route. A navigation interface is implemented as an Android application. Communication between the interface and the engine is established with WebSocket, and JSON is employed as the format for data exchange.

A database is constructed as RDF store, which stores road information. The reason why we employ RDF as data format is twofold. One is because RDF is flexible in that it is easy to add new properties (attributes). We plan to introduce additional information that can be used for route recommendation in future. For example, lighting situation of a road could be one of additional information, which could be used for recommending safety road at night [25]. It is easy to add such information to RDF store without restructuring a database, simply by defining additional property.

Another reason of employing RDF is because it is a standard for linked open data. That is, we plan to make our database open to public in future.

For constructing the RDF store, we used data provided by the OSM Japan. Road information of the OSM consists of 3 kinds of elements: node, way, and relation. A node corresponds to a point specified as latitude and longitude. A way is used to represent an ordered list of points, and relation is used to group elements.

Node and way elements within target area is obtained from the OSM Japan, which are converted into RDF data with using common and original vocabularies. The used common vocabularies are shown in Table 1. The RDF

Table 1 Used common vocabularies.

prefix	URI	Description
dcterms	< http://purl.org/dc/terms#>	Document information
lgdo	<http://linkedgeodata.org/vocabulary#>	Linked Geo Data
geo	<http://www.w3.org/2003/01/geo/wgs84_pos#>	WGS84 Geo position data
vcard	<http://www.w3.org/2006/vcard/ns#>	Data format for business cards

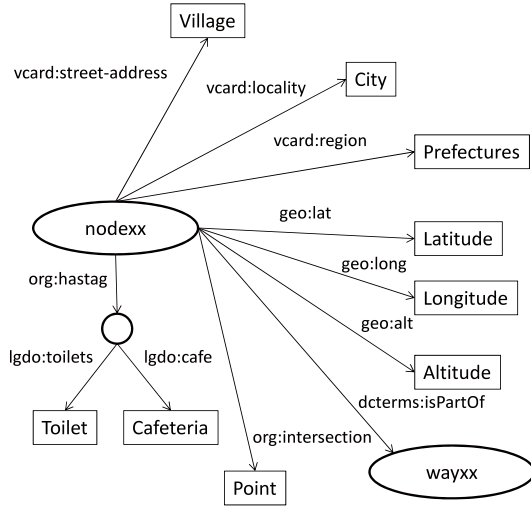


Fig. 1 RDF graph of a node element.

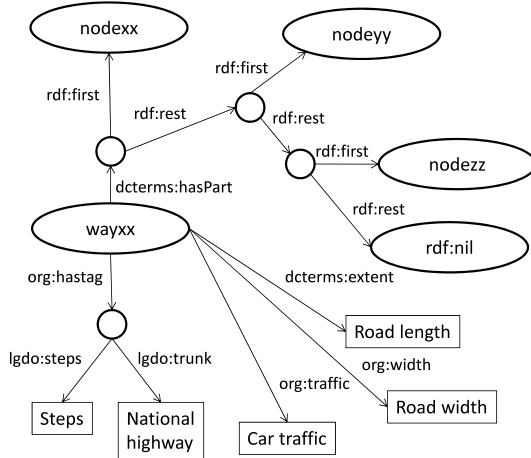


Fig. 2 RDF graph of a way element.

graphs for a node and a way element are shown in Figs. 1 and 2, respectively. In the figures, a prefix “org” indicates an original vocabulary in this paper.

3.2 Basic Route Recommendation Algorithm

A route recommendation algorithm proposed in this paper recommends a route that users can consume the target calories by walking it. The system supposes that users start walking from their home and return to it. Therefore, recommended route is always cyclic, which is different from other types of route recommendation such as traveling support or car navigation.

Figure 3 shows the proposed algorithm. As extensions proposed in Sect. 3.3 are introduced in this algorithm, it is called a basic algorithm in this paper. In the algorithm, “HOME” is the home of a target user. The GetCandidateDest() is a function that accesses the database and returns a set of possible points (nodes in OSM) the user can visit during a walk. Given user’s target calories, this function finds

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1:  $t=1, p_0=HOME$ 
2:  $S_t = \text{GetCandidateDest}()$ 
3: while  $\exists p \in S_t$  s.t.  $\text{CalcEstimatedCal}(p_{t-1}, p) < \text{rest\_cal}_{t-1}$  do
4:    $p_t = \text{RandomSelectDest}(S_t)$ 
5:    $S_{t+1} = S_t - \{p_t\}$ 
6:    $r_t = \text{FindShortestRoute}(p_{t-1}, p_t)$ 
7:   Recommend  $r_t$ 
8:    $\text{UpdateState}(p_t, \text{rest\_cal}_t)$ 
9:    $t++$ 
10: end while
11: Recommend a route from  $p_{t-1}$  to HOME

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Fig. 3 Basic route recommendation algorithm.

points where the user can visit and return to HOME within the target calories by walking on the shortest path in terms of distance. Consumed calories C [kcal] are calculated as Eq. (1),

$$C = \text{rmr} \cdot \text{METS} \cdot w \cdot t, \quad (1)$$

where rmr [$\text{kcal} \cdot \text{kg}^{-1} \cdot \text{s}^{-1}$] is a resting metabolic rate, which is the rate of energy expenditure per unit time and weight under resting conditions. It is approximately calculated based on a basal metabolic rate of a user, which is predicted based on the user’s gender, weight, height, and age using Harris-Benedict equation [6].

The METS (metabolic equivalents) means the ratio of energy expenditure during a specific physical activity to a resting metabolic rate [20], w [kg] is the user’s weight, and t [s] is the amount of time doing the physical activity. In the agent simulation in Sect. 4, we suppose a constant walking speed (4.0km/h) and METS (3.0) regardless of a road condition such as a slope. No that it is possible to consider the effect of a road condition on consumed calories by changing METS and walking speed for each road.

In this paper, the shortest path is calculated based on distance by all functions such as GetCandidateDest(), CalcEstimatedCal(), and FindShortestRoute(). As an estimated cost (distance) is available, the shortest path is found by A* algorithm. Note that as we suppose a constant walking speed in this paper, the shortest path in terms of distance is equal to that in terms of traveling time. When we consider a road condition in future, we can modify those functions to find the shortest path in terms of traveling time by considering different walking speed according to a road condition.

The algorithm manages calories consumed by the user, and rest_cal_t is remaining calories after arriving at the point p_t , which is calculated by Eq. (2). Where target_cal is user’s target calories and consumed_cal_t is consumed calories while walking from p_0 (HOME) to p_t .

$$\text{rest_cal}_t = \text{target_cal} - \text{consumed_cal}_t. \quad (2)$$

The proposed algorithm does not determine a complete route from HOME to HOME in advance. Instead, it recommends a point to be visited (visiting point) one by one, because a user does not always follow a recommended route. In the while loop, a visiting point is recommended until there is at least one point in S_t such that after visit-

ing where the user will be able to return to HOME within the target calories. The $\text{CalcEstimatedCal}(p_{t-1}, p)$ returns an estimated calories the target user will consume by walking from the current location (p_{t-1}) to HOME via p . The estimated calories are calculated based on the shortest path from p_{t-1} to p and p to HOME.

A visiting point p_t satisfying the above-mentioned condition is selected randomly by the function $\text{RandomSelectDest}()$, and a shortest path from p_{t-1} to p_t is found by the function $\text{FindShortestRoute}()$ and recommended to the target user. After recommending a route, the state of the user is updated with a function $\text{UpdateState}()$. This function checks the user's position after s/he moved based on the recommendation. If the user followed the recommended route, his/her position is equal to p_t . However, if s/he did not follow the recommendation, his/her position is different from p_t . In such a case, p_t is replaced with his/her current position. The function also updates rest_cal_t .

When a while loop of Fig. 3 ends, the system recommends the shortest path from the current position (p_{t-1}) to HOME (line 11).

3.3 Consideration of Sustainable Usage

As noted in Sec. 1, the aim of this paper is to develop a route recommender system that can support users to take a walk as daily exercise. Therefore, target calories should be consumed stably over a long period of time. If same / similar routes are repeatedly recommended, users would get bored. If users get bored with taking a walk, they would not follow the recommendation. As the algorithm proposed in Sect. 3.2 does not suppose sustainable usage of the system, it should be extended by considering these points.

This subsection proposes to introduce following extensions into the algorithm in Sect. 3.2.

1. Consideration of accumulated error of consumed calories.
2. Dynamic update of candidate visiting points.
3. Selection of robust routes in case a user does not follow a recommended route.

Regarding item (1), a fixed value of target_cal is used in the algorithm in Fig. 3. It is supposed that target calories are not always consumed owing to several reasons such as the case a user did not follow a recommended route. However, we think that daily variation of consumed calories is not so important, but target calorie can be satisfied during a certain period of time. Therefore, we propose to adjust target calories of d -th day, $\text{target_cal}(d)$, by Eq. (3), which replaces target_cal in Eq. (2).

$$\begin{aligned} \text{target_cal}(d) &= \text{target_cal} + \Delta(d - 1), \\ \Delta(d) &= \text{target_cal}(d) - \text{consumed_cal}(d), \end{aligned} \quad (3)$$

where $\text{consumed_cal}(d)$ is calories actually consumed in d -th day.

Regarding item (2), the function $\text{GetCandidateDest}()$ is modified from static one to dynamic one,

```

1: procedure FINDROBUSTROUTE( $p_{t-1}, p_t$ )
2:    $d = \text{CalcDist}(p_{t-1}, p_t) / 2$ 
3:   if  $\exists p \in \text{DenseArea} \wedge \min\{\text{CalcDist}(p_{t-1}, p), \text{CalcDist}(p, p_t)\} \leq d$  then
4:     return  $\text{FindShortestRoute2}(p_{t-1}, p, p_t)$ 
5:   else
6:     return  $\text{FindShortestRoute}(p_{t-1}, p_t)$ 
7:   end if
8: end procedure

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Fig. 4 Algorithm for finding robust route.

$\text{GetCandidateDest}(d)$, which is defined as follows.

$$\begin{aligned} \text{GetCandidateDest}(d) &= \text{GetCandidateDest}() \\ &\quad - \{p \in \text{Recommended}(d - 1)\}, \end{aligned} \quad (4)$$

where $\text{Recommended}(d)$ is a set of visiting points recommended at d -th day. By removing visiting points recommended in the previous day, the system tries to avoid recommending the same route as the previous day.

Regarding item (3), we suppose that a route going through many intersections is robust to the case where a user does not follow a recommended route. The reason is as follows. When a user does not follow a recommended route, we assume that the most difficult situation for the recommender system is that a user takes a road that goes far from his/her home without passing through intersection. In such a case, it is difficult to find a route that can return to the home within target calories. However, if the user arrives at an intersection soon, the possibility of finding alternative route to the home within target calories becomes high.

The problem when we are going to recommend a route with many intersections by the proposed algorithm (Fig. 3) is that it recommends a visiting point one by one without planning. That is, the algorithm does not determine a route in advance with some objective functions considering the number of intersections. Therefore we employ the following approaches.

1. Find a dense area containing many intersections.
2. Recommend a route from p_{t-1} to p_t via a point in the dense area.

The DBSCAN [7], which is a density-based clustering algorithm, is employed to find a dense area. We set MinPts (a minimum number of points) as 20, and Eps (the maximum radius of the neighborhood) as 150. The clustering can be done off-line.

In order to recommend such a route as noted in item (2), $\text{FindShortestRoute}(p_{t-1}, p_t)$ in Fig. 3 is replaced with the function $\text{FindRobustRoute}(p_{t-1}, p_t)$ as shown in Fig. 4. In Fig. 4, DenseArea is a set of points located in a dense area, and the $\text{CalcDist}(x, y)$ returns the distance between x and y . The function $\text{FindShortestRoute2}(x, y, z)$ returns a route consisting of the shortest path from x to y and that from y to z .

Figure 5 shows examples of robust routes. A red route is the shortest path from p_{t-1} to p_t , and colored circles show



Fig. 5 Examples of robust routes.

dense area. If a point p_g is selected from green dense area, the function FindRobustRoute() returns a green route (route 1), and a blue route (route 2) is returned if p_b is selected from blue dense area.

3.4 Map-Free Navigation Interface

The proposed system is designed so that it can be used during taking a walk. In particular, we focus on the following points when designing a navigation interface.

1. It is dangerous to walk while focusing on the screen of a smartphone.
2. A user will enjoy the landscape while taking a walk.
3. As a user is expected to be familiar with the area around his/her home, detailed navigation is not necessary.

Considering those points, proposed navigation interface does not use a map for showing a route to a user. Instead, the interface instructs only the direction to next visiting point and timing to check the interface. Although voice navigation could satisfy those conditions, we think it would decrease users' attention to their surroundings, because users have to use headphones / earphones. From the viewpoint of safety, this paper considers alternative map-free navigation that does not use voice navigation.

Figure 6 shows the screenshot of the proposed navigation interface. An arrow is displayed with AR (augmented reality) technology to show the direction to next visiting point. Showing only direction is expected to be enough for navigating familiar area to a user, which corresponds to the point (3) as mentioned above.

When using the proposed interface, a user does not have to always check the direction. In order to tell a user when to check, the interface uses vibration. When a distance

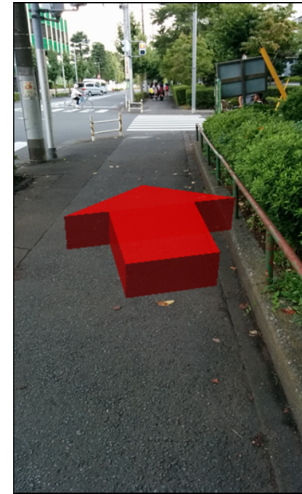


Fig. 6 Screenshot of map-free navigation interface.

between a user's current position and next visiting point is equal to 15m, the system uses vibration to let a user check the direction. This timing is determined considering the error of GPS (Global Positioning System), which is around 10m, and time lag before a user recognizes vibration.

By using vibration in conjunction with direction-based instruction, users can watch the screen of the interface only when notified by vibration. Therefore they can enjoy the landscape while taking a walk, which corresponds to the above-mentioned point (2). It also ensures the safety of a user during taking a walk as mentioned as the point (1).

4. Experiment of Recommendation Algorithm

This section evaluates the effectiveness of a route recommendation algorithm described in Sects. 3.2 and 3.3.

4.1 Settings

The proposed system is supposed to be used for supporting everyday exercise, of which the effectiveness should be evaluated for long period of time. As it is difficult to conduct experiments with test participants by asking them to use the system with various settings for long period of time, this paper employs an agent simulation. With using an agent simulation, evaluation of an algorithm with various settings can be done with a low cost. Furthermore, the comparison between different algorithms is possible, because different algorithms can be evaluated with the same agent.

Each run of a simulation corresponds to one month (31 days). we suppose an agent is a 20-year-old male, 1.687m tall weighing 64.6kg. The height and weight are taken from Japanese average reported by the Statistics Bureau, Ministry of Internal Affairs and Communications, Japan[†]. Assuming that the agent takes 2km walk with 4.0km/h (1.111m/s), target calories are determined as 193kcal based on METS [20].

In the simulation, we developed an agent that gets

[†]<http://www.stat.go.jp/english/index.htm>

bored with walking the same/similar route. Although target domain is different, Chang et al. studied tiredness of road sequence from the viewpoint of drivers [11]. The paper showed that drivers tend to get bored when no change is observed in the landscape from a car window. Lee et al. reported the results of questionnaire asking the experience of getting bored with something and its reason [17]. The frequently answered reasons of getting bored are: doing the same thing over and over, no change is observed, losing interests, going out of fashion, monotonous, become accustomed, etc. Considering these studies, we selected the following factors which could be applied to walking route recommendation.

1. No change is observed, monotonous.
2. Doing the same thing over and over.

From these factors, we define the conditions of getting bored and corresponding penalties as follows. The first and second conditions correspond to the factor (1), and the third one corresponds to the factor (2). Regarding the penalty for each condition, we consider the factor (2) has more impact on getting bored than the factor (1), because those who like to walk the same route repeatedly would not require a real-time route recommender system like the proposed one. We also consider absence of landmarks has more impact than walking the same direction, because the former one directly relates with a landscape.

- An agent continues to walk at the same direction. (penalty=1)
- An agent walks a road without any landmark such as shops and parks. (penalty=2)
- An agent walks the same road as those he has walked within the same and the previous day. (penalty=3)

When multiple conditions are satisfied at the same time, all corresponding penalties are added. When we walk the same road as the previous day, we would get bored more easily when walking more monotonous route. Considering such a situation, we decided to add all corresponding penalties. The penalty is accumulated in one month, which affects his behavior, i.e. whether to follow recommended route or not. Three types of agents are employed in the simulation, which have different behaviors according to the penalty of getting bored.

- (T1) An agent always follows recommended route.
 (T2) An agent always selects one of available roads randomly at an intersection.
 (T3) Take T1 when the accumulated penalty $\leq \theta_{th}$, otherwise take T2.

The threshold θ_{th} of T3 is set to 1,869, which is 80% of average penalty when the agent takes T1 for routes recommended by the basic algorithm (Fig. 3). Note that after exiting while loop in Fig. 3, the agent always follows recommended route until he arrives at his home regardless of behavior types. This is because it is rational that a user goes directly to his/her home on the return run.

Table 2 Experimental result (values in kcal).

Algorithm	Agent	AVG/DAY	STD/DAY	STD/MON
Basic	T1	171.2	18.4	3.0
	T2	178.7	22.3	4.8
	T3	172.6	20.3	3.3
Accumulated calories	T1	192.3	25.4	0.6
	T2	192.6	35.0	0.7
	T3	192.6	27.3	0.7
Dynamic candidates	T1	172.4	17.3	2.9
	T2	161.1	31.0	4.4
	T3	171.4	18.4	3.5
Robust route	T1	188.8	29.2	5.6
	T2	155.3	27.4	4.5
	T3	153.4	27.2	9.7
All extensions	T1	192.8	38.6	0.9
	T2	191.3	58.8	1.4
	T3	191.1	42.5	1.4

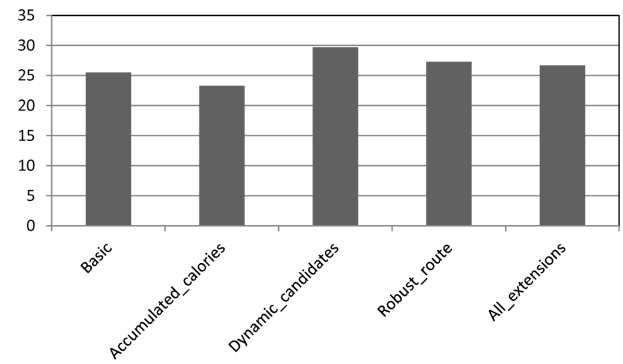


Fig. 7 Comparison of days before getting bored.

The 2-square-kilometer area around the Hino Campus of Tokyo Metropolitan University, Japan, (lat. 35.661222, long. 139.365735) is used in the simulation. Information about 13,133 nodes and 1,461 roads within the area is collected with OSM API Ver. 0.6.

4.2 Results

Table 2 compares the simulation results between basic algorithm and the proposed algorithm in terms of 3 behavior types. In the table, “AVG/DAY” and “STD/DAY” are the average and standard deviation of consumed calories per day, which is calculated by 100 simulation run. The “STD/MON” is the standard deviation of average consumed calories per day in each run, which shows the variation among 100 simulation runs.

Figure 7 shows average days spent before the agent of T1 type gets bored. In this figure, days are also calculated for the condition where only one of the extensions proposed in Sect. 3.3 is introduced, in order to examine the effect of each extension separately.

It can be seen in Table 2 that standard deviation (both of STD/DAY and STD/MON) of T1 is the smallest for all algorithms except a method with robust_route extension only. As the agent with T1 always follows the recommended route, this result shows the proposed algorithms can recommend appropriate routes.

It is also shown that average consumed calories of the algorithm with all extensions is closer to the target calories (193 kcal) than that of the basic algorithm, regardless of the behavior types of the agent. It shows the algorithm with all extensions can achieve the target calories even though the agent does not follow the recommendation. As the result of the algorithm with accumulated_calories extension only is similar to that of the algorithm with all extensions, this extension contributes to consume the target calories.

The reason why the consumed calories of the basic algorithm tends to be lower than the target calories is because the condition of while loop in Fig. 3 always recommends a route that can return to HOME within target calories. Although it is also applied to other algorithms, the extension of considering accumulated calories can compensate the shortage of consumed calories. At the same time, it also increases the standard deviation of consumed calories per day.

Regarding the STD/MON, the algorithm with all extensions is smaller than the basic algorithm in all of 3 behavior types. This result shows that the agent can stably consume the target calories for a long period of time (1 month) even though the agent does not always follow the recommendation. Table 2 also shows the accumulated_calories extension contributes to this result.

The result of using dynamic_candidates only is similar to that of the basic algorithm. It is because this extension uses the constant target calories every day. The result specific to this extension is that AVG/DAY is small and STD/DAY is large in the case of T2 behavior. As the number of possible visiting points is smaller than the basic algorithm, it was difficult to find alternative routes when an agent does not follow a recommended route.

Compared with other extensions, the robust_route extension tends to be affected by the agent's behavior. That is, difference of AVG/DAY between T1-agent and others (T2, T3) is larger than the results of using other extensions. As FindRobustRoute() (Fig. 4) can find longer route than the basic algorithm, consumed calories by T1-type agent tends to be larger than other extensions. Furthermore, STD/DAY of T2 and T3-type agents are smaller than that of T1-agent, which is also different from those using other extensions. This result shows this extension worked as we expected: the possibility of finding alternative route to the home within target calories becomes high.

As for days before getting bored as shown in Fig. 7, the agent tends to get bored soon when considering accumulated error of consumed calories. In order to compensate the shortage of consumed calories by the basic algorithm as mentioned above, considering the accumulated error tends to recommend long route. As the penalty of getting bored monotonically increases, the agent tends to get bored soon.

On the other hand, the agent spends the most days before getting bored when using dynamic update of candidate visiting points. As this extension can decrease the chance of recommending the same route as the previous day, it is effective for keeping the agent from getting bored. It is also observed the agent spends more days before getting bored

by recommending robust routes than the basic algorithm.

The result of all extensions lies between the accumulated_error extension and the dynamic_candidates extension. This result shows the opposite effects of both extensions are balanced out.

Experimental results show that using all extensions can achieve a stable result in terms of AVG/DAY and STD/MON owing to the accumulated_calories extension, while keeping an agent from getting bored owing to other two extensions.

5. Experiment of Navigation Interface

This section evaluates the effectiveness of the map-free navigation interface described in Sect. 3.4.

5.1 Settings

The proposed interface is evaluated by test participants: 16 graduate/undergraduate students in engineering. A test participant was asked to walk by following a recommended route. The proposed map-free interface is implemented on an Android tablet equipped with 7.0 inch display. For comparison purpose, the participants were also asked to walk by using a map-based interface using the same tablet, of which the screenshot is shown in Fig. 8.

After being instructed about the usage of those interfaces, test participants walked two routes around Hino Campus of Tokyo Metropolitan University, Japan, which are shown in Fig. 9 and Table 3. In order to eliminate the effect of participant's background knowledge, the routes unfamiliar with all of them are selected. The order and combination of a route and an interface is shown in Table 4.

5.2 Results

Figure 10 compares the number of times the test participants checked the screen of the interfaces between the map-free and the map-based interface. Figure 11 compares total time spent on viewing the screen of the interfaces. Table 5 summarizes the results, which includes p-values of a t-test.

The number of participants who went the wrong way



Fig. 8 Screenshot of map-based navigation interface.

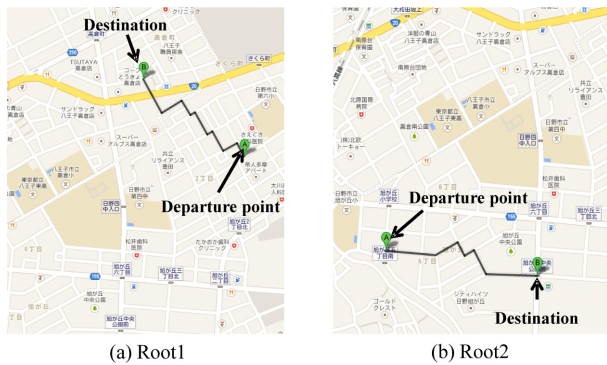


Fig. 9 Routes used in the experiment.

Table 3 Summary of routes used in the experiment.

Elements	Route1	Route2
Distance[m]	632	657
Intersection	9	6
Main street	Include	None
Crossing	Include	None

Table 4 Experimental design.

1st		2nd		Participants
Interface	Route	Interface	Route	
Map-free	R1	Map-based	R2	7,12,15,16
Map-free	R2	Map-based	R1	2,4,11,13
Map-based	R1	Map-free	R2	1,8,9,10
Map-based	R2	Map-free	R1	3,5,6,14

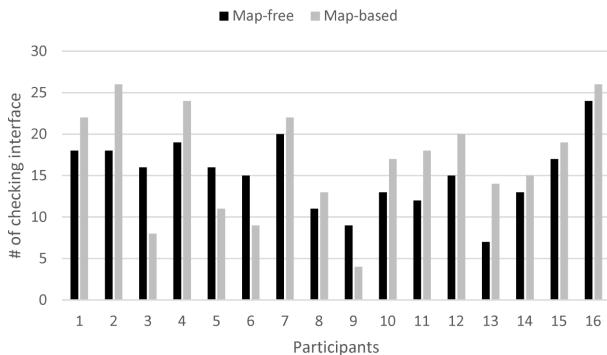


Fig. 10 Comparison of frequency of checking interface.

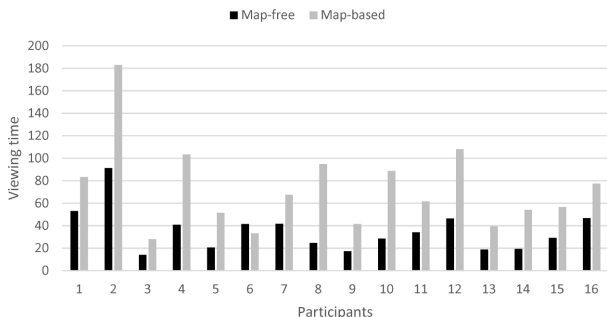


Fig. 11 Comparison of viewing time.

Table 5 Summary of experimental result (standard deviation is shown in parentheses).

	Map-free	Map-based	p-value
# of checking interface	15.2 (4.2)	16.8 (6.4)	0.223
Viewing time[s]	35.6 (18.5)	73.3 (37.1)	2.2E-5***
Time/Check[s]	2.34 (0.93)	4.64 (2.00)	0.00045***
Travel time[s]	457.1 (34.0)	453.4 (37.9)	0.7607

was 1 using the map-free interface and 2 using the map-based interface, respectively. As shown in Table 5, there is no significant difference between travel time of the map-free and the map-based interfaces. From these results, it can be said both interface has the same ability of navigating a user.

Regarding the frequency of checking the screen of the interfaces, there is no significant difference between the map-free and the map-based interfaces. It is also observed with both interfaces that most of participants checked the screen of the interface more frequently than the number of intersections as shown in Table 3.

On the other hand, total viewing time as well as the viewing time per checking the interface (Time/Check) of the map-free interface is significantly smaller than those of the map-based interface. Therefore, the proposed map-free interface is effective for keeping users from focusing on the screen of the interface. It will contribute to the safety of walking, and availability of enjoying the landscape as noted in Sect. 3.4.

6. Conclusion

A walking route recommender system is proposed for continuously supporting a user to take a walk as daily exercise. The proposed algorithm recommends a route from/to users' home, by following which users can consume their target calories without managing consumed calories by themselves. Considering the sustainable usage, the algorithm manages consumed calories on monthly basis, and recommends robust routes in case users do not follow the recommendation. It also tries to keep users from getting bored by recommending different routes from the previous day. The effectiveness of the proposed algorithm was evaluated with agent simulation that supposes to use the system for a month. The simulation result shows that the agent can consume target calories precisely and stably.

The paper also proposes a map-free navigation interface, which was evaluated with test participants. The experimental result shows viewing time of the map-free interface is significantly less than that of the map-based interface. This result indicates the proposed interface is effective for keeping users from focusing on the screen of the interface.

Although walking can be enjoyed regardless of age, we think elderly is included in our potential target users. As the test participants took part in the experiment of the navigation interface were young adult, its usability for elderly

should be evaluated. Regarding the recommendation algorithm, it always recommends the shortest path between visiting points even in the returning route (the last element in the total route). We are interested in finding the returning route in more flexible manner so that the target calories can be consumed more exactly. Furthermore, future works include evaluation of the recommendation algorithm by actual users.

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References

- [1] T. Chang, S. Hachima, and K. Sugiyama, "Road Sequence Evaluate Structure Research Focused on "Boredom"," J. Architecture of Infrastructure and Environment, vol.1, pp.163–171, 2006. (in Japanese)
- [2] J.-H. Chiang, P.-C. Yang, and H. Tu, "Pattern Analysis in Daily Physical Activity Data for Personal Health Management," *Pervasive and Mobile Computing*, vol.13, pp.13–25, 2014.
- [3] L. Chittaro and S. Burigat, "Augmenting Audio Message with Visual Directions in Mobile Guides: an Evaluation of Three Approaches," *Proc. 7th Int'l Conf. Human Computer Interaction with Mobile Devices & Services*, pp.107–114, 2005.
- [4] T. Daito, J. Tanabe, M. Tange, K. Satou, S. Ota, and T. Uchida, "Pedestrian navigation system using RFID-tag: architecture and its evaluation based on a field trial," *10th Int'l Conf. Mobility and Transport for Elderly and Disabled People*, 2004.
- [5] R.P. Darken, T. Allard, and L.B. Achille, "Spatial Orientation and Wayfinding in Large-Scale Virtual Spaces II," *PRESENCE*, vol.8, no.6, pp.3–6, 2006.
- [6] J.A. Harris and F.G. Benedict, "A Biometric Study of Human Basal Metabolism," *National Academy of Science of the United States of America*, vol.4, no.12, pp.371–373, 1918.
- [7] M. Ester, H. Kriegel, J. Sander, and X. Xu, "A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise," *2nd Int'l Conf. Knowledge Discovery and Data Mining*, pp.226–231, 1996.
- [8] W. Gu, Z. Yang, L. Shangguan, W. Sun, K. Jin, and Y. Liu, "Intelligent Sleep Stage Mining Service with Smartphones," *UbiComp '14*, pp.649–660, 2014.
- [9] A. Hamper, J. Wendt, C. Zagel, and F. Bodendorf, "Behavior Change Support for Physical Activity Promotion: A Theoretical View on Mobile Health and Fitness Applications," *49th International Conference on System Sciences*, pp.3349–3358, 2016.
- [10] Y. Inoue, A. Sashima, T. Ikeda, and K. Kurumatani, "Indoor Emergency Evacuation Service on Autonomous Navigation System using Mobile Phone," *2nd Int'l Symp. Universal Communication*, pp.79–85, 2008.
- [11] Y. Iwata, M. Yanagisawa, and N. Togawa, "A Navigation System with Visible Landmarks for Pedestrians," *DICOMO2013*, pp.702–716, 2013. (in Japanese)
- [12] T. Katayama, M. Nakamiya, M. Yamashita, K. Murao, K. Tanaka, T. Terada, and S. Nishio, "Development of a Navigation System with a Route Planning Algorithm Using Body-Worn Sensors," *6th Int'l Conf. Advances in Mobile Computing and Multimedia*, pp.88–93, 2008.
- [13] J. Kim and T. Hasegawa, "An experimental study on the positioning by M-CubITS," *7th Int'l IEEE Conf. Intelligent Transportation Systems*, pp.977–981, 2004.
- [14] S. Kitamura, K. Kitamura, Y. Nishida, K. Sakae, J. Yasuda, and H. Mizoguchi, "Community Participation Support Using an ICF-Based Community Map," *DUXU2013*, pp.516–524, 2013.
- [15] K. Kubota, F. Maeda, and Y. Kikuchi, "Proposal and Evaluation of Pedestrian Navigation System," *IPSI Journal*, vol.42, no.7, pp.1858–1865, 2001. (in Japanese)
- [16] T. Kurashima, T. Iwata, G. Irie, and K. Fujimura, "Travel Route Recommendation Using Geotags in Photo Sharing Sites," *19th ACM Int'l Conf. Information and Knowledge Management*, pp.579–587, 2010.
- [17] M. Lee, K. Tanaka, and Y. Narita, "Kansei Evaluation on the Tiresomeness of Products using Visual Images," *Transaction of Japan Society of Kansei Engineering*, vol.11, no.3, pp.407–417, 2012. (in Japanese)
- [18] K.L. Lovelace, M. Hegarty, and D.R. Montello, "Elements of Good Route Directions in Familiar and Unfamiliar Environments," *Int'l Conf. Spatial Information Theory*, vol.1661, pp.65–82, 1999.
- [19] X. Lu, C. Wang, J.-M. Yang, Y. Pang, and L. Zhang, "Photo2Trip: Generating Travel Routes from Geo-Tagged Photos for Trip Planning," *ACM Int'l Conf. Multimedia*, pp.143–52, 2010.
- [20] Ministry of Health, Labour and Welfare, Japan, "Exercise guide 2006," <http://www.mhlw.go.jp/bunya/kenkou/undou01/pdf/data.pdf>, p.6, 2006. (in Japanese)
- [21] S. Nakajima, D. Kitayama, Y. Sushita, K. Sumiya, N.P. Chandrasiri, and K. Nawa, "Route Recommendation Method for Car Navigation System based on Estimation of Driver's Intent," *IEEE Conf. Vehicular Electronics and Safety*, pp.318–323, 2012.
- [22] N. Sakata, T. Kurata, M. Kourogi, and H. Kuzuoka, "Situating Music: An Application to Interactive Jogging," *ISWC 2006 Student Colloquium*, 2006.
- [23] A. Sano and R.W. Picard, "Stress Recognition using Wearable Sensors and Mobile Phones," *2013 Humaine Association Conference on Affective Computing and Intelligent Interaction*, pp.671–676, 2013.
- [24] W. Sasaki and Y. Takama, "Walking Route Recommender System Considering SAW Criteria," *Conf. Technology and Applications of Artificial Intelligence*, pp.246–251, 2013.
- [25] X. Xu, W. Sasaki, C.-C. Yu, and Y. Takama, "Proposal of Collecting Lighting Situation of Roads at Night for Recommendation of Safety Walking Route Using Smartphone," *IEEE/SICE Int'l Symp. System Integration*, pp.414–418, 2014.
- [26] A. Shinjo and S. Yoshida, "A Study on the Effective Evacuation Guidance using Personal Digital Assistance," *18th Annual Conf. JSAI*, pp.2G2-04, 2004. (in Japanese)
- [27] M. Sumida, T. Mizumoto, and K. Yasumoto, "Smartphone-based Heart Rate Prediction for Walking Support Application," *IEICE Workshop on Smart Sensing, Wireless Communications, and Human Probes*, pp.4–11, 2013.
- [28] K. Tsukada and M. Yasumura, "ActiveBelt: Belt-Type Wearable Tactile Display for Directional Navigation," *Lecture Notes in Computer Science*, vol.3205, pp.384–399, 2004.
- [29] World Health Organization, "The Ottawa Charter for Health Promotion," *Milestones in Health Promotion: Statements from Global Conferences*, p.1, 2009.
- [30] W. Wu, L. Chen, and L. He, "Using Personality to Adjust Diversity in Recommender Systems," *24th ACM Conf. Hypertext and Social Media*, pp.225–229, 2013.
- [31] Y. Zheng, L. Zhang, X. Xie, and W.-Y. Ma, "Mining Interesting Locations and Travel Sequences from GPS Trajectories," *18th Int'l Conf. World Wide Web*, pp.791–800, 2009.
- [32] C.-N. Ziegler, S.M. McNee, J.A. Konstan, and G. Lausen, "Improving Recommendation List through Topic Diversification," *Proc. 14th Int'l Conf. World Wide Web*, pp.22–32, 2005.



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