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In engineering, the terminology of "swarms" has come to mean a set of agents whose behaviors are intimately coupled and which perform some task. Examples include autonomous ground, air, or underwater vehicles searching for an object. In biology, the terminology of swarms is reserved for certain species when they are in certain behavioral modes (e.g., honey bees after hive fission occurs and the swarm of bees is searching for, or flying to, a new home). It is sometimes useful to use biological swarms as examples of behaviors that are achievable in multiagent systems technologies (e.g., via a "bio-inspired design" approach). Moreover, multivehicle technologies have adjustable physical characteristics that can make them useful hardware simulation testbeds to emulate animal groups and hence help understand the science of animal group decision-making. These close connections between biology and engineering call for an integrated view of swarms.

To develop a generic swarms perspective, first begin by defining agents (vehicles, animals, software agents) to have sensory capabilities (e.g., position or velocity of other agents or environment characteristics), processing ability (e.g., a brain or on-board computer), and the ability to take actions via actuators (e.g., move to a location at a velocity or pick up some object and fix it). Sensor and actuator limitations (e.g, bandwidth) and errors (e.g., sensor noise), along with limited agent processing abilities (e.g., due to finite memory and computational throughput) make any agent error-prone. Physical agent characteristics (e.g., of a wheeled robot or flying vehicle) along with agent motion dynamics (e.g., a fast or slow agent) constrain how the agent can move in its environment and the rates at which it can sense and act in spatially distributed areas. To further develop a generic swarms perspective, note that there is some medium through which agents influence each other and communicate. In biology this may be via chemical communication (e.g., in bacteria) or signals (e.g., the waggle dance of the honey bee). In engineering it may be via an ad hoc wireless network. Regardless, it is useful to think of the agents as nodes, and arcs between nodes as representing abilities to sense or communicate with other agents. The existence of an arc may depend on the communication or sensing range of agents, communication network and link imperfections (e.g., noise and random delays), along with local agent abilities (e.g., an ability to only communicate with one other agent at a time) and goals (e.g., a desire to communicate with only the agents that help it complete its task). A multiagent system is a set of such communicating agents that work to solve a task.

There have been several multiagent system behaviors and task achievement goals that have been studied. For instance, coordinated motion has received significant recent attention in cooperative robotics (e.g., to make the agents stay in a tight group, achieve a spatial pattern, or track a moving object) and biology (e.g., formation of fruiting bodies by bacteria, foraging behavior of ants, or cohesive flight of swarms of bees). Such problems are closely related to a group reaching a consensus or agreement (since often preference can be likened to position). Coordinated motion is, however, only one multiagent system objective, and often not the most important one. Three examples serve to illustrate this point. First, task allocation often arises in multiagent system problems where the "tasks" arise via interactions with the environment and the tasks must be allocated across the agents for efficient execution (e.g., via dynamic allocation of tasks to various robots). In this context, methods from distributed scheduling, load balancing and assignment are integrated into coordinated motion methods to achieve a multiobjective method that must balance tight group cohesion with the pressing need to complete tasks (e.g., to search a large region). Second, there are problems where agents must be distributed across regions to execute spatially distributed tasks (e.g., monitoring a large region with a small number of sensor-limited robots, or in biology when animals distribute themselves across spatially distributed food sources to maximize their feeding rates). Third, in some applications a group of error-prone agents must work together to find and select, as fast as possible, the best task to perform. In such group choice problems there is a complex interplay between the need to search for more/better tasks and the need to come to agreement on which is the best of the discovered tasks. Generally, there is a speed-accuracy trade-off where if a choice is made fast then it is error-prone, and if more time is allowed, agents can profitably combine their erroneous task quality estimates and fully search the space to ensure that a better task choice is made. In summary, in each of these three cases, significant attention must be given to achieving tasks that are not quantifiable via standard inter-agent distance/velocity patterns as in conventional studies of coordinated motion. Task achievement demands that agent motion characteristics achieve the task and hence traditional inter-vechicle spacing and velocity objectives are not met, at least part of the time.

Combining agent, sensing and communication characteristics results in a complex and multiscale system with local spatio-temporal agent actions dynamically combining into an "emergent" global spatio-temporal pattern of group behavior. For a given set of error-prone agents and task, there is a need to predict what behavioral pattern will exist for the mulltiagent system to verify that the task will be achieved (especially in safety-critical applications). Moreover, for a given desired objective or behavior for the multiagent system, there is a need to know how to design local agent characteristics (or how evolution adapted these) so that the desired objective reliably emerges. These form two key theoretical research problems and progress on validation of correct behaviors of multiagent systems is progressing rapidly for certain problems. For instance, methods from Lyapunov stability theory have been quite useful to establish conditions on local agents so that appropriate coordinated motion and task allocation emerges. Statistical and simulation-based methods have also met with some success in spite of the complexity of the systems. On the other hand, there has been relatively little work on the establishment of an experimentally-validated multiscale mathematical model of a biological swarm, one that can in some way also lead to analytical tractability and the subsequent elucidation of principles of species-generic swarm behavior in nature (e.g., how mechanism actions at the local level dynamically combine in agent-to-agent and agent-to-environment interactions for robust achievement of emergent behaviors in spite of error-prone agents). Indeed, considering the range of technologies and species to consider the swarms research area is likely to be vibrant and growing for some time to come. This special issue is welcomed as a step in advancing the field of swarms research in several important ways.