Estimation of Traffic Pattern Analyzing UPLINK Information

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SUMMARY

Recently we have many types of two-way communication methods between traffic management center and vehicles, for instance, cellular phone, radio beacons and infrared beacons. In Japan, in order to communicate information between them point-to-point, infrared beacons were introduced and installed in urban areas. The function of this beacon is to provide two-way communication between vehicle and driver in addition to the conventional method. In this paper, in order to estimate an OD, we gathered and stored UPLINK information from infrared beacons, then we modified it using road network.

INTRODUCTION

In Japan, more than thirty years have passed since traffic control systems were first put into operation. Until recently, these systems have contributed greatly towards making vehicular traffic flow smoother, safer and more convenient. Traffic control systems are now commonly used throughout urban areas in Japan. However, in recent years, the environment of most traffic control systems have changed remarkably, and in particular, the ceaseless growth and concentration of population resulting in more vehicles in urban areas has caused a constant increase of traffic congestion. Meanwhile it has become more difficult to build new roads to handle this serious problem. The primary aim of traffic control research in Japan is to maintain the smoothness and safety of the traffic flow, and improve methods of traffic signal control.

As for infrared beacons, one of the methods of detection has been installed along ordinary roads. The function of this detector is to provide two-way communication between vehicle and driver in addition to the conventional method. The movement of each vehicle, which carries a car navigation system, can be caught various data by using two-way communication, such as travel time, trajectories, vehicle types, and so on. Especially, when it is possible to locate infrared beacon at high density on Japanese road networks, it can be utilized for traffic signal control to comprehend traffic pattern and paths of vehicles. However the effectiveness of infrared beacons is authorized, it is difficult to set up beacon on every links throughout Japan from the viewpoint of finance, scenery and so on.

In this paper, we introduce various systems using infrared beacon in Japan and the characteristic of beacon, at first. Secondly, we research the location of beacons to grasp the maximum number of routes on the limited beacons in the $n \times n$ network for simulation. Finally, we calculate the number of trajectories of vehicles in an actual road network, Yokohama suburbs.

INFRARED BEACON

VARIOUS SYSTEMS OF UTMS21 USING BEACONS IN JAPAN

UTMS21 (Next Generation Universal Transportation Management Systems) is one of the systems to realize of ITS (Intelligent Transport Systems) in Japan. Each subsystem of UTMS21 supports to create a safe, comfortable, and environmental-friendly traffic society. Most of subsystems apply infrared beacons as infrastructure by carrying out two-way communication between vehicles and roads. By using those infrastructures, UTMS21 provides real-time information to driver, and realizes priority signal control for emergency vehicles, public transportation vehicles, and so on. Subsystems, which utilize infrared beacons of UTMS21, are as follows.

Table 1 Services of Subsystems in UTMS21 Using Infrared Beacons

Sub System	Main Purpose
Advanced Mobile Information Systems (Vehicle Information and Communication System)	Information Providing (collection of traffic data)
Dynamic Route Guidance Systems	Information Providing
Public Transportation Priority Systems	Priority Signal Control
Mobile Operation Control Systems	Information Providing
Driving Safety Support Systems	Emergent Information Providing
FAST emergency vehicle preemption systems	Priority Signal Control

18,000 infrared beacon units are installed mainly on ordinary roads in Japan. It is also expected to locate approximately 30,000 units by 2001. However, there are about 166,000 signal controllers throughout Japan, and the existing number of beacons is deficient not only to realize of these services on major roads in Japan, but also to comprehend rough traffic pattern without considering the method of setting beacon.

APPLICATION OF BEACON

By exploiting characteristics of two-way communication, many kinds of information are exchanged between vehicles and roads. There are two types of information dealing in infrared beacon. One is called UPLINK information, which is communicated from vehicles to roads. The other is DOWNLINK information, which is given from roads to vehicles.

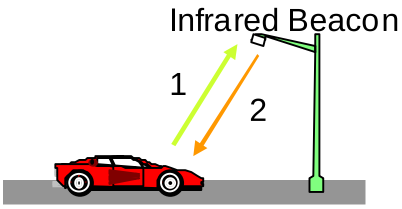

Fig. 1 Communication between Vehicles and Beacons

UPLINK Information

UPLINK information, which is communication 1 in the Fig. 1, consists of vehicle identification numbers, present passing beacon numbers, previous passing beacon numbers, previous-passing prefecture numbers, origin-beacon numbers, car types, travel time and others.

From UPLINK information, traffic control center can grasp traffic pattern such as turning rate on intersections, trajectories of each vehicle, and so on. This information is available for traffic signal control to correspond delicately to present traffic situation, and actuated signal control for special vehicles.

DOWNLINK Information

Beacons provide vehicles real-time traffic information as DOWNLINK information, for example, traffic jam, accident, parking information, road-network, in addition to optimum routes to destination, which is communication 2 in the Fig. 1.

DOWNLINK information has great effect to decide driver's behavior for many drivers who have in-vehicle unit and can receive present information from infrared beacon.

PROBABILITY OF TRAJECTORIES CALCULATION IN SIMULATION NETWORK

ISSUE

When traffic management officers arranged infrared beacons, they thought and arranged empirically. Or, the location of beacons were restricted by physical limitation of roadside and road. Therefore the location of beacons might not be optimized, suitable and effective.

APPROACH

Considering the location of infrared beacons, we introduce cover rates as performance indexes in order to evaluate ideal position of beacons. By this, the location of beacons can be deterministic, efficient and effective.

DEFINING COVER RATE

First of all, we selected four performance indexes of evaluating the location of beacons. One is OD information with its trajectory, second is OD traffic volume, third is travel time information and four is distribution rate at an intersection. Next, there are two cover rates for beacon data. One is traffic flow cover rate, and another is link cover rate. These cover rates as evaluation parameters are shown to the following.

LINK COVER RATE

Link cover rate P_L is a ration of link number N_{det}, which are located on the link, for all link number N_{all}.

TRAFFIC FLOW COVER RATE

We think that an arrangement of infrared beacon is evaluated by each evaluation values. This evaluation method is defined as traffic flow cover rate. When the same link cover rate, the better traffic flow cover rate, the better arrangement of infrared beacons. In this way, every performance indexes, each cover rate can be calculated from a ratio of traffic flow and all traffic flow that can be collected. Traffic flow cover rate of every performance indexes are shown in the following.

Traffic Flow Cover Rate of OD information with its trajectory

If infrared beacon is located on trajectory *r* between OD nodes and its trajectory is grasped, performance index would be evaluated by traffic flow $f_{ad,r}$ of trajectory *r*. In other words, traffic flow cover rate of OD information with its trajectory can be observed from a ratio of traffic flow of trajectories, which are grasped by infrared beacon, and all traffic flow of all trajectories between all OD nodes.

$$P_R = \frac{\sum_{od}\sum_{r}(f_{od,r}\delta_{l_{od,r}l_{det}})}{\sum_{od}\sum_{r} f_{od,r}} \tag{1}$$

$$\delta_{l_{od,r}l_{det}} = \begin{cases} 1; l_{od,r} \subseteq l_{det} \\ 0; l_{od,r} \not\subset l_{det} \end{cases} \tag{2}$$

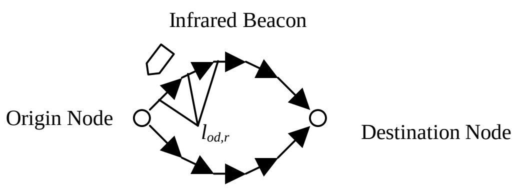

Fig.2 Beacon Arrangement of OD information with its trajectories

In equation (1), the denominator is all traffic flow, and the molecule is traffic flow that can be observed by infrared beacons. $l_{ad,r}$ is a set of link on *r* between OD nodes, l_{det} expresses a set of an infrared beacon on a link. δ is a cronecker delta, if infrared beacons on a link includes a link of trajectory *r*, then δ would be 1. If it doesn't include, then δ would be 0.

SIMULATION

Road Network Model

As shown in Fig. 3, the object intersections are given by $n \times n$ ($n = 3$) networks and several OD intersections situated next to the networks.

In the case of $n = 2$, node 1, 2, 3, 4, 9 and 14 are origin nodes, and node 8, 13, 18, 19, 20 and 21 are destination nodes. There puts infrared beacon on each link, which is from origin node, or to destination. On other links, there puts several beacons in any combination.

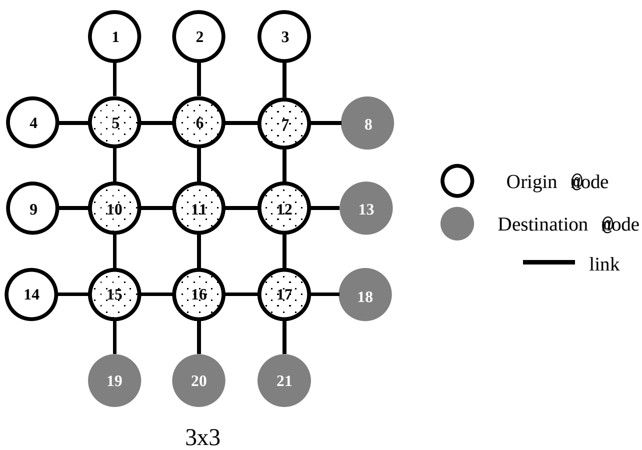

Fig. 3 Network Model

RESULT IN SIMULATION MODEL

Results in simulation model of relation between cover rates and infrared beacons are shown to the following.

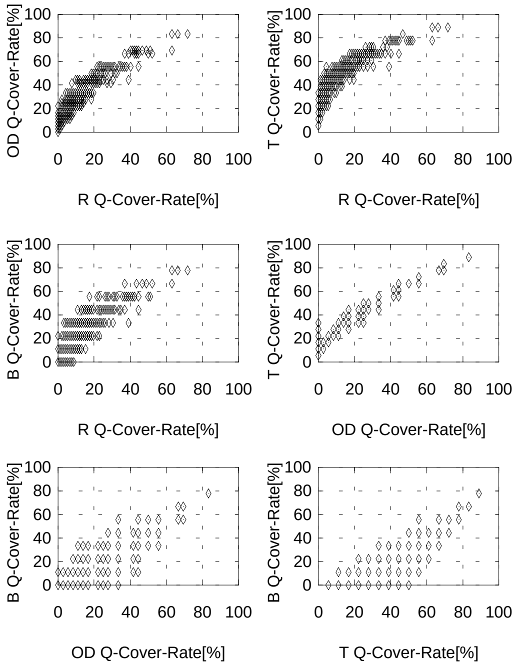

Fig. 4 Correlations between cover rates

This figure shows correlations between traffic flow cover rare and arrangement beacons on link. When beacon arrangements are the same and traffic flow cover rates are the same, if dots are conflicted and traffic flow cover rates are the same, results dots are shown on linear line from (0, 0) to (100, 100). On the other hand, when beacon arrangements are the same and traffic flow cover rates are the same, results dots are spreading. Until now, we acquire the following results. Beacon arrangement with its trajectories is not similar to the other arrangement. Beacon arrangements of OD information, travel time between neighbor intersections and distribution rate are almost the same at local. Therefore if beacons are located on exits of intersections, traffic flow cover rates are better. Finally we confirm that optimum beacon arrangement problem can be solved.

RESULT IN ACTUAL ROAD NETWORK

On the actual network in Yokohama suburbs, first we estimated traffic volume of each route from researching of traffic density and turning rate of each link. Secondly, by setting or removing infrared beacon on each link virtually, we calculate the density of beacons on all links and the rate of vehicles, whose routes can be comprehended by passing under beacons.

CONCLUSION

This paper can show the arrangement infrared beacons, the number of beacons and the alignment on the road network, to grasp traffic pattern approximately.