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Providing On-Demand Path and Arrival Time Information Considering Realtime Delays of Buses

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Abstract—This paper demonstrates the bus location system for the route bus through the experiment in the real environment. A bus location system is a system that provides information such as the bus delay and positions. This system uses actual services and positions data of buses, and those information should match data on the database. The system has two possible problems. One, the system could cost high in preparing devices to get bus positions. Two, it could be difficult to match services data of buses. To avoid these problems, we have developed this system at low cost and short time by using the smart phone with GPS and the bus route system. This system realizes the path planning considering bus delay and displaying position of buses on the map. The bus location system was demonstrated on route buses with smart phones for two months.

Keywords—Route Bus, Path Planning System, GPS, Smart Phone.

I. Introduction

THIS paper demonstrates the function that we have developed to reduce the uncertainness of the bus, and it is demonstrated through the experiment in the real environment.

We have developed the shortest path searching system called "Bus-Net"[1], [2], [3] as a web application to improve the usability of the public transportation. The path planning system is one of the functions of a previous Bus-Net. This path planning method can find paths including not only bus transfers but walking transfers. An actual public transportation may be delayed by weather and road conditions. Therefore, passengers may miss the targeted bus at the transfer when the bus delays, and feel irritation and anxiety. To solve this problem, we propose new methods for the bus location system.

This paper proposes a way to develop the bus location system. Bus location systems have already been introduced to a lot of bus companies in great cities around the world. Those bus location systems offer information about the position and the delay of the bus. However, these informations are not enough to reduce passengersf irritation and anxiety. For example, when a passenger needs to transfer to other buses or trains that run not so frequently, the arrival time will be much more uncertain, and he/she would feel anxiety. We have developed a more advanced bus location system than other systems. We achieved advanced system by constructing the bus location system into the Bus-Net. We obtain information about a position and delays of buses from the bus location system and offer the best route for users by adding those information in the route search of the Bus-Net. It enables to offer a dynamic route that changes depending on the situation of a bus when searching a route.

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The bus location system uses information about passing bus stops, bus-service conditions, bus delays and a position of a bus. It is important for this system to associate these information. We cannot ignore devices in order to get bus positions too. We use smart phones with GPS (Global Positioning System) to obtain these information. We reduce costs by using information about bus-service and bus stops on Bus-Net database. Therefore we have developed our system at low cost and short time.

The research about the bus location system exists all over the world. A lot of researchers only measure the position of the railway and the bus by GPS[4]. There are researches who relate user's position to the position of the digital map[5] and synchronize with a virtual 3D display of real time bus system, too[6]. The arrival time of the bus is offered in real time with a special equipment as the advanced research[7], [8], [9], [10]. The algorithm that estimates the arrival time of the bus is also researched[11], [12]. We have developed the system that offers more advanced information than those researches.

This paper consists of ten sections. Section 1 is the introduction. Section 2 describes the uncertainness in utilizing public transportation, and section 3 describes the approach to reduce uncertainness. Section 4 describes the outline and features of our bus location system. Section 5 describes the method for a calculation of delay of a bus and getting data by a smart phone. Section 6 describes the function that uses our bus location system. Section 7 develops the path planning considering bus delay. Section 8 demonstrates the effectiveness of the proposed methods through experiment. Section 9 describes a conclusion and future work.

II. Uncertainness in Utilizing Public Transportation

Public transportation has various advantages over a car especially in terms of its safety and predictability. A user of bus or train does not need to worry about safety while moving, and does not need to worry about arrival time at the destination, because both bus and train run based on the time table. Owning to these characteristics, public transportation plays an important role in our society. However, there still remains some uncertainness in terms of temporal accuracy especially for bus service, and that reduces usability of public transportation.

Uncertainness of arrival time at the bus stop is one of the problems in utilizing a bus. A user of a bus expects a bus to

come on time, however, it often delays due to the bad weather or traffic congestion. He/she needs to wait at the bus stop without knowing how long he/she needs to wait, which would irritate the user. If he/she arrives at the bus stop almost too late, and the bus does not run frequently, he/she will be anxious if he/she miss the bus. It is not possible to run every bus on time, because a bus runs on a road with other cars. However, it is possible to provide accurate arrival time to the user and reduce his/her irritation and anxiety.

Even if a user knows the accurate arrival time of the bus, he/she is still uncertain if he/she can arrive the destination on time. Especially when he/she needs to transfer to other buses or trains that run not so frequently, the destination arrival time will be much more uncertain. He/she needs to see the time table of the line he/she will transfer in order to know the arrival time at the final destination. Also, it might be better to transfer at another bus stop if there are two or more possible paths to the destination. Prediction of arrival time considering these factors is difficult for a user.

By reducing these uncertainness in utilizing public transportation, people who are planning to use public transportation can be more proactive. If he/she knows that the delay of the bus he/she is waiting does not affect his/her final arrival time while waiting the bus, he will not be irritated and anxious. If he/she knows that he/she cannot arrive at the destination on time due to the delay beforehand, he/she can choose other way to move such as a taxi. In order to increase the usability of public transportation, providing information to reduce uncertainness is important.

III. Approach to Reduce Uncertainness

A. Approach

We solve the problem by offering accurate information about the future of the bus to reduce user's uncertainness. We provide information about not only arrival time of the bus at the bus stop he/she is waiting, but also final arrival time and appropriate path to the destination considering the delay of the bus. We have developed the system with the following features.

1) The system calculate the delay of the bus from the position of the bus, and offer the user the delay information.
2) The system searches for the route considering the delay, and we offer the user it.

We use a smart phone equipped with GPS and 3G always-on connection to develop the system at low-cost. The smart phone is used to obtain the position and operation information of the bus.

B. technology

We solve the problem of showing in section 2 by constructing the bus location system. A bus location system is one of the ITS(Intelligent Transportation System) that provides a position and a condition of a bus. This system is introduced almost bus companies in the whole country in Japan. A common bus location system offers information that a bus passed bus stops and the delay. We have develop the system to offer advanced information. The delay of the bus obtained with the bus location system is reflected in path planning system of the Bus-Net.

Our path planning system of Bus-Net runs on the assumption that public transportation runs service s that base on a bus schedule correctly. A route bus is greatly influenced by weather such as snowfall and road conditions such as traffic jam and road repairing. A bus delay is caused by these factors. Therefore, a passenger may be unable to get on a target bus at the transfer when a bus is delayed. We have improved the function of Bus-Net by constructing a bus location system. We obtain information about a position and a delay of buses by bus location system. We can offer the best route for users by adding those information in the route search of the Bus-Net. The system that can obtain a dynamic route achieves.

IV. Bus Location System Using a Smartphone

This section describes the outline and features of the system.

A. Outline of the system

Fig. 1 shows the system that we have developed the bus location system. We install a smart phone with GPS in a route bus. The smart phone sends information about a longitude and a latitude, a bus service to the server every minute. As a base for these information, the server calculates a bus delay and updates information that a bus passes bus stops. This system develops on the Bus-Net. The Bus-Net has a lot of data that bus-service and bus stops in our research area. We are able to develop this system without preparing those data.

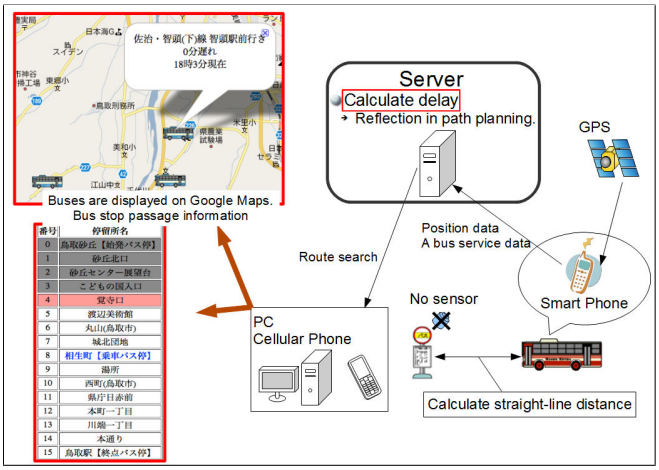

Fig. 1. Construction of our bus location system

B. Feature of the system

This system does not only show a bus delay like a lot of existing bus location systems. Our bus location system reflects the bus delay in the path planning system. The route changes dynamically when Bus-Net search route. So the route suitable for the situation is displayed. This system displays the position of buses on Google Maps by using the data on Bus-Net server. Additional, we can know a bus stop which a bus was passing from a route search result.

V. Calculation of Delay and Method of Getting Data by Smart Phone

A. Method of getting data by smart phone

The bus location system runs by a bus driver controls a smart phone. It is difficult for a bus driver to do the complicated process. We develop an application for a smart phone that makes this process easily. This application makes it easy to obtain information such as a bus-service. The setting of operation information and acquisition of the location information are done by this application. The application can be used with various smart phones as long as it installs.

Fig. 2 and Fig. 3 shows flow that using the application for a smart phone. There are two buttons in a first screen. A driver pushes a button above when runs a bus-service on schedule. A bus-service is selected automatically from a number of services when pushing a button above. Others, a driver pushes a button below when runs a bus-service on behind schedule. A driver selects a bus-service that runs now when pushing a button below. The smart phone sends information that a bus-service and positions of a bus when the selection of service is completed.

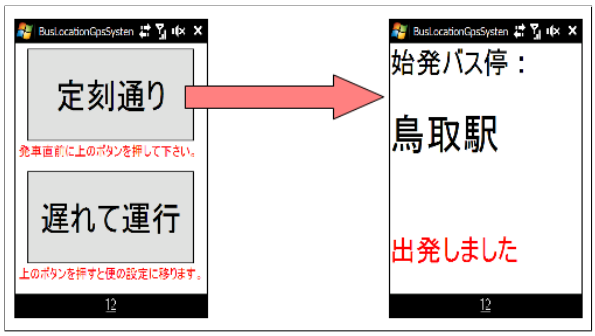

Fig. 2. Push a button above.

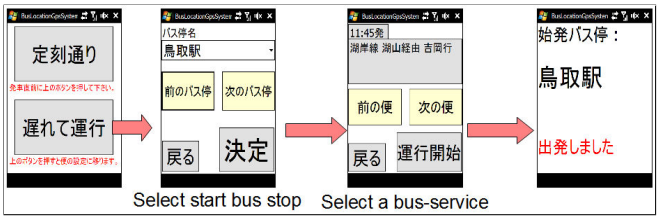

Fig. 3. Push a button below.

B. Calculation of delay of bus

We are confronted by a problem that existent system manages road information such as curve. We can not install a sensor and telecommunications device on bus stops and bus. So, a database of Bus-Net does not have such the road information. Because of this problem, it is not possible to calculate bus delay by comparing the location of a bus stop with the location of a route bus. So, we have developed algorithm to estimate delay by obtaining a straight-line distance from latitude and longitude at location of the bus and the bus stop, and using it. Detailed account of the algorithm is given below.

1) Distances of bus position and all bus stops are calculated based on information about latitude and longitude.
2) The shortest distance is defined the nearest bus stop among the distances calculated in the preceding clause.
3) Scheduled time that a bus passes over present location is calculated based on the scheduled time of passage of the nearest bus stop and bus stop before that.
4) Difference between the passage schedule time of the present location of the bus and current time is estimated as a delay.
5) The estimated delay is reflected in the running bus information.
6) It is assumed that a bus has passed over bus stops from the first bus stop to nearest bus stop, and reflected in the bus stop passage information.

This algorithm is executed every time when information is sent from smart phones. The algorithm can not judge whether to have passed accurately.

VI. Display Bus Condition by Bus Location System

We develop functions that displays a position of a bus by Google Maps and passed bus stops from a route search result.

A. Display position of bus by using google maps

Fig. 4 shows a bus location display using Google Maps API. When a bus icon is clicked, this function displays information of the bus such as passage scheduled time of a bus stop, a destination, a route, and a bus delay. This information is obtained from database of Bus-Net about the position of a bus. The method of getting This information is explained section 3. There are 2 kinds of a bus location displays. The one is a detailed display of map where a bus stop that people will get on a bus is made center. The other one is large area display of map which shows all buses running at our research area.

B. Display information passed bus stops

Information about passed bus stops is shown in Fig. 5. This function is displayed this information on bus stops. This information is obtained from database of Bus-Net about passed bus stops. The bus stop that a bus passed in the label A. The bus stop that is the nearest a bus as shown in the label B. The bus stop that people will get on a bus is emphasized as shown in the label C.

VII. Path Planning Considering Bus Delay

A. Outline of path planning system

The path planning system is explained. To do the path planning, this system constructs a network. The network is constructed with nodes which denote bus stops, arcs which denote bus routes and weights of the arcs which denote the needed time between bus stops. The path planning system uses the Serializable Network. The Serializable Network including static part of network is made to shorten the search time when people do a search for bus routes by using this system. Static part of network is drawn up and saved in files previously.

Fig. 4. Bus location display using Google Maps.

	番号	停留所名
A	0	鳥取砂丘【始発バス停】
A	1	砂丘北口
A	2	砂丘センター展望台
A	3	こどもの国入口
B	4	覚寺口
	5	渡辺美術館
	6	丸山(鳥取市)
	7	城北団地
C	8	相生町【乗車バス停】
	9	湯所
	10	西町(鳥取市)
	11	県庁日赤前
	12	本町一丁目
	13	川端一丁目
	14	本通り
	15	鳥取駅【終点バス停】

Fig. 5. Information about passed bus stops.

B. Route search reflects bus delay

This system prepares a file that bus delay information. The value of bus delay and bus-service information are assumed to be bus delay information. The server draws up bus delay information in files per minute. The path planning system reads this file when it search routes. In searching time, arrival times of each bus stop are reflected delay that is estimated by determining a position of a bus. The path planning system obtains arrival time of each bus stop by reading the network. A procedure of the path planning considering bus delay is displayed as follows.

1) The bus delay is estimated by determining a position of a bus.
2) The server draws up bus delay information in files.
3) In searching time, the path planning system reads the Serializable Network and those files.
4) The value of the bus delay is added in arrival times of each bus stop in Serializable Network.
5) It searches for a path based on changed arrival times.

The path planning considering bus delay is implemented on Bus-Net. Therefore, the path planning system corresponds to the following situations.

(A) A certain bus runs on schedule, and a target bus at the transfer runs on schedule. In this case, this system runs the path planned by previous Bus-Net.
(B) A certain bus is delayed, and a target bus at the transfer runs on schedule. When the certain bus is greatly delayed, passengers that get on a certain bus may be unable to get on a target bus at the transfer. In this case, this system runs the path planning considering bus delay. Its result is different from a path that the path planning of the previous Bus-Net displays.
(C) A certain bus runs on schedule, and a target bus at the transfer is delayed. When the target bus is greatly delayed, passengers that get on a certain bus may be able to get on the other bus at the transfer. And like the case (B), a path is different from the path of the case (A).
(D) A certain bus is delayed, and a target bus at the transfer is delayed. In this case, there is a possibility that case (B) and case (C) happen. Moreover, a certain bus and a target bus are greatly delayed. Then, a path that the path planning considering bus delay displays may be quite different from the path of case (A).

VIII. Experiments

We demonstrate our bus location system. We have done to check that changing a path when a bus is delayed. A bus-service is selected correctly by using smart phones.

A. Outline

We prepare 70 smart phones with the support two bus companies. We install smart phones in buses in the research area for about two months from December, 2010 to January, 2011. We install an application that we have developed in smart phones. Fig. 6 shows installed smart phone in a bus.

Fig. 6. Installed smart phone in a bus.

B. Evaluate our system

First, Experiments have done to check that changing a path when a bus is delayed. We have gotten on the bus with a smart phone. In additional, a bus delay is estimated by getting information such as the position and a bus-service actually. The bus delay has become 5 minutes as a result of getting

on the bus in a certain point. We have used to the path planning system at this time. In the case of starting point; “Jouhoku elementary school”, destination; “civic gymnasium” and departure time: 14:50, the path not considering bus delay and the path considering bus delay it are indicated as shown in the Fig. 7 & 8. In Fig. 7, the path is displayed to get on “Hinomaru Saigo and Sanki line” at 15:10. On the other hand, it cannot get on “Hinomaru Saigo and Sanki line” because “Hinomaru Karo line” is delayed as shown in Fig. 8. However, the path planning considers bus delay has run, and the path is displayed to get on “Hinomaru Saji and Chizu line” at 15:20 as shown in Fig. 8. Moreover, the required time became the shortest when considering bus delay. At this time, the time required becomes longer when not considering bus delay.

Next, We confirm the accuracy of the selected service. The number of the service runs for experimental period was 1465 at one support company. It is about 70 percent to succeed in them. At the other company, the number of the service runs for experimental period was 779. It is about 75 percent to succeed in them. The cause of the failure of remain about 30 percent, the application fail in selecting a bus-service automatically. Moreover, a lot of failures are discovered when going through a tunnel.

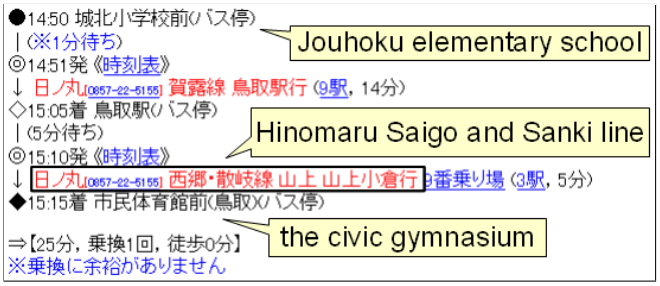

Fig. 7. Path planning result not considering bus delay.

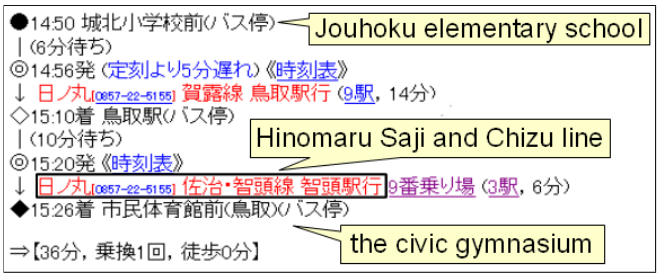

Fig. 8. Path planning result considering bus delay.

IX. Conclusion

In this study, the bus location system is implemented to improve the practicality of Bus-Net. Information such as the position of a bus and a bus-service are obtained by smart phones with GPS. Then, the estimation of a bus delay becomes possible by using these information. In addition, the application for the smart phone makes operation to obtain information easy, and the path planning considering bus delay becomes possible by estimating the delay.

Understanding from the experiment, the application developed in this study is still unstable. We must stabilize the application for a smart phone as a future task. In addition, it is necessary to review the processing when going through a tunnel. The place where a bus delay occurs can be easily discovered by taking statistics of the bus delay.

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