PAPER

Design Differences in Pedestrian Navigation Systems Depending on the Availability of Carriable Navigation Information

Tetsuya MANABE[†a)], ***Member and*** **Takaaki HASEGAWA**[†], ***Fellow***

SUMMARY In this paper, the differences in navigation information design, which is important for kiosk-type pedestrian navigation systems, were experimentally examined depending on presence or absence of carriable navigation information in order to acquire the knowledge to contribute design guidelines of kiosk-type pedestrian navigation systems. In particular, we used route complexity information calculated using a regression equation that contained multiple factors. In the absence of carriable navigation information, both the destination arrival rate and route deviation rate improved. Easy routes were designed as M (17 to 39 characters in Japanese), while complicated routes were denoted as L (40 or more characters in Japanese). On the contrary, in the presence of carriable navigation information, the user's memory load was found to be reduced by carrying the same navigation information as kiosk-type terminals. Thus, the reconsideration of kiosk-type pedestrian navigation systems design, e.g., the means of presenting navigation information, is required. For example, if the system attaches importance to a high destination arrival rate, L_Carrying without regard to route complexity is better. If the system attaching importance to the low route deviation rate, M_Carrying in the case of easy routes and L_Carrying in the case of complicated routes have been better. Consequently, this paper presents the differences in the designs of pedestrian navigation systems depending on whether carriable navigation information is absent or present.
key words: *pedestrian navigation, route complexity, normalized travel time, route deviation rate, multiple regression analysis*

1. Introduction

Pedestrians need comfortable mobility environments in various locations, such as stations, airports, shopping centers, and malls. Pedestrian navigation systems improve human mobility. Such systems have several components [1]. The navigation information presented to users, one of the components in pedestrian navigation systems, is important for providing comfortable mobility environments. Previous studies regarding navigation information have considered navigation information components [2], [3], methods for generating guidance sentences [4], and presentation methods [5], [6].

Two types of pedestrian navigation systems are used: kiosk-type and mobile-type. A kiosk-type system does not require positioning techniques, e.g., a global positioning system (GPS), because the device is fixed and the user's location and direction can be uniquely determined. However, a user cannot bring along navigation information displayed on a kiosk-type terminal but must memorize the information. Excessive detail in navigation information prevents a user from remembering all of it, creating difficulty for the user to arrive at the desired destination. Moreover, if a path becomes complicated, the navigation information provided by the kiosk-type navigation to a user increases; hence, the user's memory load increases as well. Thus, navigation information presented on kiosk-type systems must be designed in consideration of user memory loads. Refs. [7] and [8] focused on the number of turns, e.g., the number of instructions or simplicity of guidance sentences rather than passage distance, which is typically used for route computation.

One of the methods for reducing the loads on user's memories required by kiosk-type pedestrian navigation systems involves users bringing navigation information along using other media, such as paper. This method reduces users' memory loads but might require reconsideration of the design of kiosk-type pedestrian navigation systems, e.g., the means of presenting navigation information, from the viewpoint of user mobility. This paper clarifies the design differences in kiosk-type pedestrian navigation systems that depend on the availability of carriable navigation information. Moreover, we acquire the knowledge to contribute design guidelines of kiosk-type pedestrian navigation systems.

2. Provision of Navigation Information and Complexity of Routes on Pedestrian Navigation Systems

Conventional studies of route guidance in linguistics and cognitive psychology have considered navigation information components (in particular, navigation sentences) and human recognition processes [9]–[12]. May et al. [2] examined the navigation information that is required in pedestrian navigation systems, e.g., distance, junctions, landmarks, road types, and street names and numbers.

Pedestrian navigation devices are of two types, mobile-type, which use mobile devices such as smartphones [13]–[15], and kiosk-type which use fixed installation apparatus [4], [16]. The mobile-type pedestrian navigation systems require high-quality location and orientation information to provide high-quality service. Positioning techniques widely used on mobile devices are GPSs and the access points of wireless local area networks (WLANs). GPSs, the first positioning social infrastructure, can provide accurate positioning in open-sky areas but do not work properly inside buildings, in outdoor areas of multistory buildings, or in underground malls. For example, Kojima et al. [17] evaluated the positioning performance of GPS-equipped mobile phones in the west exit area of Shinjuku Station and reported that the

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[†]The authors are with the Division of Mathematics, Electronics and Informatics, Graduate School of Science and Engineering, Saitama University, Saitama-shi, 338-8570 Japan.
a) E-mail: manabe@hslab.ees.saitama-u.ac.jp
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average and maximum errors were 79.95 m and 812.61 m, respectively. The positioning technique using WLAN access points is becoming the second positioning social infrastructure after GPSs. Constructing and updating methods are concern for stably providing accurate and precise positioning performance [18]. Mobile-type pedestrian navigation systems therefore need positioning subsystems (e.g., GPSs and WLANs) that can provide accurate and precise positioning. In contrast, kiosk-type pedestrian navigation systems do not require such positioning techniques, because devices of such systems are fixed in location and direction. Moreover, mobile-type systems need some kind of belongings, e.g., smartphone; on the other hand, any users can use kiosk-type systems regardless of the belongings. However, a user cannot carry navigation information presented on kiosk-type devices, but must memorize it. Therefore, navigation information on kiosk-type pedestrian navigation systems must be designed with consideration of user memory load.

Examples of methods for presenting navigation information include navigation sentences (including audio guidance) [4], maps [3], [5], and arrows [16], [19]. Kray et al. [6] compared different presentations, such as text, speech, 2D sketches (e.g., arrows), 2D maps, and 3D maps, from the viewpoints of location- and orientation-information requirements and cognitive and technical resources. Moreover, the paper reported that the cognitive resources of textual and speech instructions were low-medium, and that the others (2D sketches, 2D maps, 3D maps) were required medium-high cognitive resources.

Shao et al. [7] used two criteria (travel distance and turning) and the following cost function to examine route complexity:

$$\lambda \cdot Cost_{distance} + (1 - \lambda) \cdot Cost_{instructions}, \tag{1}$$

where $Cost_{distance}$ is derived from the cost function based on distance, $Cost_{instructions}$ is derived from the cost function based on turning (instruction complexity), and $\lambda \in [0, 1]$ is a heuristic parameter used for a weighted sum. Duckham et al. [8] proposed an algorithm that can be used to select routes that minimize the complexity of instructions, rather than the distance traveled. Golledge [20] ranked route selection criteria experimentally. On the other hand, as described below, there are other route complexity criteria in addition to the travel distance and the number of turns, and they must be considered simultaneously.

This paper clarifies experimentally the navigation information design differences that are important for kiosk-type pedestrian navigation systems that depend on whether carriable navigation information is available. In particular, this paper focuses on the text-based navigation system that uses a kiosk-type device singly as the milestone for establishing the design methodology of pedestrian navigation systems. In the experiments, we used the route complexities calculated using a regression equation containing multiple factors.

3. Route Complexity

Route complexity is a numerical measure combining various factors. This paper discusses two types of route complexity. Route complexity type I (RC-I) is based on the concept that complicated routes require long travel times. Route complexity type II (RC-II) is based on the concept that complicated routes cause many deviations from recommended routes.

Route complexity was calculated using multiple regression analysis. The candidate explanatory variables of the multiple regression analysis were passage distance and number of nodes, turns, or landmarks. The passage distance is the distance using an optimal route, e.g., the shortest path, from an origin to a destination. The optimal route can be calculated from weighted graphs using shortest-path algorithms, e.g., Dijkstra's method [21]. The number of nodes is the number of intersections that people pass through. The number of turns is the number of times that people move in new directions at the nodes of the optimal routes. The number of landmarks is the number of locations on the optimal routes that are easy to recognize and help people understand where they are. The objective variables used for RC-I and RC-II were the normalized travel time and the route deviation rate, respectively. The normalized travel time is defined in Ref. [16] as

$$NormalizedTravelTime = \frac{TravelTime}{ReferenceTravelTime}, \tag{2}$$

where the reference travel time is the total time that people who know the optimal route in an area spend walking to reach their destination. The travel time is the total time that people who are not familiar with an area spend walking to reach their destination, using a system and reading navigation information. Use of the normalized travel time decreases the effect of differences in distance to destinations and walking velocities. For example, if a person were to lose his or her way, the travel time would become greater than the reference travel time. As a result, the normalized travel time would be far from 1. If a person were not to wander, the travel time would become nearly equal to the reference travel time. As a result, the normalized travel time would be nearly equal to 1. The route deviation rate is the number of deviations[†] occurring during a trip from an origin to a destination versus the total number of trips.

The route complexity was calculated using the following procedures.

i) The shortest paths of each origin-destination (OD) in the target area were calculated using Dijkstra's method [21].
ii) The passage distance and numbers of nodes, turns, and landmarks of each route computed in i) were determined.

[†]A deviation was defined in Ref. [22] as a person reaching a node that was not included on the navigated route.

iii) The normalized travel time and deviation condition for each time that people travel in the target area were observed.
iv) The multiple regression analysis was performed. The explanatory variables used were the passage distance and the numbers of nodes, turns, and number of landmarks. The objective variable was either the normalized travel time or the deviation condition. The normalized travel times were calculated using Eq. (2). In the event that a person could not arrive at the destination, the normalized travel time of the trip was given an arbitrary large value, e.g., 10. In the event that deviation occurred, the deviation condition was given the value 1.
v) The route complexity of each route was calculated using the regression equation of iv). RC-I and RC-II used the normalized travel time and route deviation rate, respectively, as the objective variable.

The analysis method using route complexity was as follows.

i) Two graphs were created: one for the destination arrival rates of the normalized travel time within N versus RC-I, where N is an arbitrary constant such as 2 or 4, the other for the route deviation rates versus RC-II.
ii) Quadratic approximation curves were drawn using the least-squares method in order to observe the graph trends.

4. Design Differences in Pedestrian Navigation Systems Depending on the Availability of Carriable Navigation Information

Kiosk-type pedestrian navigation systems, as described in Sect. 2, show navigation information on a terminal's display, with the result that users cannot take the navigation information with them. Thus, such systems must be designed considering user memory load. One of the methods for reducing user memory load on a kiosk-type system is for users to carry the navigation information using other media, such as paper. However, reconsideration of the design of kiosk-type pedestrian navigation systems, e.g., in the means of presenting navigation information, might be required from the viewpoint of user mobility. This section presents the results of experiments that examined this possibility. Then, we divide participants (subjects) of the experiments into two groups. The first group's participants were permitted to use only the kiosk-type terminal. On the other hand, the other group's participants were permitted to use both the kiosk-type terminal and the mobile-type terminal including paper. The cases wherein carriable navigation information was absent and present are described in Sects. 4.1 and 4.2, respectively.

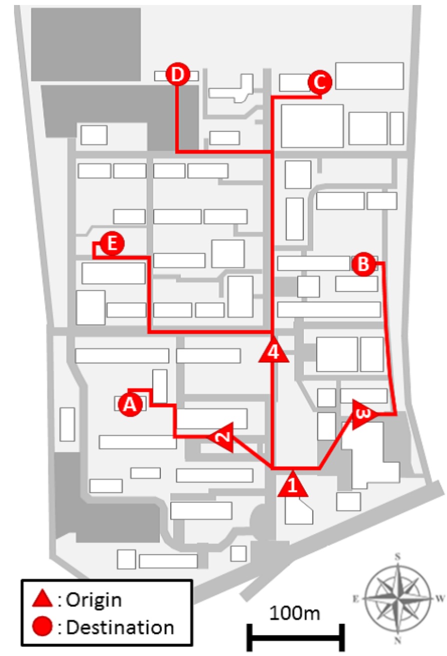


Fig. 1 Experimental environment in Saitama University.

4.1 Experimental Results in the Absence of Carriable Navigation Information

4.1.1 Experimental Overview

The experimental area was the outdoors of Saitama University (380 m east–west and 500 m north–south). The participants included 48 university students (38 men and 10 women). The experiment routes were of 10 different complexities (four origins and five destinations)†. Figure 1 and Table 1 show the origins, destinations, routes, and candidate explanatory variables of each OD. The navigation information for the participants included guidance sentences, direction of travel, passage distance, and travel time. This experiment was carried out by changing the level of detail of the navigation information, that is, the length of the navigation instructions, in order to design kiosk-type pedestrian navigation systems considering user memory load. Then, the navigation sentences, in Japanese, were prepared in three different lengths, as follows:

- Short (S): 16 or fewer characters
- Medium (M): 17 to 39 characters
- Long (L): 40 or more characters

†Saitama University is consisted of five faculties (Faculty of Liberal Arts, Faculty of Education, Faculty of Economics, Faculty of Science, Faculty of Engineering), and most of the students in Saitama University use nearby facilities of the departments that they belong. The experiments in this paper were carried out based on our empirical knowledge that there are an extremely low number of students who have some knowledge of the whole area of the University.

Table 1 Candidate explanatory variables of each OD in 4.1.

Origin	Destination	Passage distance	Num. of nodes	Num. of turns	Num. of landmarks
1	A	220	10	6	6
1	B	275	11	3	5
1	C	440	17	2	5
1	D	450	15	3	4
1	E	400	17	5	6
2	A	130	7	4	5
3	B	180	7	1	4
4	C	280	11	1	4
4	D	290	9	2	3
4	E	240	11	3	5

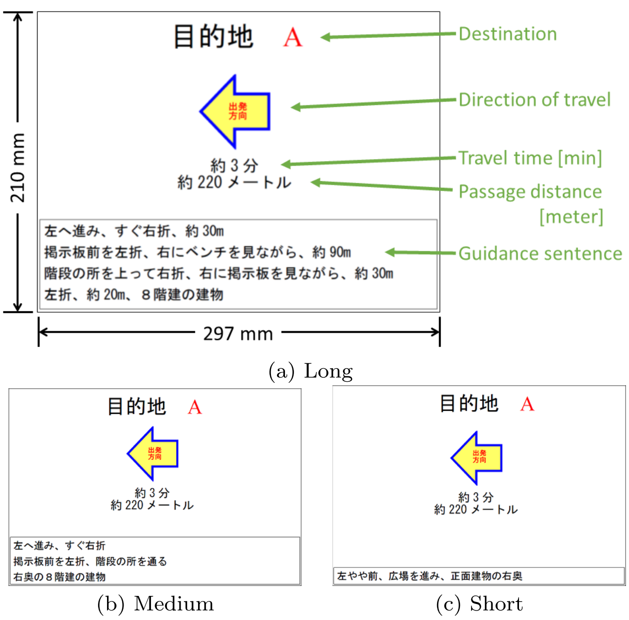


Fig. 2 Navigation information presented on kiosk-type terminal described in Sect. 4.1.

M has enough route information, e.g., corners and landmarks, for reaching a destination; and the number of characters is that most of people can memorize. S has a lack of route information; however, most of people can memorize them easily, because the number of characters is smaller than M. L has detailed route information; however, most of people can not memorize them easily, because the number of characters is too large. Here, proper names of destinations and landmarks were not used to reduce the effects of participants' prior knowledge against experiment results. For example, destination names were replaced with letters from "A" through "E." The descriptions of landmarks were such features as shapes, colors, and the number of floors of buildings. The directions of travel, passage distance, and travel time were displayed independently of the length of navigation sentences. Figure 2 shows an example of the navigation information†.

†The experiments were conducted in Japanese. S, M, and L were determined from the number of characters in Japanese, hence Fig. 2 has been shown in Japanese. Table 2 shows the English translations of the guidance sentences of Fig. 2.

Table 2 English translations of guidance sentences of Fig. 2.

(a)	Long	Go left and turn right for 30 meters. Turn left in front of bulletin boards and go straight for 90 meters seeing benches on your right. Climb stairs and then turn right. Go for 30 meters seeing bulletin boards on your right. Turn left and go for 20 meters. The eight-storied building is your destination.
(b)	Medium	Go left and turn right. Turn left in front of bulletin boards and climb stairs. Your destination is the eight-storied building at the right-hand side of the back.
(c)	Short	Go left forward and pass through a plaza. Your destination is the right-hand side of the back of the front building.

The experiment was conducted using the following procedure.

i) Navigation sentences were presented to each participant at a departure location (origin). The destinations and different lengths of the navigation instructions were shown in a random order.
ii) Each participant read and memorized the navigation sentences after taking note of the time at which he or she began to read.
iii) Each participant began moving after taking note of his or her departure time.
iv) Each participant searched for his or her destination by relying on the memorized navigation sentences.
v) Each participant took note of his or her destination arrival time, if he or she arrived at the destination. Arrival to the destination was defined in this experiment as a participant standing in front of the doorplate of the destination. The doorplates were 99 mm wide and 70 mm high; hence, the participants could not recognize the plates visually unless standing in front of them. The search time was limited according to the travel distance. When the search time exceeded the time limit, the trial was counted as a non-arrival trial.
vi) Each participant returned to the starting point immediately after v).
vii) Each participant took note of the time at which he or she returned back to the starting point.
viii) Each participant drew the traversed route on a blank map and answered questionnaires about the usage frequency of the facility. If the usage frequency of the facility was high, the trial data was excluded from the calculation objects.
ix) Each participant repeated processes i)-viii) five times.

4.1.2 Analysis in terms of Route Complexity

We calculated the normalized travel time and route deviation rate of each trial based on the results of the steps described in Sect. 4.1.1. In this paper, the normalized travel time was calculated as follows:

$$\begin{aligned} &ReferenceTravelTime \\ &\quad = ReturnedTime - DestinationArrivalTime \end{aligned} \tag{3}$$

and

$$\begin{aligned} &TravelTime \\ &\quad = DestinationArrivalTime - DepartureTime. \end{aligned} \tag{4}$$

The deviation was determined from an actual path using a map drawn by a participant. The following regression equations were obtained from the route complexities described in Sect. 3:

$$\begin{aligned} RC-I \ = \ &0.361 \times (Num.ofTurns) \\ &+0.006 \times (Pass.Dist.) - 0.317 \end{aligned} \tag{5}$$

and

$$\begin{aligned} RC-II \ = \ &0.045 \times (Num.ofLandmarks) \\ &+0.002 \times (Pass.Dist.) - 0.452. \end{aligned} \tag{6}$$

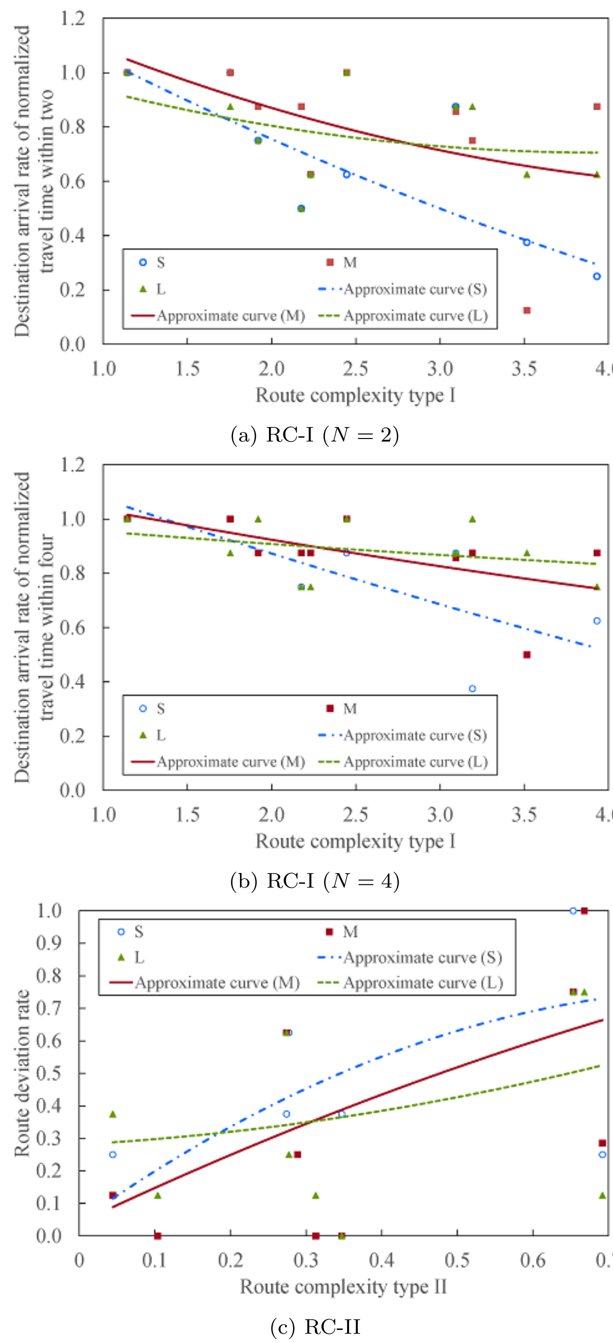
RC-I, which was based on the concept that complicated routes require longer travel times, increased when the number of turns was large or the passage distance was long. The explanatory variables of Eq. (5) are the same as those of the cost function Eq. (1) of Ref. [7]. In other words, the passage distance had a greater influence than the number of turns on RC-I; however, RC-I was not determined entirely by either facror. RC-II, which was based on the concept that complicated routes cause many deviations from the recommended route, increased when the passage distance was long or the number of landmarks was large. RC-II showed an increasing tendency with increasing number of landmarks, because the participant passed through many locations. That is, routes that contained many landmarks were not necessarily easy-to-understand. The number of landmarks had a greater influence than the passage distance on RC-II. Consequently, from the viewpoint of deviations, the factors of route complexity did not include only the passage distance and number of turns, which represent a difference between the cost function Eq. (1) and RC-I.

Table 3 shows the route complexity of each experimental route calculated using Eqs. (5) and (6). RC-I tends to increase with increasing number of turns, even if the passage distance was short. For example, RC-I from Origin-2 to Destination-A is 1.92. In constrast, the passage distance from Origin-4 to Destination-C was more than twice as long, but the value of RC-I is 1.75, because the number of turns was small. RC-II tends to increase with increasing number of landmarks, even if the passage distance was short. However, in constrast to RC-I, an order change did not occur, because the difference between the coefficients is small.

Figure 3 shows the analysis results using route complexity, and Table 4 shows residual sum of squares (RSS). Figures 3(a) and 3(b) present the destination arrival rates of the normalized travel time versus RC-I when $N = 2$ and $N = 4$,

Table 3 Calculation results of route complexity in absence of carriable navigation information.

Origin	Destination	RC-I	RC-II
1	A	3.19	0.28
1	B	2.45	0.35
1	C	3.09	0.69
1	D	3.52	0.67
1	E	3.93	0.65
2	A	1.92	0.04
3	B	1.14	0.10
4	C	1.75	0.31
4	D	2.18	0.29
4	E	2.23	0.27



(a) RC-I ($N = 2$)

(b) RC-I ($N = 4$)

(c) RC-II

Fig. 3 Analysis results in absence of carriable navigation information.

Table 4 RSS of Fig. 3.

	S	M	L
RC-I ($N = 2$)	0.281	0.469	0.237
RC-I ($N = 4$)	0.164	0.124	0.097
RC-II	0.913	0.987	0.754

Table 5 Values of F of Fig. 3.

	S vs. M	M vs. L	L vs. S
RC-I ($N = 2$)	1.67	1.98	1.19
RC-I ($N = 4$)	1.33	1.28	1.69
RC-II	1.08	1.31	1.21

respectively. The S arrival rates are generally low. A possible reason is the lack of navigation information as described in Sect. 4.1.1. The M arrival rates are high in the case of low route complexity (an easy route), and those of L are high in the case of high route complexity (a complicated route). In this experiment, the length of the navigation instructions was equivalent to the level of detail of the navigation information; hense, complicated routes required detailed navigation information, and L that had detailed navigation information as described in Sect. 4.1.1 was advantageous. Figure 3(c) shows the relationships between RC-II and the route deviation rates. The S route deviation rates are generally high. In the case of low route complexity, the M route deviation rates are low. In the case of high route complexity, the L route deviation rates are low, for the same reason as for RC-I.

Here, we consider errors between the curve and the plotted data. The calculation results of RSS (residual sum of squares) were shown in Table 4. In Table 4, M's RSS of RC-I when $N = 2$ is slightly larger than S or L. Then, we carried out F-test for checking the homoscedasticity of variances, and Table 5 showed the values of F for F-test. All of them were smaller than $F_{0.05}(9, 9) = 3.18$, that is, all of the quadratic approximation curves in Fig. 3 had the homoscedasticity of variances.

Consequently, the navigation instruction lengths of the kiosk-type navigation systems that improved both the destination arrival and route deviation rates were M (17 to 39 characters in Japanese) in the case of easy routes and L (40 or more characters in Japanese) in the case of complicated routes.

4.2 Experimental Results in the Presence of Carriable Navigation Information

4.2.1 Experimental Overview

The experimental location and routes, navigation information displayed on the kiosk terminals, and experimental procedure were all the same as in Sect. 4.1. The participants included 85 university students (54 men and 31 women). In this experiment, the participants could bring the navigation information displayed on the kiosk terminals with them on paper. We call the instruction lengths S_Carrying, M_Carrying, and L_Carrying, corresponding to those in Sect. 4.1. Figure 4 shows the navigation information that participants could bring, and it was assumed to be displayed on a smartphone.

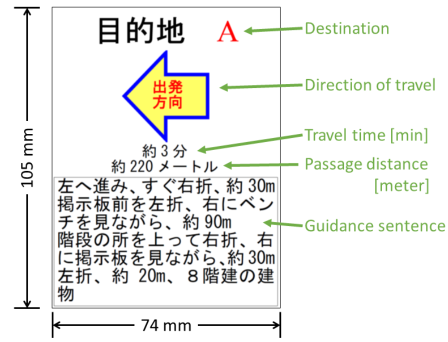


Fig. 4 Navigation information presented on mobile-type terminal described in Sect. 4.2. (English translation of guidance sentence is identical to that in Table 2(a).)

Table 6 Calculation results of route complexity in presence of carriable navigation information.

Origin	Destination	RC-I	RC-II
1	A	2.82	0.65
1	B	2.15	0.37
1	C	2.41	0.37
1	D	2.72	0.44
1	E	3.12	0.67
2	A	1.97	0.39
3	B	1.28	0.10
4	C	1.61	0.17
4	D	1.92	0.23
4	E	2.04	0.37

4.2.2 Analysis in terms of Route Complexity

We calculated the normalized travel times and route deviation rates of each trial based on the results of Sect. 4.2.1. The following regression equations were obtained from the route complexities described in Sect. 3:

$$RC-I = 0.280 \times (Num.ofTurns) + 0.003 \times (Pass.Dist.) + 0.333 \quad (7)$$

and

$$RC-II = 0.102 \times (Num.ofTurns) + 0.015 \times (Num.ofNodes) - 0.089. \quad (8)$$

The explanatory variables of Eq. (7) are the same as those of Eq. (5), while the coefficients of Eq. (7) are smaller than those of Eq. (5), because the participants' memory loads were reduced since the navigation information was carriable. The explanatory variables of Eq. (8) are different from those of Eq. (6) due to the availability of carriable navigation information.

Table 6 shows the complexity of each experimental route calculated using Eqs. (7) and (8). The results are different from those in Table 3, because of the differences between the coefficients of RC-I and the explanatory variables of RC-II.

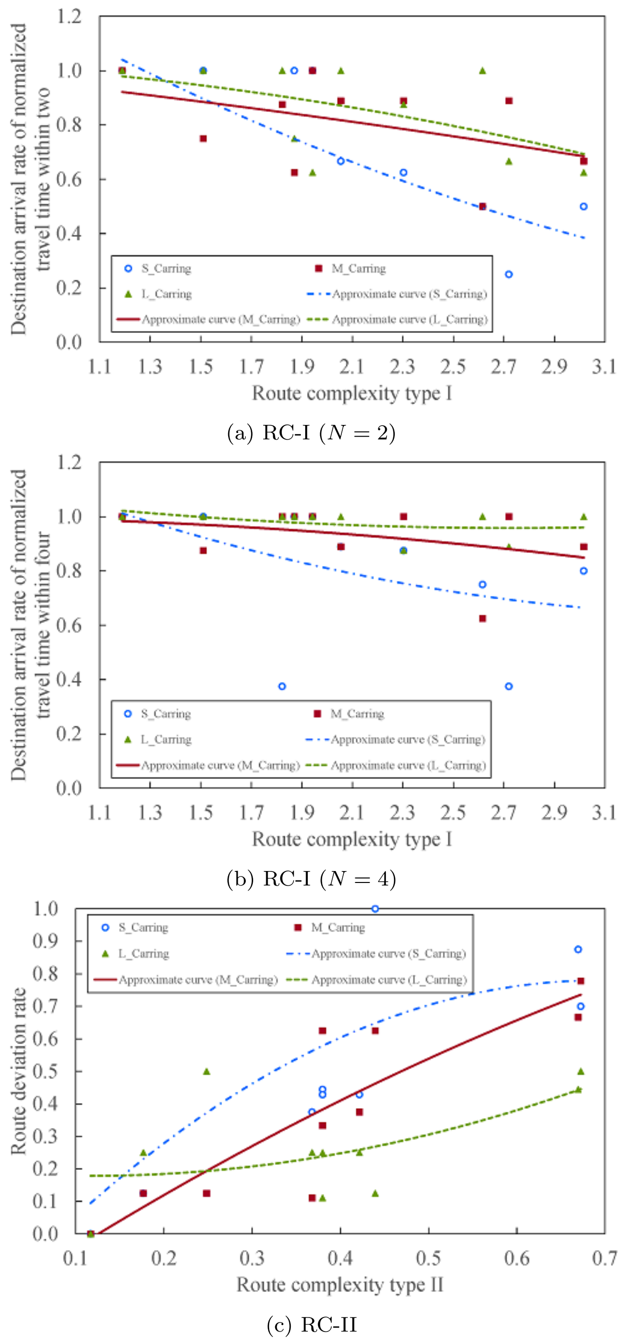


Fig. 5 Analysis results in presence of carriable navigation information.

Figure 5 shows the analysis results obtained using route complexity, and Table 7 shows RSS. Figures 5(a) and 5(b) show the destination arrival rates of the normalized travel time versus RC-I when $N = 2$ and $N = 4$, respectively. The S_Carrying arrival rate of is low overall. S has insufficient navigation information as described in Sect. 4.1.1; hence, the carriable navigation information of S is useless. The L_Carrying arrival rate is high overall. There is no intersection between L_Carrying and M_Carrying. This result differs from those in Sect. 4.1.2, because the participants did not need memorize verbose navigation information. Figure 5(c) shows the relationships between RC-II and the route deviation rates. The S_Carrying route deviation rate is high. In the case of low route complexity, the M_Carrying route deviation rate is low. In the case of high route complexity, the L_Carrying route deviation rate is low. In comparison with Fig. 3(c) described above, the point at which the optimum navigation information length switches from M (M_Carrying) to L (L_Carrying) at a smaller value; specifically, this point occurs at 0.31 and 0.25 in the absence and presence of carriable information, respectively.

Table 7 RSS of Fig. 5.

	S	M	L
RC-I ($N = 2$)	0.481	0.201	0.185
RC-I ($N = 4$)	0.433	0.113	0.019
RC-II	0.527	0.170	0.171

In Table 7, each RSS of S was slightly larger than M or L. On the other hand, each RSS of M and L, that were especially discussed in this paper, were smaller than the values in Table 4.

Consequently, the users' memory loads were reduced by carrying navigation information identical to that presented by the kiosk-type terminals. Thus, a reconsideration of the design of kiosk-type pedestrian navigation systems, e.g., a change in the presentation of navigation information, is required. For example, if the system attaches importance to a high destination arrival rate, L_Carrying is preferable regardless of the route complexity. If the system attaches importance to a low route deviation rate, then M_Carrying and L_Carrying are preferable in the cases of easy and complicated routes, respectively.

5. Conclusion

In this paper, the design differences in navigation information, which are important for kiosk-type pedestrian navigation systems, were experimentally evaluated depending on the availability of carriable navigation information in order to acquire the knowledge to contribute design guidelines of kiosk-type pedestrian navigation systems. In particular, we used route complexities calculated using a regression equation that contained multiple factors. In the absence of carriable navigation information, both the destination arrival rate and route deviation rate were found to be better for M (17 to 39 characters in Japanese) in the case of easy routes and for L (40 or more characters in Japanese) in the case of complicated routes. In contrast, in the presence of carriable navigation information, the users' memory loads were reduced by carrying the navigation information provided by kiosk-type terminals. Thus, a reconsideration of the design of kiosk-type pedestrian navigation systems, e.g., a change in the presentation of navigation information, was found to be necessary. For example, if the system attaches importance to a high destination arrival rate, then L_Carrying is preferable regardless of the route complexity. If the system attaches importance to a low route deviation rate, then M_Carrying and L_Carrying are preferable for easy and complicated routes, respectively. Consequently, this paper revealed that differences in pedestrian navigation system design depending on the availability of carriable navigation information are necessary.

These results were obtained under an area and complexity of Saitama University; and it is a first step for establishing the design methodology of pedestrian navigation systems. We want to clarify the relationship with the length of navigation sentences, human memory, an area or complexity of environments. In this paper, text-based navigation information was evaluated; however, map-based navigation information might yield different results. Thus, the necessary design differences between navigation systems in the presence and absence of carriable map-based navigation information will be investigated in future research. The future research will deal with designing and evaluating pedestrian navigation systems based on route complexity.

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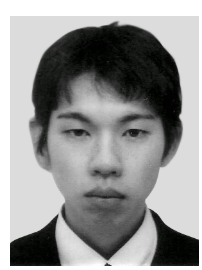

Tetsuya Manabe received his B.E., M.E., and Ph.D. degrees in Electrical and Electronic Systems from Saitama University, in 2006, 2008, and 2012 respectively. He has been an assistant professor in the Division of Mathematics, Electronics and Informatics, Graduate School of Science and Engineering, Saitama University since 2013. His current research interest is IT-based systems innovation for human mobility sophistication, in particular, realizing information society infrastructure in the real world, e.g., pedestrian navigation systems including seamless positioning and information systems that can save lives during disasters. He is a member of the Institute of Electrical and Electronics Engineers (IEEE), the Information Processing Society of Japan (IPSJ), the Japan Society of Civil Engineers (JSCE), and the Japan Society of Traffic Engineers (JSTE).

Takaaki Hasegawa received his B.E., M.E., and Ph.D. degrees in Electrical Engineering from Keio University in 1981, 1983, and 1986, respectively. He joined the Faculty of Engineering at Saitama University in 1986. Currently, he is a Professor of Division of Mathematics, Electronics and Informatics, Graduate School of Science and Engineering, Saitama University. During 1995–1996, he was a visiting scholar at the University of Victoria. His research interests include mobility and economic vitalization systems innovation based on quality of spatial comfort (QoSC) with information and communication technology (ICT) as well as intelligent transport systems (ITS) in particular, applications, platforms, architecture, communications, positioning, and HMI techniques for ITS. He was a chair of the technical research group on ITS as well as on spread spectrum technology (SST) at the IEICE. He was also a member of the board of governors of the IEEE ITS Society. He is currently a fellow of IEICE and a member of the IEEE, the International Association of Traffic and Safety Sciences (IATSS), the IPSJ, the Society of Automotive Engineers of Japan (JSAE), and the Japan Society of Applied Science.