Self-organizing Route Guidance Systems

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***Abstract*— This paper proposes Self-organizing Route Guidance Systems which cooperates with self-organizing control of traffic signals. Self-organizing control of traffic signals provides the fully distributed approach to coordinate a number of signals distributed in a wide area according to the local information of the traffic flow so that split and offset between traffic signals are adjusted for the efficient traffic flow. The idea of Self-organizing Route Guidance Systems is to form the efficient route which facilitates the offset adjustment of self-organizing control of traffic signals by self-organizing multi-layered vector fields. Simulation demonstrates the effectiveness of proposed system under the traffic situation dynamically changes.**

I. INTRODUCTION

Recently, heavy traffic congestion at an urban area has brought several social problems such as increasing traffic accidents, environmental pollution, and economic losses. Intelligent Transportation Systems (ITS) is proposed for new transportation systems that is expected to solve these problems. To cope with the problem of traffic congestion, two major approaches are attempted in Japan.

The first approach is traffic flow control by the route guidance system using Vehicle Information and Communication System (VICS)[1][2]. VICS provides drivers with several information such as traveling time, traffic congestion, and route guidance through optical beacons or radio beacons located at roadside[3]. Route guidance system has ability to manage the amount of traffic at an urban area for to improve the traffic congestion problem. In order to provide the information on shortest route, the time-constrained A^* algorithm is proposed[4]. To minimize the expected travel time, dynamic progamming techniques are applied in [5]. Also, to avoid the traffic congestion caused by the concentration of traffic flows, the routing method based on the estimation of the travel time is proposed in [6].

The second approach deals with an optimization of traffic signals in which parameters of traffic signals are adjusted to improve the performance of traffic flow [7][8]. We have proposed self-organizing control of traffic signal network[9]. It is fully distributed approach for improving the efficiency of the traffic flow according to dynamical changes of the environment. Traffic signals are represented by coupled nonlinear oscillators. Offsets between signals and splits are adjusted according to the local information of traffic flows so that the desired signals network offset patterns are self-organized through a mutual synchronization. Self-organizing control of traffic signals has the function for adjustment of the offset between traffic signals. Alhough, there are some limitations as we describes later. From the perspective of traffic signal control researche, traffic flow is treated as static or dynamic environment that is uncontrollable. On the other hands, from the perspective of traffic flow control researche, traffic signal is not treated explicitly. In this paper, we propose the more efficient traffic system named Self-organizing Route Guidance Systems (SRGS) which cooperate with traffic signal control so that the problem of traffic congestion is improved. Since the traffic situation dynamically changes, it is difficult to manage a number of signals based on surveillances of the global information. In contrast, the self-organizing control of traffic signals provides the fully distributed approach to coordinate a number of signals distributed in a wide area according to the local information of the traffic flow so that the efficient traffic flow is realized. So, we adopt the self-organizing control of traffic signals in propose system. The main idea of SRGS that cooperates with self-organizing control of traffic signals generates group of vehicles as traffic flow which facilitates self-organization of offset pattern between signals network for improving the performance of urban traffic (Fig.1).

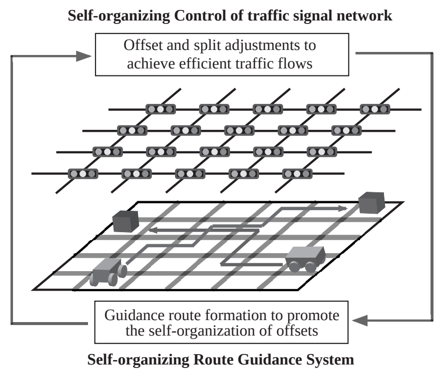


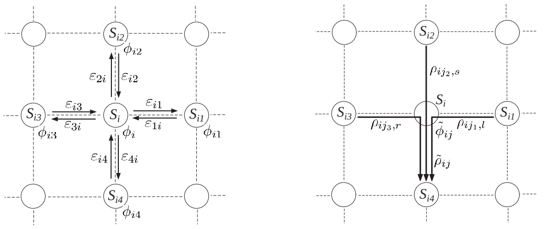
Fig. 1. Concept of Self-organizing Route Guidance Systems

II. EXTENSIONS OF SELF-ORGANIZING CONTROL OF TRAFFIC SIGNAL NETWORK[9]

A. Urban Traffic Network Model

In this section, we outline the orverview of the theory of self-organizing control of traffic signal network. Despite the route guidance system needs offset adjustment in any route, self-organizing control of tafffic signals deals with the traffic flow that pass thorough an intersection straight. Thus, we describe the extension of that theory so that the traffic flow turns at an intersection is dealt with.

A model of an urban traffic signal network used in self-organizing control of signals is described by a bi-directional graph network as depicted in Fig.2(a). Node $S_i, (i = 1, \ldots, N_S)$ denotes the intersection and $S_{ij}, (j \in 1, 2, \ldots, n_i)$ denotes the neighboring intersection of S_i. ε_{ij} is normalized



(a) Urban Traffic Signal Network Model

(b) Traffic flows through the intersection S_i

Fig. 2. Traffic inflows and outflows on signal network

amount of traffic flows defined by

$$\varepsilon_{ij} = \frac{1}{\rho_{im} T_i} \int_t^{t+T_i} \rho_{ij}(s) ds. \tag{1}$$

Where $\rho_{im} = const.$ is traffic capacity and ρ_{ij} is traffic density in the road between the intersection S_i and S_{ij}.

B. Modeling of Signal Network by Coupled Phase Oscillators

We describe the traffic signal network using a system of nonlinear oscillators with the nearest coupling. Specifically, we apply the phase description model of coupled oscillators. The following model for the oscillator,

$$\dot{\phi}_i(t) = \omega_i + \frac{K}{n_i} \sum_{j=1}^{n_i} \varepsilon_{ij} \sin(\phi_{ij} - \phi_i), \tag{2}$$

is used in the self-organizing control. By applying the Eular's formula, (2) is reformed as

$$\dot{\phi}_i(t) = \omega_i + \sigma_i K \sin(\bar{\phi}_i - \phi_i). \tag{3}$$

Where $\bar{\phi}_i$ is the weighted phase average field depending on the amount of traffic flows from the neighboring signals S_{ij}.

C. Self-organizing control of Offset Pattern

Self-organization of offset pattern on the signal network is realized through a mutual entrainment in (2). Let $\Delta\phi_{ij}$ be the phase difference with respect to ϕ_i defined by

$$\Delta\phi_{ij} = \phi_{ij} - \phi_i. \tag{4}$$

Let t^*_{ij} denote the expected time required for a vehicle to reach the signal S_i from S_{ij}, then the desired offset between the signals S_{ij} and S_i is given by

$$\Delta\phi^*_{ij} = 2\pi \frac{t^*_{ij}}{T_i} \pmod{2\pi} \tag{5}$$

where T_i is the cycle time of the signal S_i. The expected time t^*_{ij} is given by

$$t^*_{ij} = \frac{l_{ij}}{v^{max}_{ij}} \tag{6}$$

where, l_{ij} is the distance between the adjacent signal interval (S_{ij}, S_i), and v^{max}_{ij} is the speed limit of the road. We adopt $\Delta\phi^*_{ij}$ defined in (5) as a desired offset between the oscillators in the east-west direction where $\phi_i = 0$ corresponds to the start of the green period. However, we need to define the desired relative phase between oscillators in the north-south direction where $\phi_i = 0$ corresponds to the start of the red period as

$$\Delta\phi^*_{ij} = 2\pi \frac{t^*_{ij} + (T_{i-1,1} - T_{i,1})}{T_i} \pmod{2\pi}, \tag{7}$$

since the offset is defined as the time difference in the start of the green period. In this light, the desired natural frequency of the oscillator S_i is given by

$$\omega^*_i = \Omega_i - \tilde{\sigma}^*_i K \sin \Delta\bar{\phi}^*_i. \tag{8}$$

In order to achieve the desired relative phase,

$$\Delta\bar{\phi}^*_i = \arctan\left(\frac{\sum_{j=1}^{n_i} \varepsilon_{ij} \sin \Delta\phi^*_{ij}}{\sum_{j=1}^{n_i} \varepsilon_{ij} \cos \Delta\phi^*_{ij}} \right), \tag{9}$$

with respect to the weighted phase average field, $\bar{\phi}_i$, through mutual entrainment. Furthermore, we consider approximation of the natural frequency of the weighted phase average field $\bar{\phi}_i$. The natural frequency of the wieghted phase average field is approximated as

$$\Omega_i \cong \frac{1}{1 + \frac{1}{n_i} \sum_{j=1}^{n_i} \frac{\varepsilon_{ij}}{\varepsilon_{ji}}} \left(\omega_i + \frac{1}{n_i} \sum_{j=1}^{n_i} \frac{\varepsilon_{ij}}{\varepsilon_{ji}} (\omega_{ij}) \right). \tag{10}$$

The desired natural frequency ω^*_i in (8) is update by

$$\omega_i(\tau_i + 1) = \omega_i(\tau_i) + \alpha(\omega^*_i - \omega_i(\tau_i)) + \beta(\tilde{\omega}^*_i - \omega_i(\tau_i)). \tag{11}$$

Where τ_i is a scaled time associated with the period of the signal, and $\alpha, \beta \in (0, 1)$ is a positive constant. In (11), a base frequency $\tilde{\omega}^*_i$ for each signal is introduced to prevent the drift of the natural frequency of all the signals.

D. Split Adjustments

Consider the split settings which are adjusted according to the amount of incoming traffic. Now, define the cycle time of the signal S_i as

$$T_i(\tau_i) = T_{i1}(\tau_i) + T_{i2}(\tau_i) + 2T_{cl}, \tag{12}$$

where $T_{cl} = 5(sec)$ is clearance time, and $T_{i1}(\tau_i)$ and $T_{i2}(\tau_i)$ are the split time of the signal S_i in the east-west and north-south direction respectively. The split time T_{ik} is updated at the beginning of each signal cycle in proportion to the sum of the normalized amount of incoming traffic of the east-west and north-south direction.

$$r_{i1} = \sum_{k=1}^{2} \varepsilon_{i,2k-1}, \quad r_{i2} = \sum_{k=1}^{2} \varepsilon_{i,2k}. \tag{13}$$

as

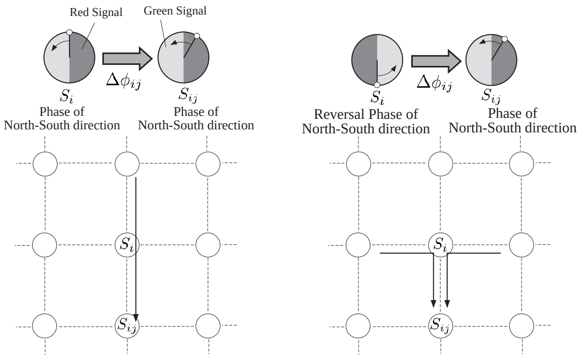
$$T^*_{ik} = \frac{r_{ik}(\tau_i)}{r_{i1}(\tau_i) + r_{i2}(\tau_i)} (T_i(\tau_i) - 2T_{cl}), \tag{14}$$

$$T_{ik}(\tau_i + 1) = T_{ik}(\tau_i) + \gamma(T^*_{ik} - T_{ik}(\tau_i)), (k = 1, 2). \tag{15}$$

Where γ is an updating constat.

E. Offset Adjustment Considering Left-Right Turns

Our previous work of the self-organizing control of signal network did not deal with left-right turns explicitly[9]. In this paper, we incorporate the effect of left-right turns into the previous model. In the previous method, the offset pattern is effectivily self-organized in the case of traffic situation is depicted in Fig.3(a). However, when the traffic situation is as shown in Fig.3(b) where the traffic flow turns left or right at the intersection S_i, the effective offset pattern is not available. The synchronization between the phase of north-south direction of S_{ij} and the *reversal* phase of north-south direction of S_i, which is equivalent to the phase of east-west direction, should



(a) Traffic going straight (b) Traffic turning left or right

Fig. 3. Offset adjustment between S_i and S_{ij}

be realized for offset adjustment in the case of Fig.3. To select the synchronization pattern of Fig.3(a) or Fig.3(b), we use the traffic outflow from S_i. As shown in Fig.2(b), the amount of traffic outflow which turns left through the intersection S_i is denoted by $\rho_{ij_1,l}(t)$, the amount of traffic outflow which goes straight denoted by $\rho_{ij_2,s}(t)$ and the amount of traffic outflow which turns right denoted by $\rho_{ij_3,r}(t)$. Total amount of traffic outflow $\tilde{\rho}_{ij}(t)$ is given by

$$\tilde{\rho}_{ij}(t) = \rho_{ij_1,l}(t) + \rho_{ij_2,s}(t) + \rho_{ij_3,r}(t). \tag{16}$$

In order to adjust offset between the phase of north-south direction of S_{ij} and the reversal phase of north-south direction of S_i, we define the phase considering left-right turns of S_i denoted by $\tilde{\phi}_{ij}$. Turn rate κ_{ij} on S_i is defined by

$$\kappa_{ij} = \frac{\rho_{ij_1,l} + \rho_{ij_3,r}}{\tilde{\rho}_{ij}}. \tag{17}$$

Hence, the modified phase considering left-right turns is defined by

$$\tilde{\phi}_{ij} = \phi_i + \xi_{ij}\frac{2\pi T_{i,2}}{T_i}. \tag{18}$$

Where μ, c are constants. Also turn sensitivity ξ_{ij} is defined by

$$\xi_{ij} = \frac{1 + \tanh(\mu\kappa_{ij} - c)}{2}. \tag{19}$$

(19) is introduced to select the synchronization pattern of Fig.3(a) or Fig.3(b).

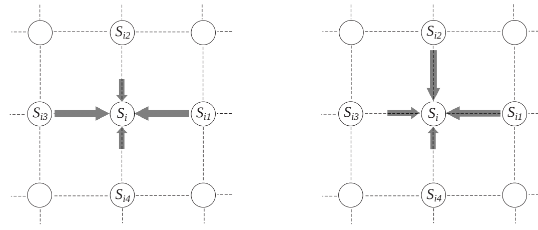
III. Architecture of SRGS

A. Even Two-way Traffic Problem of Traffic Signal Network

The offset is not adjusted in the certain traffic situation, called even two-way traffic, where the difference between the amounts of traffic flow on the east-west and north-south directions that face toward each other is little (Fig.4). To cope with this problem, we consider the route guidance system which forms the route avoiding the even two-way traffic flow such that effective offset patterns are self-organized.

B. Configurations of SRGS

The SRGS is composed of vehicle guidance units depicted in Fig.5. Each intersection S_i at the guidance area has a vehicle guidance unit U_i, which has a reward variable corresponding to the destination $h, (h = 1, 2, \cdots, N_h)$ denoted by R_i^h. The



(a) Even two-way traffic flows (b) Uneven two-way traffic flows

Fig. 4. Traffic flow patterns on signal network

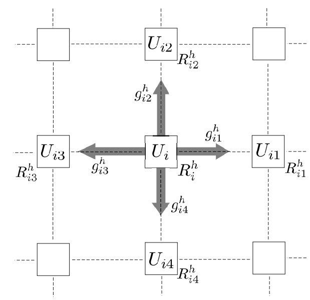


Fig. 5. Reward and guidance vector of U_i on layer h

SRGS has a multi-layered guidance vector fields corresponding to each destination for the route guidance (Fig.6). The guidance unit decides the route guidance corresponding to the destination of the vehicle based on the guidance vector. The guidance vector of the guidance unit U_i corresponding to the destination h denoted by

$$\boldsymbol{g}_i^h = \{g_{i1}^h, g_{i2}^h, g_{i3}^h, g_{i4}^h\}. \tag{20}$$

Where $g_{ij}^h \geq 0,\ \sum_{j=1}^4 g_{ij}^h = 1$. In SRGS, vehicles communicate with a guidance unit at every intersection. Every guidance unit has the local route guidance information for each destination. Vehicle transmits the own destination toward the guidance unit. The guidance unit transmits the route guidance information to the vehicle. Units can observe the local information and self-organize a route corresponding to each destination through a local interaction. The vehicle send its own destination to the guidance unit when it enter the intersection. The guidance unit corresponding to destination receives reward value according to frequency of transmission. Reward value is difused over the guidance unit through the local interaction of guidance units. Guidance vector field corresponding to each destination is formed by the reward field spreading on the urban. The route for the destination which many vehicles select is reinforced. We adopt the distributed and self-organizing strategy because distributed and self-organizing strategy are effective under the dynamical traffic environment.

IV. Self-organizing Method of Multi-layered Guidance Vector Fields

A. Evaluation of Traffic Flows

In this section, we propose the self-organizing method of multi-layered route guidance vector field (Fig.6, 5). The main theme of SRGS is how does SRGS generate the traffic flow that facilitates a self-organization of an offset pattern of traffic signal network. On the other hand, traffic congestion occur when large amount of vehicles flow into the same

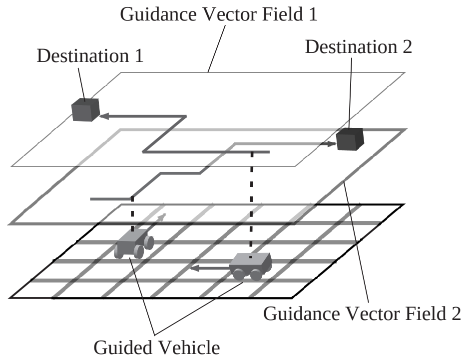


Fig. 6. Multi-layered vector fields of SRGS

intersection. Therefore, we consider the method to facilitate offset adjustment of traffic signals under avoiding traffic jam raises. Multi-layered guidance vector field is formed by reward difference between intersections. We describe the evaluation of traffic, the method of spreading the reward field and deciding guidance vectors in following.

Consider evaluation of traffic flow pattern which inflow to the intersection S_i. Self-organizing control of signal network is able to adjust the offset between signals on the condition that uneven two-way traffic. Although, the offset adjustment does not function on the condition that even two-way traffic. Therefore, uneven two-way traffic is needed to facilitate the offset adjustment.

In order to evaluate the traffic pattern of S_i, let $E_{i,1}, E_{i,2}$ denote unevenness of east-west and north-south two-way traffic define by as follows,

$$E_{i,1}(\tau_i) = \frac{1}{2}\left|\frac{\varepsilon_{i1}(\tau_i) - \varepsilon_{i3}(\tau_i)}{\varepsilon_{i1}(\tau_i) + \varepsilon_{i3}(\tau_i)}\right|, \tag{21a}$$

$$E_{i,2}(\tau_i) = \frac{1}{2}\left|\frac{\varepsilon_{i2}(\tau_i) - \varepsilon_{i4}(\tau_i)}{\varepsilon_{i2}(\tau_i) + \varepsilon_{i4}(\tau_i)}\right|. \tag{21b}$$

Where, τ_i is discrete time based on the period of S_i. The higher value of $E_{i,1}$ and $E_{i,2}$ imply that the unevenness of S_i is large. Large amount of traffic flow cause the traffic congestion even though the traffic flow pattern is facilitating the offset adjustment. Thus, we consider the congestion degree denoted by F_i. F_i is defined by

$$F_i(\tau_i) = \prod_{j=1}^{n_i}(1.0 - \varepsilon_{ij}(\tau_i)). \tag{22}$$

Note that the traffic congestion degree F_i will go to 0 when the traffic congestion occurs. Also, we define the traffic evaluation value E_i based on $E_{i,1}$, $E_{i,2}$ and F_i, as follows.

$$E_i(\tau_i) = F_i(\tau_i)\ (E_{i,1}(\tau_i) + E_{i,2}(\tau_i)). \tag{23}$$

Weighted evaluation $\bar{E}_i$ of recent time steps T is given by

$$\bar{E}_i(\tau_i) = \sum_{n=0}^{L} \lambda^{n-L} E_i(\tau_i - n), \tag{24}$$

where $\lambda \in (0,1)$ is decay rate. $\bar{E}_i$ will take a large value in the condition that the traffic flow pattern facilitates an effective offset adjustment for the traffic flow.

B. Update Law of Reward Variable and Guidance Vector

The reward R_i^h is decided by the evaluation of traffic and a neighboring reward R_{ij}. The route between S_i and S_{ij} is reinforced when traffic flow from S_i to S_{ij}. Now, normalized traffic density ε_{ij} is divided into the traffic density of every layer according to the destination h, which is denoted by ε_{ij}^h. Where the relation between ε_{ij} and ε_{ij}^h holds as follows,

$$\varepsilon_{ij} = \sum_{k=1}^{N_h} \varepsilon_{ij}^k. \tag{25}$$

The in-out relation of traffic flow between S_i and S_{ij} is defined by

$$e_{ij}^h = \frac{\varepsilon_{ji}^h + \left(1.0 - \varepsilon_{ij}^h\right)}{2},\ (0 \le e_{ij}^h \le 1). \tag{26}$$

When the amount of traffic flow from S_i to S_{ij} is larger and the amount of traffic flow from S_{ij} to S_i is smaller, a in-out relation e_{ij}^h approaches to 1. The reward R_i^h is updated with (26) and (24) as follows,

$$R_i^h(\tau_i+1) = \bar{E}_i(\tau_i)\left(R_i^h(\tau_i) + \frac{\eta}{n_i}\sum_{j=1}^{n_i} e_{ij}^h \Delta R_{ij}^h(\tau_i)\right). \tag{27}$$

Where $\eta \in (0,1)$ is updating constant, ΔR_{ij}^h is the difference of a reward R_i^h and a neighboring reward R_{ij}^h is given by

$$\Delta R_{ij}^h(\tau_i) = R_{ij}^h(\tau_i) - R_i^h\,(\tau_i)\,. \tag{28}$$

By this updating law, a reward spread to intersections having high evaluation value of traffic. Then, the guidance vector is updated by following law.

$$g_{ij}^h(\tau_i+1) = \frac{g_{ij}^h(\tau_i) + \theta\Delta R_{ij}(\tau_i)}{\sum_{j=1}^{n_i}\left(g_{ij}^h(\tau_i) + \theta\Delta R_{ij}(\tau_i)\right)}. \tag{29}$$

Where, $\theta \in (0,1)$ is an updating constant.

C. Route Selection Method

The route guidance information is transmitted to the vehicle is selected by a probability p_{ij}^h corresponding to the destination h. Let u_j be the coefficient to restrict a U-turn defined by

$$\begin{aligned} u &= \{u_1, u_2, u_3, u_4\} \\ &= \begin{cases} \{0,1,1,1\} & \text{if vehicle's position is east} \\ \{1,0,1,1\} & \text{if vehicle's position is north} \\ \{1,1,0,1\} & \text{if vehicle's position is west} \\ \{1,1,1,0\} & \text{if vehicle's position is south} \end{cases}. \end{aligned} \tag{30}$$

Then, the route selection probalility p_{ij}^h is defined with u_j as follows,

$$p_{ij}^h = \frac{u_j exp\left(Dg_{ij}^h\right)}{\sum_{j=1}^{n_i} u_j exp\left(Dg_{ij}^h\right)}. \tag{31}$$

Where D is a constatnt.

TABLE I

SIMULATION PARAMETERS

v_{max}	maximum velocity	50 km/h(13.89 m/s)
a^{+}_{max}	acceleration	1.5 m/s^2
a^{-}_{max}	decceleration	-3.0 m/s^2
K	coupling constant	0.1
α, β	updating rate of ω	0.5, 0.05
$\tilde{\omega}^{*}_{i}$	base natural frequency	0.10147
ρ_{im}	road capacity	80 vehicles
μ, c	turn sensitivity constant	30, 15
λ	decay rate of E	0.8
θ	updating rate of g	0.05
D	decision constant	25

V. SIMULATIONS

A. Vehicle Model

We use the vehicle model and the road model depicted in Fig.7. The road has a two-lane. One is a straight line, and the other is a right-turn lane. In the vehicle model, the desired velocity of the vehicle m is detemined by

$$v^{*}_{m} = \begin{cases} v_{max} & \text{if} \quad x_m > \frac{(v_{max})^2}{\left|2a^{-}_{max}\right|} \\ \sqrt{2\left|a^{-}_{max}\right| x_m} & \text{if} \quad x_m \le \frac{(v_{max})^2}{\left|2a^{-}_{max}\right|}, \end{cases} \tag{32}$$

according to the distance between the preceding vehicle $m+1$, and each vehicle follows this desired velocity with the acceleration/deceleration of $a^{\pm}_{max}$, where v_{max} is the speed limit.

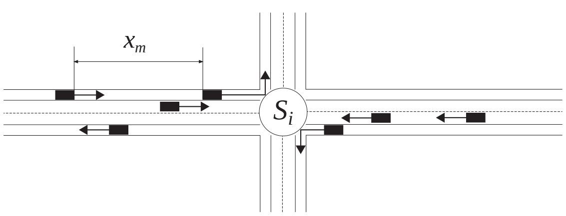


Fig. 7. Traffic flow model

B. Comparative Method

Now, to observe the effectiveness of the proposed system, we introduce a simple route selection method. The route selection probability $\tilde{p}^{h}_{ij}$ is decided by a normalized direction vector $\boldsymbol{d}^{h}_{i}$ from the intersection S_i to the destination h.

$$\boldsymbol{d}^{h}_{i} = \{d^{h}_{i1}, d^{h}_{i2}, d^{h}_{i3}, d^{h}_{i4}\}, \tag{33}$$

where $d^{h}_{ij} \ge 0,\ \sum_{j=1}^{4} d^{h}_{ij} = 1$. The probability $\tilde{p}^{h}_{ij}$ is defined with d^{h}_{ij} and u_j in (30) as follows,

$$\tilde{p}^{h}_{ij} = \frac{u_j d^{h}_{ij}}{\sum_{j=1}^{n_i} u_j d^{h}_{ij}}. \tag{34}$$

By using this simple route selection method, a vehicle avoids the roundabout route, and the traffic flow is dispersed in a measure. We call this method basic direction route guidance.

TABLE II

SIMULATION ENVIRONMENT

t = 0∼20000	Traffic situation 1 (Fig.8(a))
t = 20000∼40000	Traffic situation 2 (Fig.8(b))
t = 40000∼60000	Traffic situation 3 (Fig.8(c))

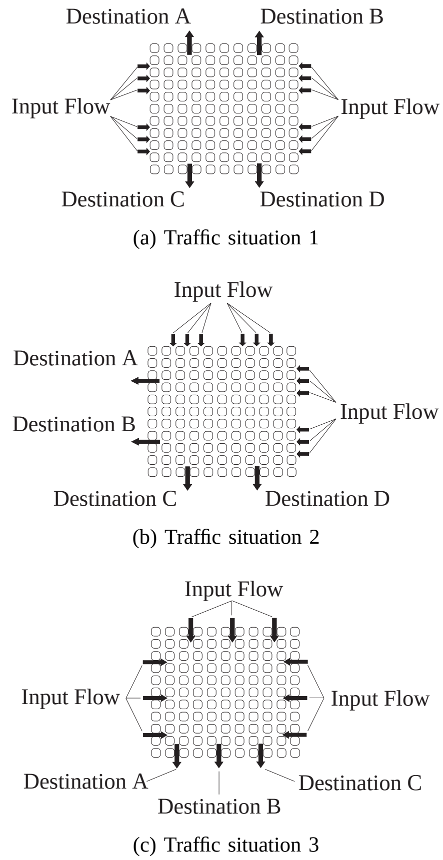


Fig. 8. Traffic situations used in simulations

C. Simulation settings

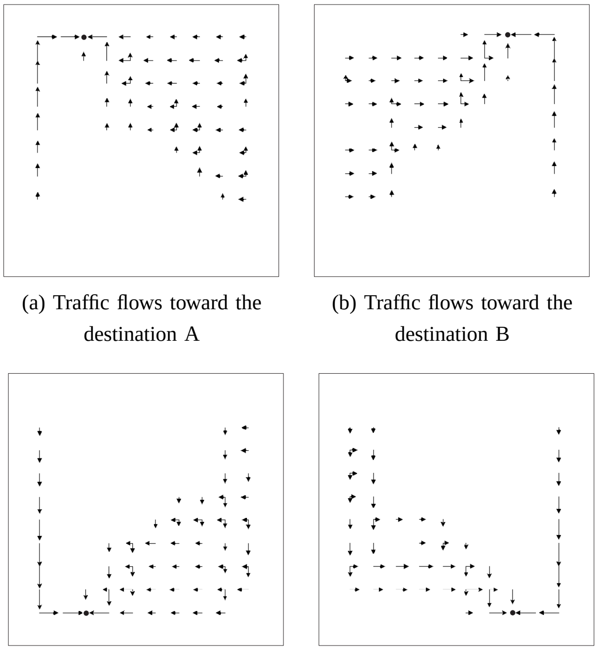
Consider the traffic signal network with the 10 × 10 grid. We examine the proposed system in several traffic situations. Vehicles flow into the signal network from the specified intersections called inflow intersection. Then, each vehicle chooses the destination randomly with the same probability. Following two cases are examined.

- self-organizing route guidance
- basic direction route guidance

The amount of inflow is set to 5 vehicles/min on each inflow intersection. The initial natural frequency (rad/s) and phase (rad) of each signal is given randomly as 0.08 $\pm$ 0.02 rad/s and $0 \sim 2\pi$ rad respectively.The initial route guidance vectors are $\boldsymbol{g}^{h}_{i} = \{0.25, 0.25, 0.25, 0.25\}$. The distance between signals is 200 meters, and the other parameters are listed in Table.I

D. Simulation Results

Consider the traffic situation as shown in Fig.8(a) - 8(c). We simulate the dynamical environment where the traffic situation changes according to Table.II.



(a) Traffic flows toward the destination A

(b) Traffic flows toward the destination B

(c) Traffic flows toward the destination C

(d) Traffic flows toward the destination D

Fig. 10. Average traffic flows toward each destination during t = 0∼20000

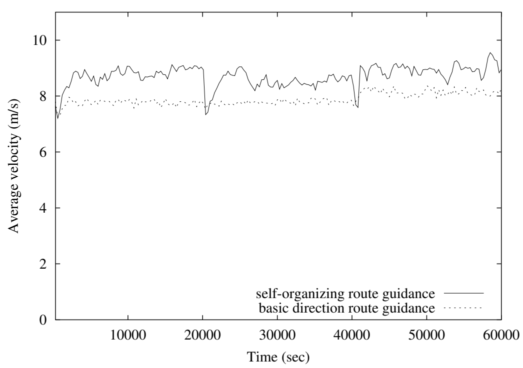


Fig. 9. The average velocity of all vehicles. The traffic simulation is changed at t = 20000 and t = 40000.

The simulation result, the average velocity of all vehicles, is shown in Fig.9. The solid line shows the result of the case where self-organizing route guidance is used, and the dotted line shows the result of the case where basic direction route guidance is used. In the case of self-organizing route guidance is used, the average velocity of all vehicles during t = 0∼20000 is 8.72 m/s = 31.4 km/h. In contrast, when we use basic direction route guidance, the average velocity of all vehicles during t = 0∼20000 is 7.75 m/s = 27.9 km/h. The proposed system achieves the effective traffic flows. The average traffic flow corresponding to each destination during t = 0∼20000 is as shown in Fig.10. Guidance vector fields avoiding even two-way traffic flow patterns are self-organized by proposed method even though the even two-way traffic flow pattern occurs frequently in this traffic situation.

Then, we discuss the traffic situation dynamically changes. In this simulation, the traffic situation is changed at t = 20000 and t = 40000. Thought the average velocity comes down at t = 20000 and t = 40000, the proposed system adapts to changes of the traffic situation immediately. In the case of self-organizing route guidance is used, the average velocity of all vehicles during t = 20000∼40000 is 8.50 m/s = 30.6 km/h. On the other hand, the average velocity of all vehicles during t = 20000∼40000 is 7.77 m/s = 28.0 km/h when we use basic direction route guidance. By the same, the average velocity during t = 40000∼60000 is 8.91 m/s = 32.1 km/h when self-organizing route guidance is used, and the average velocity during t = 40000∼60000 is 8.13 m/s = 29.1 km/h when basic direction route guidance is used. The simulation result illustrates effectiveness of the proposed system under the dynamic traffic situation.

VI. Conclusions

In this paper, we proposed Self-organizing Route Guidance Systems (SRGS), which integrates the self-organizing control of signal network and the route guidance systems. The route guidance system navigates the traffic flow with the same destination to a specific path so that the self-organization of signal network functions more efficiently. In the simulation, the guidance vector fields, which avoid the traffic congestion and the traffic flow pattern preventing the offset adjustment, are generated. The simulation results show the effectiveness of this unified approach in the dynamical traffic situation. In general, since each vehicle has its own destination, some technique should be introduced to put together similar destinations into roughly defined destination. This is a future work.

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