Introduction to MULTI-AGENT SYSTEMS

"But even as the influence of decentralized ideas grows, there is a deep-seated resistance to such ideas. At some deep level, people seem to have strong attachments to centralized ways of thinking. When people see patterns in the world (like a flock of birds), they often assume that there is some type of centralized control (a leader of the flock). According to this way of thinking, a pattern can exist only if someone (or something) creates and orchestrates the pattern. Everything must have a single cause, and ultimate controlling factor. The continuing resistance to evolutionary theories is an example: many people still insist that someone or something must have explicitly designed the complex, orderly structures that we call Life." (Resnick, 1994)

In today's world, development of network science has helped us achieved an unprecedent success in science, engineering, biology etc. The advancement in this field can be attributed in two ways. On one hand, it allows us to understand contribution of the individual agent on the collective behaviour of the system. This has been vital in deeper understanding of the biological and chemical systems. While, on the other hand, this help to develop the network distributed systems that resembles the natural counterparts, for example, flocking of the bird.

Multi Agent Systems (MAS)

Multi-agent system are the powerful paradigm for developing and understanding the network distributed systems, where the information is shared using the avaliable communication channel to achieve the desire objective. Each system, also know as *agent* can enjoy the certain degree of autonomy, based on the system being modelled. The autonomy of agents, their normed freedom of interaction, and the possibility of deploying large-scale systems with minimal care on issues related to distributed systems are few of the major benefits of approaching modeling and simulation of complex systems with agents.

Application of MAS

In biological process, where MAS have been successful exploited regarding the study of biological phenomena, is the protein synthesis, a common and relevant phenomenon in nature.

In recent years, consensus, coordination and synchronization [1] problems have been popular subjects in systems and control, motivated by many applications in physics, biology, and engineering. These problems arise in multi-agent systems with the collective objective of reaching agreement about some variables of interest.

1 Network Dynamics

2 Applications

3 Consensus

In the consensus literature, the emphasis is on the communication constraints rather than on the individual dynamics: the agents exchange information according to a communication graph that is not necessarily complete, nor even symmetric or time-invariant, but, in the absence of communication, the agreement variables usually have no dynamics. It is the exchange of information only that determines the time-evolution of the variables, aiming at asymptotic synchronization to a common value. The convergence of such consensus algorithms has attracted much attention in recent years.

4 Synchronization

Synchronization can be considered as the most important phenomenon to describe the interaction between two or more agents. Due to this reason, it has gain significant attention and extensively studied in area such as physics, biology, chemistry etc. In the synchronization literature, the emphasis is on the individual dynamics rather than on the communication limitations: the communication graph is often assumed to be complete (or all-to all), but in the absence of communication, the time-evolution of the systems' variables can be oscillatory or even chaotic. The system dynamics can be modified through the information exchange, and, as in the consensus problem, the goal of the interconnection is to reach synchronization to a common solution of the individual dynamics .

From the system dynamics point of view, synchronization mainly depends on type and strength of the interconnection, network structure and the dynamics of the individual agent. More precisely, the type of interconnection can be of different type, either linear or non-linear, diffusive or global etc. The diffusive coupling mean the near neighbor interconnection and while in global coupling, every agent has a communication channel with every other agent in the network. Network structure is usually represented by graphs and they can directed graphs (information flows in single direction), undirected graphs (information flows in both directions) etc.

From dynamical-systems viewpoint, synchronization depends on the following key factors,

- the type and strength of the interconnection among the nodes,
  -depends on the strength of the coupling and on output function of the nodes' state variable.
  -also on the type of coupling, linear, non-linear, global, diffusive.
- the network structure - usually represented by graphs, directed, un-directed.
- the dynamics of the individual units- dynamics of the systems, linear, non-linear and the homogeneous (systems have similar dynamics) or heterogeneous (systems has different dynamics).

Diffusive Coupling and Network Periodicity: A Computational Study Eun-Hyoung Park,* Zhouyan Feng,† and Dominique M. Durand* —Synchronization, one of the most universal phenomena to describe the behavior of two or more interacting systems, has been extensively studied in various areas such as physics, biology, chemistry, and neuroscience (1,2). Synchronization is commonly understood as adjustment of rhythms due to an interaction between two or more oscillators, and therefore it does not necessarily require complete temporal coincidence of signals.

A key mechanism of synchronization is a mutual interaction due to the coupling between oscillatory systems. One of well-understood coupling mechanisms is global coupling (or all-to-all coupling) through which each oscillator interacts with equal strength with all of the other oscillators in the system. This type of coupling has been extensively studied (see Okuda (3) and references therein). Lesser attention has been paid to another type of coupling, local coupling, equally termed as nearest-neighbor coupling or diffusive coupling. This diffusive coupling has been introduced initially based on a diffusion like process (4). Unlike global coupling that generates a mean field in the ensemble of oscillators, diffusive coupling produces a local interaction only between each component of the network and its nearest neighbors. Several theoretical studies on diffusive coupling have appeared in the literature in recent years. Some of them concentrate on mathematical theory (5–8) and others include physiological aspects (9–11). Although diffusive coupling is more common and realistic in many physical systems (12–14), it is neither well understood nor widely studied compared to the global coupling (12,13,15).

Throughout this study, we will use the terms "lateral diffusion" mechanism and "diffusive coupling" interchangeably. In general, the term "diffusive coupling" is used for describing a coupling type, i.e., how the elements in the network are coupled with each other, and therefore, the use of this concept is not limited to the actual diffusion process. Also, we will use the terms "dispersion" mechanism and "global coupling" interchangeably. To avoid confusion, throughout this study, we will use "potassium dispersion" instead of "potassium diffusion." —-

Mean Field Behavior: average of the initially disordered individual systems.

5 Co-ordination

Coordination problems encountered in the engineering world can often be rephrased as consensus or synchronization problems in which both the individual dynamics and the limited communication aspects play an important role. Designing interconnection control laws that can ensure synchronization of relevant variables is therefore a control problem that has attracted quite some attention in recent years

References

[1] L. Scardovi and R. Sepulchre, "Synchronization in networks of identical linear systems," *Automatica*, vol. 45, pp. 2557–2562, 07 2009.