On the Automatic Generation of Route Bus Timetables According to the Classification of Destinations

KAZUNORI TOSHIOKA
Graduate School of Engineering
Tottori University
4–101, Koyama-Minami, Tottori
JAPAN
s032035@ike.tottori-u.ac.jp

TAKAO KAWAMURA
Faculty of Engineering
Tottori University
4–101, Koyama-Minami, Tottori
JAPAN
kawamura@ike.tottori-u.ac.jp

KAZUNORI SUGAHARA
Faculty of Engineering
Tottori University
4–101, Koyama-Minami, Tottori
JAPAN
sugahara@ike.tottori-u.ac.jp

Abstract: Route bus system is fundamental transportation device for aged people, and have important role in every province. However passengers decreases year by year. Therefore we have developed the shortest path searching system called “BUS-NET” to sustain the public transport. Here, generation of timetables is picked up. In general, it is considered as very simple problem, however the route bus system has very complicated routes. So we have developed algorithm which arrange timetable by bus destinations with SOM for timetable generation, and have implemented the function. In this paper, we report on developed algorithm and implementation, experiments of the function.

Key–Words: Public Transportation System, Route Bus, Timetable, SOM, Web service

1 Introduction

As is well known, Japan faces 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.

Route bus system is fundamental transportation device for aged persons and should be preserved, however the number of passengers decreases year by year under present circumstances. Local governments try to keep the system by subsidy, which becomes immensely large sum of money and bear severely on finance of local governments.

Increase of private car is thought to be main aftereffects of these phenomena. Local governments and bus companies should attempt to enhance the convenience of passengers to increase them and should make efforts to drive system costs down.

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[1, 2, 3]. The average number 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. In general, generations of timetables according to the traffic control data are considered as very simple problems. However, the route bus system has very complicated routes and fully automatic timetable generation is not easy. We should deal with following cases, i.e., the cases that more than two bus stops of the identical name can exist according to the directions of bus routes, the cases that buses of plural 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 describes 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.

2 Bus Route Timetable

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

Though there are many bus stops in most bus route timetables, all of them are not needed for a individual user in most case. Some bus stops therefore may be excluded when the user intends to obtain a bus

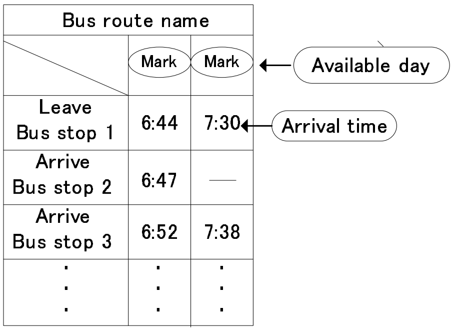

Fig. 1: An overview of bus route timetable.

route timetable. In addition, because elapsed times from a bus stop to the next bus stop are 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 of the route and the final bus stop of the route.

2. The nearest bus stop for the place of the 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 larger 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 represented as the following equation.

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

where μ 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.

3 Bus Stop Timetable

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

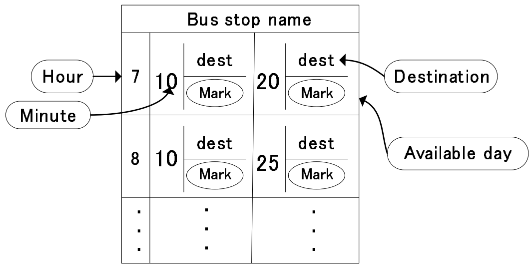

Fig. 2: An overview of bus stop timetable.

Usually, there are two bus stops which have identical 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 which have identical name according to the form of a road. In this paper, we refer a collection of bus stops having identical name as a "bus stop group".

In addition to the difference of the numbers of bus stops in bus stop groups, the role of each bus stop in a bus stop group is not fixed. Namely, there are cases that buses having the same final destination may stop at one of the both bus stops having identical name as illustrated in Fig. 3. Furthermore, some buses on a circulation route run in reverse, so there are cases that buses may stop at one of the both bus stops having identical name as illustrated in Fig. 4.

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. In addition, buses bound for same destination on each timetable should

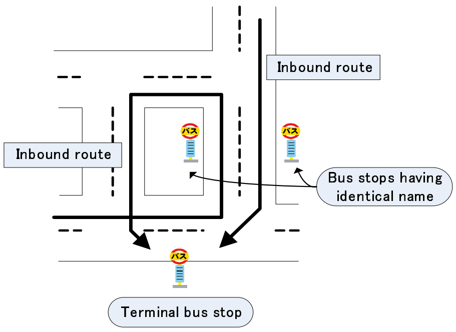

Fig. 3: Paths of bus routes bound for a terminal bus stop.

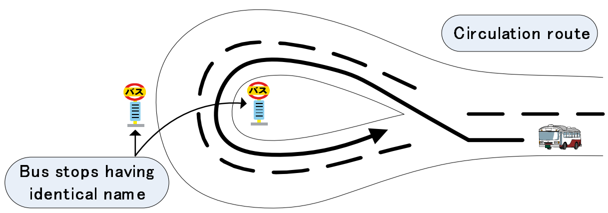

Fig. 4: Paths of a circulation route.

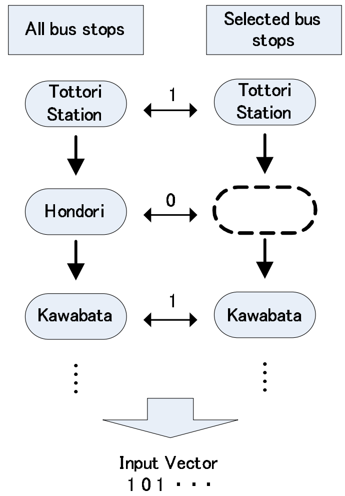

Fig. 5: Generation of an input vector.

be gathered near to generate timetables from which necessary information is easily accessible.

To do that, the following algorithm using SOM is developed.

1. List up the following n bus stops after the target bus stop for every bus.

2. Generate all bus stops list by collecting n bus stops lists generated in Step 1.

3. Compare each n bus stops list with the all bus stops list to generate an input vector for a SOM. For each bus stop in the all bus stops list, if it exists in n bus stops list then the corresponding element in the input vector is set to 1; otherwise, set to 0 as illustrated in Fig. 5.

4. Classify all input vectors which were made in Step 3 by using the SOM.

5. 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 same.

4 Implementation

We have implemented the functions of timetable generation using the algorithms that are presented in Section 2 and 3 as a part of “BUS-NET”[3]. Currently, the system covers the east of Tottori Prefecture in Japan. There are 1079 bus stops and 117 bus routes in the region.

According to the algorithm which is told in Section 2, for example, it is able to store a big bus route timetable in one A4 paper by pushing one button. Figure 6 shows a part of a bus route timetable which is made by the function. Star marks of left side of bus stop names show that bus stops are excluded before, the star mark number is the number of excluded bus stops. This function is also able to exclude bus stops where the influence when excluded is limited manually, confirming the necessary number for storing in one paper, and exclude bus services. This function has other options, those are able to change layout of the timetable by use. First it is able to select paper size from A3, A4 and fit size. Next when the timetable is divided to some pages, it is able to exclude information on connection part of timetable, for example bus stop names and the bus route name. It assumes that the timetables are arranged.

Figure 7 shows result of classification using SOM. In this display, it is able to fix the result by drag & drop of the bus route names in the groups. The numbers of Fig. 7 correspond to the group numbers of Fig. 8 In the following, we show the result of classification such that. Figure 9 shows a part of bus stop timetable which is made by the function.

日本交通 - 岩井(下)									
運行パターン	㊊	㊊㊏㊐	㊊㊏	㊊㊏㊐	㊊㊏㊐	㊊	㊊㊏㊐	㊊㊏	㊊㊏㊐
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
東秋里		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
覚寺口	17	07:40	27	17	10:10	57	11:30	17	57
☆☆ 浜湯山	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
☆ 県	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. 6: A part of a bus route timetable.

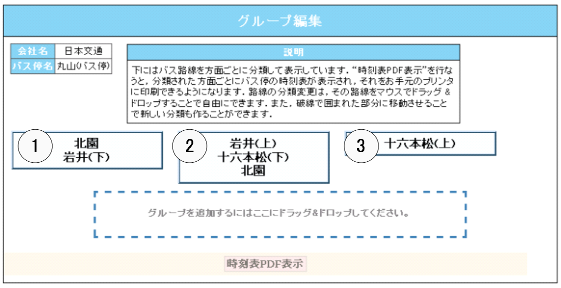

Fig. 7: A result of classification using SOM.

Group1	Group2
Kitasono Iwai(Outbound)	Iwai(Inbound) Juropponmatsu(Outbound) Kitasono

Group3
Juropponmatsu(Inbound)

Fig. 8: A result of classification using SOM.

湖山 停留所								
7	03	鳥取駅	09	岩倉 ㊊	10	鳥取駅 ㊊		
			36	鳥取駅			45	鳥取駅 ㊊
8	05	鳥取駅 ㊊	10	鳥取駅	10	鳥取駅	19	鳥取駅
9	05	鳥取駅 ㊊	08	鳥取駅	10	鳥取駅 ㊊	37	鳥取駅
10	08	鳥取駅	18	鳥取駅				
11	02	鳥取駅	08	鳥取駅				
12			12	鳥取駅	13	鳥取駅		

Fig. 9: A part of a bus stop timetable.

5 Experiment

5.1 Experiment about Automatic Selection of Bus Stops

In this experiment, we confirm bus stops that may be excluded from bus route timetable are chosen by developed algorithm and the chosen bus stops are distributed as uniformly as possible on a whole route.

Figure 10 shows a route timetable with exclusion of bus stops where the influence when excluded is limited by proposed algorithm. First bus stop of the route is Tottori station, last bus stop of the route is Kaburajima, the nearest bus stop for the place of the user is Iwaionsen. Variance σ^2 of normal distribution used in proposed algorithm is set to 1.

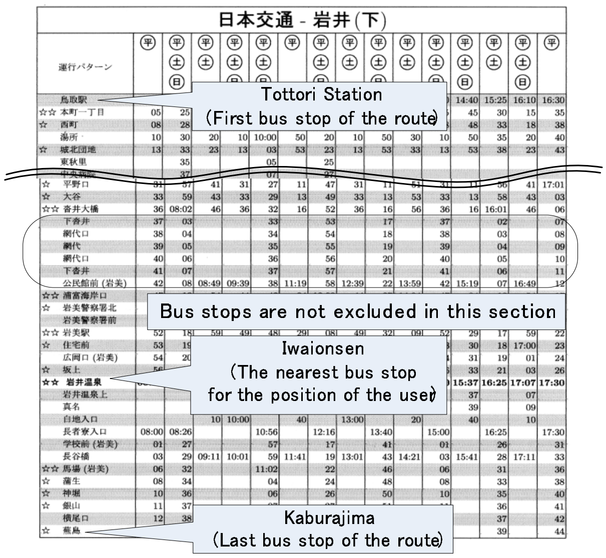

Fig. 10: A bus route timetable with exclusion of bus stops where the influence when excluded is limited (σ=1).

We see from Fig. 10 below. First and 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 when we compare bus stops of the frame of Fig. 10 with the others. Consequently the bus stops are given relatively high importance. In addition, star marks in the timetable are at most two and are distributed uniformly on a whole route. As it turned out, we can confirm the algorithm is valid.

Here, we determine appropriate σ. σ is set to 1 in Fig. 10 and set to 5 in Fig. 11. In Fig. 11, excluded bus stops are frequently connected in comparison with Fig. 10. Because If σ of normal distribution is large such that, evaluation values near excluded bus stop are little increased. Consequently importance of the bus stops are little increased. So σ had better be small.

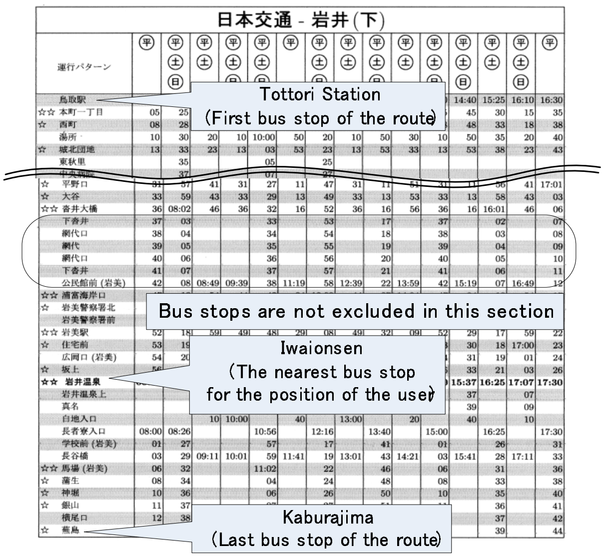

Fig. 11: A bus route timetable with exclusion of bus stops where the influence when excluded is limited ($\sigma = 5$).

5.2 Experiment 1 of Classification using SOM

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

In this experiment, parameters are set below. n and d mentioned in Section 3 are set to 3, 1.5. Classification using SOM is operated by two stages, size of map is 15×12 in both stages. In stage 1, a number of learning steps is 2000, a neighborhood width is 15, a rate of learning is 0.05. In stage 2, a number of learning steps is 20000, a neighborhood width is 3, a rate of learning is 0.02.

To take the case of Karokaigan, there are two bus stops which have identical name in the bus stop group, and buses of three bus routes, Karo outbound route, Karo inbound route and Karo circulation route, arrive at the bus stop group. Buses of Karo outbound route and Karo inbound route run in reverse each other. Therefore buses of these bus routes are completely classified. On the other hand, some buses of Karo circulation route start from Tottori station and run into Karo area clockwise, however the others run in reverse. So even if the bus route name of buses are same, bus stops at which the buses arrive can be different. Consequently buses of Karo circulation route are classified into plural groups.

Figure 12 shows result of classification using SOM at the bus stop group Karokaigan. we can confirm the algorithm is valid. Here, n mentioned in Section 3 is set to 3 in Fig. 12. On the other hand, n is set to 10 in Fig. 13. There are five groups in Fig. 13. This shows that even if buses leave for same destination, the buses do not arrive at same bus stops up to last bus stop of the routes. Therefore, n had better be small.

Group1	Group2
Karo circulation Karo(Outbound)	Karo circulation Karo(Inbound)

Fig. 12: A result of classification by bus stop using SOM (n=3).

Group1	Group2	Group3
Karo circulation	Karo circulation Karo(Inbound)	Karo(Outbound)

Group 4	Group5
Karo circulation	Karo(Outbound)

Fig. 13: A result of bus classification by bus stop using SOM (n=10).

5.3 Experiment 2 of Classification using SOM

In this experiment, we confirm buses bound for same destination are really arranged by the developed algorithm. Parameters used in the algorithm are same as experiment 1.

To take the case of Johokudanchi, the bus stop group is located at star mark point in Fig. 14. The numbers of Fig. 14 show group numbers by destinations. Group 1 includes Iwai outbound route, Kitasono circulation route, Group 2 includes Kajikawachubyo inbound route, Chuobyouin outbound route, Juropponmatsu inbound route, and Group 3 includes Iwai inbound route, Kitasono circulation route, Chuobyouin inbound route, Juropponmatsu outbound route, and Group 4 includes Kajikawachubyo outbound route. Consequently buses of the bus routes should be classified such that.

Figure 15 shows result of classification by developed algorithm. Numbers of Fig. 15 and numbers of Fig. 14 correspond each other. Therefore we can confirm the algorithm is valid. Here, there are same bus route names in 15, however as I said earlier, that is the reason bus stops at which buses on same bus

Fig. 14: Moving directions of bus routes passing through Johokudanchi.

Group1	Group2
Juropponmatsu(Inbound) Kitasono Iwai(Outbound)	Kajikawachubyo(Inbound) Juropponmatsu(Inbound) Chuobyouin(Outbound) Iwai(Outbound)

Group3	Group4
Iwai(Inbound) Juropponmatsu(Outbound) Kitasono Chuobyouin(Inbound)	Kajikawachubyo(Outbound)

Fig. 15: A result of classification by bus destination using SOM.

route really arrive can be different like the example of experiment 1.

6 Conclusion

In this study, we have developed algorithms to generate two kinds of bus timetable, i.e., bus route timetable and bus stop timetable. In regard of bus route timetable, bus stops 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. In regard of bus stop timetable, when one intends to obtain the timetable of a bus stop group, the proposed algorithm first 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 each timetable, buses bound for same destination are gathered in the same sheet.

The function of generating two kinds of bus timetable is implemented and opened as a part of "BUS-NET"[3]. Every person 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.

In future work, extra information, such as the low-floor bus which enables people with disabilities and older persons to get on and off buses easily, will be provided on our bus timetable.

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References:

[1] T. Kawamura, G. Kusugami, K. Sugahara, Path Planning System for Bus Network including Walking Transfer, IPSJ Journal, Vol.46, No.5, pp. 1207–1210 (2005).

[2] T. Kawamura, K. Sugahara, Practical Path Planning System for Bus Network, IPSJ Journal, Vol.48, No.2, pp. 780–790 (2007).

[3] BUS-NET, http://www.ikisaki.jp/

[4] H. Tokutaka, S. Kishida, K. Fujimura, Application of Self Organizing Maps and The Two Demension Visualization of Multi-demensional Information, KAIBUNDO (1999).