論 文 の 内 容 の 要 旨

論文題目　Methods for easing traffic jams by microscopic behaviors
（ミクロな相互作用による渋滞改善方法）

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Jams on road traffic cause huge financial losses, e.g., 11 trillion yen in 2005 year in Japan, therefore in this thesis we aim to reduce them. The characteristic of this thesis is to utilize microscopic interactions of cars for easing jams. In the field of traffic engineering, traffic dynamics has been developed by observations and making traffic models. Moreover, various methods to ease jams, for instance, ramp metering, variable speed limits and route guidance have been studied and applied in real traffic. Great efforts have been made for these methods. However, it is important to seek other methods for further improvement of traffic flow. On the other hand, in the field of physics, traffic flow has been studied as a dynamics of the self-driven particles (SDPs). SDP is the general term of particles which move by themselves, e.g., cars, pedestrians, ants and animals. SDPs move and stop by themselves and the interactions among them are not always symmetric so that the law of action-reaction is not satisfied in SDP-systems. The systems contain rich collective phenomena such as phase transitions from free flow to jams and self-clustering. The relationships between microscopic interactions among SDPs and the collective phenomena have been studied and clarified. For instance, in traffic flow from 90's, the three phase traffic flow theory was proposed by Kerner, spontaneous traffic jams were observed in circuit experiments by Sugiyama et al. and metastable branches have been studied in simple models such as Cellular Automata (CA).　As a next step, we use microscopic interactions, e.g., car-following behaviors and lateral interactions, for improving the efficiency of the collective flow. There are related fields to utilize microscopic behaviors such as the driver-assistance systems (e.g., adaptive cruise control). In this thesis, we aim to improve the flow with least devises since the rate of propagation of the assistance systems is low, e.g., ACC is spread only 1 percent for the total cars and large-sized

cars made for the use in Japan in 2010. As to the jams to be eased, we choose the two jams, jams due to merging behaviors and spontaneous jams. We choose them since they are the major jams in the three Japanese highways. Besides, jamming formations of the two jams are closely related to the microscopic behavior of each car so that they are expected to be eased by tuning microscopic behaviors. As to the methods, we utilize the microscopic behaviors as follows. We study to improve the merging flow by stirring emergent zipper configuration before merging since this configuration realizes smooth merging. We study to realize the zipper merging by only drawing orange compartment lines on the roads without any additional devices equipped with cars. On the other hand, we study to remove spontaneous jams by tuning a single car's car-following behavior such as taking large headways before entering a jam and absorbing it. This method was firstly demonstrated by Beaty. Beaty's study lacks theoretical studies so that we make the methodology of this driving. This thesis covers mainly the construction of methodology and the study of basic phenomena with simple models since fundamental studies are the basis of more extended studies such as numerical simulations with the latest traffic models. Regarding the zipper merging, firstly we have covered the emergent zipper configurations before merging as an arrangement of our previous results. We have prepared a plan to induce zipper merging such that we draw a compartment line between the two lanes in a merging area. We have used a simple cellular automaton model with a lateral interaction such that cars tend to decelerate in responding to the existence of other cars on the neighboring lane. Moreover, we have defined the degree of zipper configurations as a measurement value. Numerical simulations have shown that emergent zipper configurations are achieved before merging by only this local hesitation. Furthermore, we have constructed how to obtain analytical results of spatial change of the configurations and intensions (corresponding to velocities) with mean field analysis. The analytical results agree with the results of numerical simulations. Then, we have studied the effect of zipper merging by using flux and travel time as measurement values. We have used as dynamics a multiple-lane CA model with a slow-to-start (SlS) rule where SlS rules represent the delay of action of cars after the blocked state. We have used an open system such as a two-lane lattice connected with a cell to investigate the flux. From numerical simulations we have observed that the flux in case zipper merging is higher than that in case non-zipper merging when the slow-to-start rule is relatively strong. Moreover, we have depicted how the achievement of zipper merging depends on the length of interaction-area, the parameter of hesitation and the injection probability. Furthermore, we have constructed the analytical flux with mean field analysis. This analytical result agrees with the results obtained by numerical simulations. For investigating the travel time, we have used a semi-open system such that a two-lane lattice connected with three cells. Cars are initially placed and we set two kinds of cars such as cars determined to go out of the system with or without merging behaviors. Cars without merging behaviors go straight through the system. We have investigated the travel time by changing the ratio of the two kinds of cars. We have found that the improvement of travel time by zipper merging needs not only the relatively strong SlS rule, relatively small hesitation, sufficient length of the interaction area and relatively high initial density but also relatively high ratio of merging cars. Furthermore, we have investigated the cases of the existence of cars which do not interact with other cars on the neighboring lane. In the system for investigating flux, we have set the case that cars on the one lane do not have hesitations. In the system for investigating the travel time, we have set the ratio of cars in both lanes which have no hesitations. Numerical simulations show that in the presence of these ignoring cars, the efficiency of merging is not improved well. This result suggests that each car should interact with other cars for improving the efficiency of merging. Regarding the driving for jam-absorptions, we have made the framework of this driving. We have used a simple kinematic model for representing the movement of cars. We have calculated the propagation of perturbations caused by the car performing this driving and analyzed in detail the point where the perturbations disappear. We have also calculated the driving for jam-absorption in two steps. This two-step absorption leads to multiple patterns of collisions among perturbations and we have divided the patterns clearly. As pointed above, from the results of the zipper merging, we have obtained the possibility to improve the efficiency of merging behaviors. From the results of the driving for jam-absorption, we have obtained the whole image of this driving helpful to perform this driving. Therefore, our results show the possibility to reduce the two major jams in highways and their related roads so that we conclude that our methods contribute to reduce traffic jams.