

# Web Application to Generate Route Bus Timetables

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**Abstract**—Bus route system is the fundamental transportation device for aged people and students, and has an important role in every province. However, passengers decreases year by year, therefore the authors have developed the shortest path searching system called “BUS-NET” as a web application to sustain the public transport. Here, we take up generation of timetables. In general, timetable generation is considered as a very simple problem. However, there are some difficult problems. Firstly, bus stops of the same name are managed as one bus stop in the database of our system on grounds that error and cost decrease. Therefore, when timetables are generated, such bus stops must be distinguished. Secondly, there are so many bus stops in the timetables of bus route. However, all of them are not needed for an individual user in most cases. Thus, some bus stops may be excluded when a user intends to obtain a timetable of a bus route. In this paper, the authors report on the algorithms to solve those problems and the implementations, experiments of the functions.

## I. INTRODUCTION

As is well known, Japan faces the problems of aging population, and these problems cover a wide range. The sustaining of local public transportation systems is one of these problems and it increases in importance for local governments.

Bus route system is the fundamental transportation device for aged persons and students and should be preserved. However the number of passengers decreases year by year under present circumstances. Local governments try to keep the system by subsidies, which become immensely large sum of money and bear severely on finance of local governments.

Increase of private cars is thought to be main aftereffects of these phenomena. Local governments and bus companies should attempt to enhance the convenience for passengers and should make efforts to drive system efficiently.

Adoption of information technology (IT) is one of the effective methods. We have developed the shortest path searching system called “BUS-NET” and release it to the public as a web-service[3], [4], [8]. The average of accesses to the system is more than 16,000 per month. Taking into account of the current target area of the system is restricted, the number is very large and the importance of the system is confirmed. The system has many unique aspects such as an original path searching algorithm, however, they are not referred in this paper.

Here, generation of timetables is picked up. Printed timetables are needed for not only bus stops bus also public facilities,

hospitals, stores and so on. “BUS-NET” has a function of searching timetables, but does not have a generation function of printing timetables. In general, generations of timetables according to the traffic control data are considered as very simple problems. However, the bus route system has very complicated routes and timetable generation is not easy. We should deal with following cases, i.e., the cases that more than two bus stops of the same name can exist according to the directions of bus routes, the cases that buses of multiple routes stop at one bus stop. The timetable of such bus stop should arrange according to the bus destination for passengers’ conveniences.

In this paper, we report problems about generation of timetables and propose two algorithms to solve the problems. This paper is organized in six sections. Section 2 and 3 describe algorithms for generating bus route timetable and bus stop timetable, respectively. Implementation details are given in Section 4. Section 5 demonstrates the effectiveness of the proposed algorithms through experiments. Finally, Section 6 gives a brief conclusion of this paper.

## II. BUS ROUTE TIMETABLE

Bus route timetable shows the names of bus stops along a bus route and the arrival times of each bus stop as shown in Fig. 1.

Bus route name		
	Mark	Mark
Leave Bus stop 1	6:44	7:30
Arrive Bus stop 2	6:47	—
Arrive Bus stop 3	6:52	7:38
.	.	.
.	.	.

Fig. 1. An overview of bus route timetable.

Though there are many bus stops in most bus route timetables, not all of them are needed for an individual user in most cases. Some bus stops may be excluded when the user intends to obtain one bus route timetable. In addition, because elapsed time from a bus stop to the next bus stop is usually short,

it is not difficult to estimate the arrival time of a bus at an excluded bus stop. However, the following types of bus stops are important and may not be excluded.

- 1) The first bus stop and the last bus stop of a bus route.
- 2) The nearest bus stop for the place of a user.
- 3) Bus stops at which some buses stop and other buses do not stop.

The third type of bus stops may not be excluded because if they are excluded from bus route timetable one can not estimate whether a bus will stop at the excluded bus stop or will pass it.

In addition, because the connected excluded bus stops make it difficult to estimate the arrival time of a bus at an excluded bus stop, excluded bus stops should be distributed as uniformly as possible on a whole route.

We have developed the following procedure to choose bus stops that may be excluded from bus route timetable.

- 1) Let all bus stops of a bus route have an order number in the bus route and an evaluation value. A smaller evaluation value indicates a higher probability of exclusion. Those evaluation values are initially set to 0.
- 2) Add appropriate values to the evaluation values of the above important bus stops.
- 3) Choose a bus stop as the excluded bus stop which has the smallest evaluation value. If several bus stops have the same smallest evaluation value, choose one of them randomly.
- 4) Exit from the procedure if enough number of bus stops are excluded.
- 5) Increase the evaluation values of the rest bus stops according to the normal distribution[2] represented as the following equation.

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \quad (1)$$

where  $\mu$  is the order number of the excluded bus stop while  $x$  is the order number of each bus stop. The purpose of this step is to distribute excluded bus stops uniformly.

- 6) Go to Step 3.

### III. BUS STOP TIMETABLE

Bus stop timetable shows the arrival times and the destinations of buses that stop at a bus stop as shown in Fig. 2.

Usually, there are two bus stops with the same name facing each other across a road. In some cases, however, there is only one bus stop or there are more than two bus stops with the same name according to the form of the road. In this paper, we refer a collection of such bus stops as a “bus stop group”.

We manage bus stops with the same name as one bus stop in our database. It is due to the difficulty of managing the database with distinction of the bus stops having the same name. The reason is explained in the following.

In general, there are inbound route and outbound route. In Fig. 3, the bus leaving the station is the outbound route and the bus going to the station is the inbound route, therefore inbound

Bus stop name		Destination	
Hour	Minute	Bus Route Name	Bus Route Name
7	10	15	13
8	11	17	13
			19
.	.	.	.
.	.	.	.
.	.	.	.

Annotations: "Via legend" points to the '13' in the first row, second column. "Available day legend" points to the '13' in the second row, second column.

Fig. 2. An overview of bus stop timetable.

route buses usually stop at the bus stop  $A_1$  and outbound route buses usually stop at the bus stop  $A_2$  like bus route  $\alpha$ . However, buses of bus route  $\beta$  (inbound) stop at the bus stop  $A_2$ . Thus, it is impossible to identify the bus stop at which buses actually stop by only inbound and outbound.

Besides, the buses going to the station directly and the buses via downtown run different path, and stop at different bus stops like bus route  $\gamma$  in Fig. 4. In the example of Fig.4, buses going to the station stop at the bus stop  $B_1$ , and buses via downtown stop at the bus stop  $B_2$ . Furthermore, in circulation route like bus route  $\delta$  of Fig.5, similar situations occur. Some buses on a circulation route run in reverse. There are cases that some buses stop at one of the both bus stops with the same name and the others stop the bus stop opposite the road as illustrated in Fig. 5. Therefore, not all buses of same bus route always stop at same bus stop.

Moreover, if events are held, bus route paths may be briefly changed, therefore, it is needed to fix the database with it. However, it consumes more time and energy by distinction of bus stops with the same name. Therefore when we consider management cost and error possibility, it is not desirable to continue maintaining database with distinction of bus stops with the same name.

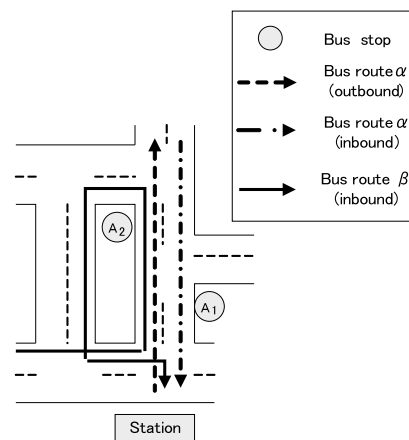


Fig. 3. Paths of bus routes bound for a station.

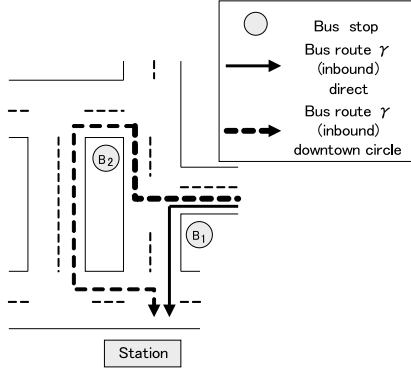


Fig. 4. Paths of a bus route bound for a station.

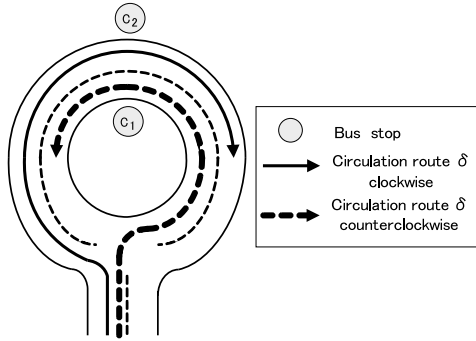


Fig. 5. Paths of a circulation route.

Considering those conditions, we have concluded that it is not practical to keep distinguishing each bus stop in a bus stop group in the database for our system. Consequently, when the timetable of a bus stop group is generated, buses that arrive at the bus stop group must be classified according to which bus stop in the group they actually arrive at. The fundamental idea of the classification is comparison of bus stops at which buses stop around the target bus stop. Bus stops at which buses of different bus routes stop are mostly different. If the all bus stops of the bus routes are used for the comparison, the buses are discretely classified. Therefore, bus stops around the target bus stop are used for the comparison. Furthermore, some buses on the same bus route run a little different path. Therefore perfect matching is not available.

Thus, we have developed the following algorithm using SOM (Self-Organizing Maps)[1], [5], [6]. In the following explanation of the algorithm, we assume classification of buses which stop in one bus stop group.

- 1) List the following bus stops from the target bus stop to final bus stop for every bus  $i$ . Define the bus stops as  $L1_i$ .
- 2) List  $n$  bus stops from each  $L1_i$ . Define the bus stops as  $L2_i$ .
- 3) Generate  $L3$  by collecting  $L2_i$  generated in Step 2.
- 4) Compare each  $L2_i$  with  $L3$  to generate an input vector

for a SOM. For each bus stop in  $L3$ , if it exists in  $L2_i$  then the corresponding element in the input vector is set to 1; otherwise, set to 0 as illustrated in Fig. 6.

- 5) Classify all input vectors made in Step 4 by using the SOM.
- 6) Calculate Euclid distance between every pair of labeled input vectors, if the distance is shorter than  $d$ , buses represented by the vectors are regarded as the same.
- 7) Repeat one more times from step 1 to step 6. However, list bus stops prior to the target bus stop in step 1 and step 2.
- 8) Buses classified into the same group in either first classification or second classification are regarded as the same group.

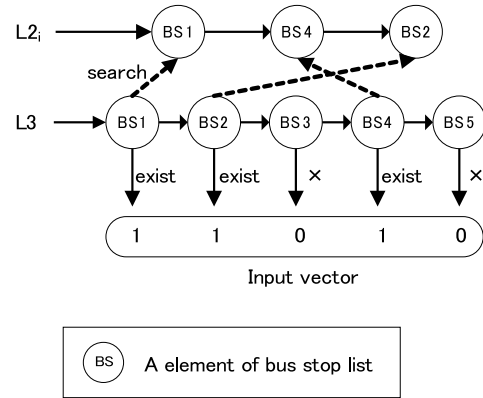


Fig. 6. Generation of an input vector.

#### IV. IMPLEMENTATION

We have implemented the functions of timetable generation using the algorithms that are described in Section 2 and Section 3 as a part of "BUS-NET"[8]. Currently, the system covers Tottori Prefecture in Japan. There are 2237 bus stops and 220 bus routes in the region.

In this section, we describe the implementation of the generation function of two kinds of timetables.

##### A. Generation Function of Bus Route Timetable

Fig. 7 shows a part of a bus route timetable which is generated by our system. Star marks of left side of bus stop names indicate that some bus stops are excluded before the bus stop. The number of star marks corresponds to the number of excluded bus stops.

When a user intends to obtain a bus route timetable, he can select paper size and the number of sheets of paper, if needed. He can also select whether the route name and the bus stop names are printed on all sheets or on only the first sheet of the multiple sheets of paper. If the bus route timetable is too large to print on the selected papers, user can exclude bus stops chosen by using the algorithm described in Section 2 just by clicking one button. A user can also specify bus stops to be excluded by hand.

運行パターン	甲	甲	甲	甲	甲	甲	甲	甲	甲
	(土)	(土)	(土)	(土)	(土)	(土)	(土)	(土)	(土)
	(日)	(日)	(日)	(日)	(日)	(日)	(日)	(日)	(日)
鳥取駅	07:00	07:20	08:10	09:00	09:50	10:40	11:10	12:00	12:40
☆☆ 本町一丁目	05	25	15	05	55	45	15	05	45
☆ 西町	08	28	18	08	58	48	18	08	48
☆☆ 城北団地	13	33	23	13	10:03	53	23	13	53
☆ 裏秋里		35			05		25		
中央病院		37			07		27		
血液センター前		37			07		27		
丸山	07:15		08:25	09:15		10:55		12:15	12:55
渡辺美術館前	16		26	16		56		16	56
寛寺口	17	07:40	27	17	10:10	57	11:30	17	57
☆☆ 新湯山	21	44	31	21	14	11:01	34	21	13:01
☆ 山湯山	23	46	33	23	16	03	36	23	03
海士	25	48	35	25	18	05	38	25	05
☆ 果	27	50	37	27	20	07	40	27	07
福部保育園前		51			21		41		
福部中学校前		51			21		41		
福部町総合支所前		52			22		42		
細川口	07:28	54	08:38	09:28	24	11:08	44	12:28	13:08
☆ 平野口	31	57	41	31	27	11	47	31	11
☆ 大谷	33	59	43	33	29	13	49	33	13

Fig. 7. A part of a bus route timetable.

Fig. 8 shows the result of the classification of buses by using SOM. A user can change the grouping of buses by drag & drop if needed. Fig. 9 corresponds to Fig. 8 with the group names written in English. The group numbers such as “Group 1” and “Group 2” in Fig. 9 correspond to the circled numbers such as ① and ② in Fig. 8.

### B. Generation Function of Bus Stop Timetable

The algorithm described in Section 3 can classify the buses which stop at a bus stop group by difference of the bus stops, and output Bus Stop Timetable. However, we cannot output practical Bus Stop Timetable as they are. We need to order the information of Bus Stop Timetable. Therefore, we have developed the following algorithm for timetable layout.

- 1) Classify buses into multiple groups by the destinations.
- 2) Subdivide each group by the bus route names.
- 3) If all buses of multiple groups generated in Step 2 run same path, collect the buses into same group.
- 4) If a bus run via different path in comparison with other buses of the bus route, indicate the legend symbol.

Fig. 10 shows a part of a bus stop timetable which is generated by our system. The algorithm described above classifies buses by destinations and bus route name. In Fig. 11, buses of multiple bus routes which run the same route are collected in the same row.

We can output orderly timetables by above algorithm. However, it is impossible to insert all buses into a page, because paper size is limited. Therefore, large timetables need to be divided into multiple pages. Thus, we have developed the following algorithm.

- 1) If the timetable can be inserted into a page as it is, this algorithm finishes. If next page exists, apply this algorithm to the next page.
- 2) Adjust timetable width by following order. If there are not a row classified by destinations which can be narrowed, go to Step 3.



Fig. 8. A result of the classification of buses by using SOM.

Group 1	Group 2
Iwai(Inbound)	Kitazono
Juropponmatsu(Outbound)	Juropponmatsu(Inbound)
Kitazono	Iwai(Outbound)

Fig. 9. The same result of Fig. 8 written in English.

- a) Select one of rows classified by destinations which can be narrowed and have the largest empty space.
- b) Narrow the row width selected in Step a.
- c) Go to Step 1.
- 3) Select one of rows classified by destinations whose width is the smallest, and insert the row into next page.
- 4) Go to Step 1.

## V. EXPERIMENT

### A. Experiment for Selection of Excluded Bus Stops

In this experiment, we confirm that bus stops which may be excluded from bus route timetable are chosen appropriately and they are distributed as uniformly as possible on a whole route.

Figs. 12 and 13 show route timetables for the same bus route with exclusion of bus stops by proposed algorithm. In those examples, the first bus stop of the route is Tottori station, the last bus stop of the route is Kaburajima, the nearest bus stop for the place of the user is Iwaionsen. The variance  $\sigma^2$  in Equation (1) is 1 in Fig. 12 and 5 in Fig. 13, respectively.

In both Figs. 12 and 13, the first bus stop of the route, the last bus stop of the route, and the nearest bus stop for the place of the user are not excluded. Furthermore, bus stops at which some buses stop and other buses do not stop are not excluded.

Next, we investigate the distribution of the excluded bus stops. Star marks in the timetable are at most two in Fig. 12, while there is one bus stop having four star marks in Fig. 13. The result indicates that a too large  $\sigma$  causes a non-balanced distribution of the excluded bus stop, because the evaluation values near the excluded bus stop are increased only little.

### B. Experiment for Classification by using SOM

In this experiment, we confirm that buses which arrive at a bus stop group are really classified according to which bus stop in the group they actually arrive at by developed algorithm.

通過予定時刻表 湖山			
行先	鳥取駅		
路線名	湖山鳥大(布勢)	鹿野	湖岸, 賀露循環, 賀露
時刻			
7		10●	03
	50●		32● 36
8	10 25●	19	15 39
9	12●学 35	37	10● 13
10			18 28
11		02	48 51
12		12	43
13		33	06 48

Fig. 10. A part of a bus stop timetable.

通過予定時刻表 本通り			
行先	鳥取駅		
路線名	岩井, 十六本松, 北園, 米里, 中央病院		
時刻			
7	16	20●	35 41● 45● 51
8	00●	06▲	17 21●
	31 34● 35		46● 51●
9	05	19●	29 36 40● 46●
10	04●	15 17 21●	39 40 50▲
11	05	17 24●	30 40● 51●
12		09	30 36 48 54●

Fig. 11. A part of a bus stop timetable.

Classification by using SOM is operated through two stages where the size of the map is  $15 \times 12$  in both stages. In stage 1, the number of learning steps is 2000, the neighborhood width is 15, the rate of learning is 0.05. In stage 2, the number of learning steps is 20000, the neighborhood width is 3, the rate of learning is 0.02. In addition,  $d$  mentioned in Section 3 is 1.5.

We tried to generate timetables of 1079 bus stop groups, which are all bus stop groups of east of Tottori prefecture, and compare those with real timetables which are given by bus companies. As a result, 1062 bus stop groups are correctly classified, but the others are not correctly classified.

Fig.14 shows partial example of a successful case. This is the example of circulation route told in Section 2. Each bus of the bus route is divided into the timetable of the bus stop which buses actually stop.

17 bus stop groups which are not correctly classified have a following feature. Bus stops at which buses stop after and before the target bus stop of each bus route are completely different as illustrated Fig. 15. Proposed algorithm can't properly classify such cases.

## VI. CONCLUSION

In this study, we have developed the algorithms to generate two kinds of bus timetable, i.e., bus route timetable and bus stop timetable. With regard to bus route timetable, bus stops

日本交通 - 岩井(下)															
運行パターン	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)			
鳥取駅	00	23									14:40	15:25	16:10	16:30	
☆ 鳥取 丁目	08	28									45	35	15	35	
☆ 森野	10	30	20	10	10:00	50	20	10	50	30	10	50	35	20	40
☆ 城崎西側	19	38	29	19	08	35	25	19	35	33	13	35	38	25	43
☆ 秋草	35					05	25								
☆ 宇野川	37	05	41	31	27	11	47	31	11	41	11	31	21	41	17:01
☆ 大坪	33	59	43	33	29	13	49	33	13	53	33	13	58	43	03
☆ 赤井大橋	36	08:02	46	36	32	16	52	36	16	56	36	16	16:01	46	06
☆ 子母沢	37	06				39	53	17	37	07	07	07	07	07	07
☆ 網代口	35	04				34	54	18	38	03	03	03	03	03	03
☆ 網代	39	05				35	55	19	39	04	04	04	04	04	04
☆ 網代口	40	06				36	56	20	40	05	05	05	05	05	05
☆ 下妻井	41	07				37	57	21	41	06	06	06	06	06	06
☆ 公民館前(岩井)	42	08	08:40	09:39	38	11:19	58	12:39	22	13:59	42	15:19	07	16:49	14
☆ 渡瀬原口															
☆ 中央警察署北	02	19	00	00	00	00	00	00	00	00	00	00	00	00	00
☆ 中央警察署南	03	18	00	00	00	00	00	00	00	00	00	00	00	00	00
☆ 石見駅	04	18	00	00	00	00	00	00	00	00	00	00	00	00	00
☆ 広瀬口(岩井)	04	21									31	19	01	24	
☆ 飯上	05	21									33	21	03	26	
☆ 岩井温泉	06	22									15:37	16:25	17:07	17:30	
☆ 岩井温泉上	07	22									37	25	07	30	
☆ 高名	08	22									39	26	09	32	
☆ 白城入口	08:00	08:26				10	10:00				13:00	20			
☆ 長春堂入口	08:00	08:26				10:56	40	12:16	13:40	20	15:00	16:25	17:30		
☆ 学校前(岩井)	09	27				57	17	41	01	01	26	26	31		
☆ 長谷津	03	29	09:11	10:01	59	11:41	19	13:01	43	14:21	03	15:41	28	17:11	33
☆ 公民館前(岩井)	06	32				13:00	22	46	06	06	31	31	36		
☆ 藤生	08	34				04	24	48	08	33	33	38			
☆ 神楽	10	36				06	26	50	10	35	35	40			
☆ 網代口	11	37									36	41			
☆ 網代口	12	38									37	42			
☆ 飯島											39	44			

Fig. 12. A bus route timetable with exclusion of bus stops ( $\sigma = 1$ ).

日本交通 - 岩井(下)															
運行パターン	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	(L)			
鳥取駅	00	23									14:40	15:25	16:10	16:30	
☆ 鳥取 丁目	08	28									45	35	15	35	
☆ 森野	10	30	20	10	10:00	50	20	10	50	30	10	50	35	20	40
☆ 城崎西側	19	38	29	19	08	35	25	19	35	33	13	35	38	25	43
☆ 秋草	35					05	25								
☆ 宇野川	37	05	41	31	27	11	47	31	11	41	11	31	21	41	17:01
☆ 大坪	33	59	43	33	29	13	49	33	13	53	33	13	58	43	03
☆ 赤井大橋	36	08:02	46	36	32	16	52	36	16	56	36	16	16:01	46	06
☆ 子母沢	37	06				39	53	17	37	07	07	07	07	07	07
☆ 網代口	35	04				34	54	18	38	03	03	03	03	03	03
☆ 網代	39	05				35	55	19	39	04	04	04	04	04	04
☆ 網代口	40	06				36	56	20	40	05	05	05	05	05	05
☆ 下妻井	41	07				37	57	21	41	06	06	06	06	06	06
☆ 公民館前(岩井)	42	08	08:40	09:39	38	11:19	58	12:39	22	13:59	42	15:19	07	16:49	14
☆ 渡瀬原口															
☆ 中央警察署北	02	19	00	00	00	00	00	00	00	00	00	00	00	00	00
☆ 中央警察署南	03	18	00	00	00	00	00	00	00	00	00	00	00	00	00
☆ 石見駅	04	18	00	00	00	00	00	00	00	00	00	00	00	00	00
☆ 広瀬口(岩井)	04	21									31	19	01	24	
☆ 飯上	05	21									33	21	03	26	
☆ 岩井温泉	06	22									15:37	16:25	17:07	17:30	
☆ 岩井温泉上	07	22									37	25	07	30	
☆ 高名	08	22									39	26	09	32	
☆ 白城入口	08:00	08:26				10	10:00				13:00	20			
☆ 長春堂入口	08:00	08:26				10:56	40	12:16	13:40	20	15:00	16:25	17:30		
☆ 学校前(岩井)	09	27				57	17	41	01	01	26	26	31		
☆ 長谷津	03	29	09:11	10:01	59	11:41	19	13:01	43	14:21	03	15:41	28	17:11	33
☆ 公民館前(岩井)	06	32				13:00	22	46	06	06	31	31	36		
☆ 藤生	08	34				04	24	48	08	33	33	38			
☆ 神楽	10	36				06	26	50	10	35	35	40			
☆ 網代口	11	37									36	41			
☆ 網代口	12	38									37	42			
☆ 飯島											39	44			

Fig. 13. A bus route timetable with exclusion of bus stops ( $\sigma = 5$ ).

where the influence when excluded is limited are automatically chosen by our algorithm. Consequently, a bus route timetable can be fit into a couple of selected-sized sheets of paper. With regard to bus stop timetable, when a user intends to obtain a timetable of a bus stop group, the proposed algorithm classifies buses that arrive at the bus stop group according to which bus stop in the group they actually arrive at, by using SOM. Then, timetables are generated for each bus stop in the bus stop group. On the latter algorithm, we tested the algorithm for 1079 bus stop groups in the east of Tottori prefecture in Japan, and the tests were successful at most bus stop groups except for 17 bus stop groups. Bus stop groups which are not correctly classified are only about 1.6%, and the cost for modification is very small.

The function of generating two kinds of bus timetable is

通過予定時刻表 賀露海岸		
行先	湖山賀露ジャスコ	鳥取駅
路線名	賀露循環	
時刻		
7		48
8	38●	
9	48	

通過予定時刻表 賀露海岸			
行先	湖山賀露ジャスコ	賀露湖山	湖山賀露
路線名	賀露循環		
時刻			
7			21●
8	04		
9			02

Fig. 14. Partial example of a bus timetable.

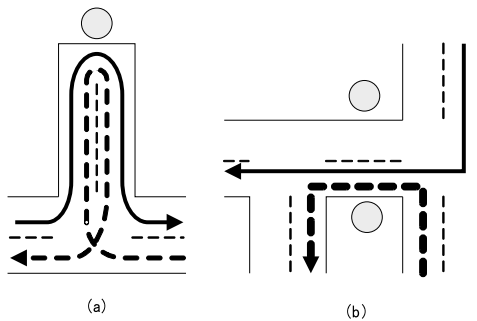


Fig. 15. Failure cases of classification algorithm.

implemented and opened as a part of “BUS-NET”[8]. Every user can view bus timetables in PDF format on the computer screen and can print them out using a printer in anywhere, in anytime if he is connected to the Internet, therefore this service will contribute to progress in convenience of route bus.

In future work, extra information, such as the low-floor bus which enables disabled people or senior adults to get on and off buses easily, will be provided on our bus timetable. Furthermore the timetable layout will be adjusted. We aim at posting the timetables at the bus stops without modification. This will lead to decrease of cost and time for modification of bus schedule.

In this paper, we proposed the algorithm which identify the bus stop which buses actually stop in bus stop groups by using a SOM, however this algorithm can apply to classification of buses by destinations[7]. If it succeed, this function can offer better timetables which are easily accessible to necessary information.

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