Abstract of Doctoral Dissertation

Degree requested Doctor of (Life Science) / Pharmaceutical Science / Clinical Pharmacy Applicant's name: Udoy Sankar Basak

Title of Doctoral Dissertation

Study on Identification of Leader and Follower Agents and its Interaction Domain from Trajectories in a Collectively Moving Colony

(協同的コロニーの軌道データによる先導・従エージェントと
それらの相互作用領域の同定に関する研究)

Collectively moving animals is one of the most beautiful creations of Nature Mother. The synchronized movement of bird flocks at dusk, or the beauty of schools of fish can fill our heart with an abundance of love, joy and endless happiness again and again. Collective migration can also be observed at cellular level, e.g., wound healing, cancer development, and organogenesis.

For instance, the Vicsek model (VM) has been studied as the minimalist model for shedding light on unveiling the mechanisms of collective motion of a group of self-propelled particles. A modified version of the VM can also be used to study the leader and follower classification.

The general conjecture of collectively moving agents is the presence of influential individuals, known as `leaders', who control the movement of the whole group. These special agents employ asymmetric influence on the other group members, known as the 'followers'. Identifying leader and follower particles is a puzzling endeavor. Although the relative cell position might be an indicator of potential leaders in MDCK epithelial cells, cancer growth, and fish shoal, what characterizes leaders and followers is an open question in general, for instance, for Dictyostelium discoideum cells where there is no apparent indication of which cells might have more influence over others. Various types of empirical data, e.g., ensemble of trajectories of agents, can be used to infer the differential influence in interaction and leader-follower relationship. Leaders are expected to be more persuasive compared to the followers. In other words, it can be said that leader agents control the movement of the follower agents, which means that it is the leaders who 'cause' the movement of followers. Consequently, leader and follower agents can be identified by determining the direction of 'causality'.

Transfer entropy (TE), as a probability distribution-based measure, can identify the non-linear interaction between agents. Hence can be used to identify leader and follower particles. It has been found that cAMP concentration data can capture leader and follower cells in a D. Discoideum colony. TE has been used for this purpose.

For experimental data one cannot identify the leader in a certain way. To check the reliability of TE in identifying leader and follower, the modified VM has been used. It has been found that TE outperforms the linear measure cross-correlation in classifying leader and follower particles.

Interactions among agents are an important feature of spatiotemporal coordination of the agents. In most cases two agents cannot communicate over infinite distance, and thus it is natural to suppose the interactions are inherently local. By quantifying information flow between particles as a function of the distance between them, the interaction domain is expected to be inferred. It is found that transfer entropy along with this scheme achieves more accurate results than (time) cross correlation in estimating the interaction domain. Furthermore, the classification of leaders and followers is significantly improved by using the identified optimal interaction domain compared to the case in which transfer entropy is computed over all pairs irrespective of distance.