論文の内容の要旨

論文題目　Unified Analysis on Shock Wave Formation in Traffic Jam
（交通渋滞における衝撃波形成の統一的解析）

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Various kinds of jamming phenomena are observed in our daily life. In particular, a traffic jam on a motorway is a very familiar phenomenon and attracts not only traffic engineers, but also physical and mathematical scientists. In the engineering field, the study of traffic flow plays an absolutely important role that various kinds of infrastructures are improved so that traffic congestions are resolved. In contrast, from the physical viewpoint, the system of traffic flow is considered as a non-equilibrium and dynamical system of interacting particles, in which the several feature such as phase transition, bifurcation of a dynamical system, pattern formation, etc., due to collective motion of interacting particles are observed. Moreover, in terms of mathematical science, common mathematical structure underlies the dynamics of traffic flow, which is described by various "*microscopic*" and "*macroscopic*" models. It is known that some of these models are related with each other, which is shown by using mathematical method such as ultra-discretization method or Euler-Lagrange transformation.

In this thesis, we have investigated the jamming formation, i.e. shock wave formation in two new models : one describes the dynamics of one-dimensional traffic flow on a motorway as a compressible fluid model, so-called "*macroscopic*" approach, based on the dynamical wave theory, and the other describes the dynamics of public conveyance system as a stochastic cellular automaton model so-called "*microscopic*" approach.

In the former study, we have proposed a new compressible fluid model for traffic flow, which focuses on the anisotropic behavior of particles and the variation of the reaction time of drivers. Previous models are good in terms of stabilized shock wave and the instability of homogeneous flow, which are the essential feature in traffic flow, however they certainly include the diffusion term which has an isotropic nature. It is impossible that vehicles in traffic jam move backward according to the diffusion term, in order to resolve the traffic congestion. The goal of this study is to propose a new model which shows the instability of homogeneous flow and stabilized shock wave without diffusion term. From actual measurements, we have found that the reaction time of drivers is changed according to situations of roads, that is, the reaction time of drivers decreases as the density of particles increases, although all previous models treat the reaction time of drivers as a constant value. We propose a new compressible fluid model by changing this parameter from constant value to variable value given by the function of density based on experimental results. The linear stability analysis on this model shows the existence of instability of homogeneous flow. Moreover, small perturbation is propagated without numerical divergence as a saturated wave, which indicates the cluster of traffic jam propagates as a stable wave. This nonlinear saturation is demonstrated by numerical calculations and also shown analytically by reductive perturbation method. In particular, we have obtained Burgers equation and higher-order Burgers equation by reductive perturbation method.

In the latter study, we have proposed a new public conveyance model applicable to buses and trains by using stochastic cellular automaton. We have found the optimal density of vehicles, at which the average velocity becomes maximum, significantly depends on the number of stops and passengers behavior of getting on a vehicle at stops. The efficiency of the hail-and-ride system is also discussed by comparing the different behavior of passengers. Moreover, we have found that a big cluster of vehicles is divided into small clusters, by incorporating information of the number of vehicles between successive stops.

Additionally, by expanding road structure, public conveyance model is applied to the dynamics of elevators. We introduce the collective effect of cages based on the behavior of embarking and disembarking passengers explicitly to the elevator system and estimate the efficiency of the system by computer simulations and analytical calculations. Furthermore, introducing the network structure into public conveyance model, we make a real-time simulator of Tokyo Metro Railway Network. In the railway transportation service, on-time operation of trains is quite important. However, once an accident occurs, on-time operation becomes difficult due to a change of the passenger flow pattern. In this case, it is crucial to estimate how the flow pattern changes. Our simulator can immediately estimate the change of the passenger flow pattern even if an accident occurs at the busiest area. Moreover, we have presented a homogenization re-schedule method to alleviate congestion of crowded train. It is found that our method is more efficient than the conventional one.