

Coordination of Groups of Mobile Autonomous Agents

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Currently there is considerable interest in understanding on the one hand, how various animal aggregations such as fish schools, bird flocks, deer herds, etc. coordinate their collective motions to perform useful tasks and on the other, how groups of mobile autonomous agents such as AUV schools, UAV flocks, etc., might be instructed to cooperate in a similar manner [1]. In this talk we will briefly overview several problems within this area. Not surprisingly, each involves some aspect of graph theory.

Flocking: In a recent *Physical Review Letters* paper, Vicsek *et al.* propose a simple but compelling model of n autonomous agents {i.e., points or particles} all moving in the plane with the same speed but with different headings. Each agent's heading is updated using a local rule based on the average of its own heading plus the headings of its "neighbors." In their paper, Vicsek *et al.* provide a variety of interesting simulation results which demonstrate that the nearest neighbor rule they are studying can cause all agents to eventually move in the same direction despite the absence of centralized coordination and despite the fact that each agent's set of nearest neighbors change with time as the system evolves. We outline a theoretical explanation for this behavior [2].

Rendezvousing: The problem of interest here is concerned with a system consisting of a group of n mobile autonomous agents which can all move in the plane. Each agent is able to continuously track the positions of all of its current neighbors within its sensing region. The *multi-agent rendezvous problem* [3] is to devise "local" control strategies, one for each agent, which without any active communication between agents, cause all members of the group to eventually rendezvous at single unspecified location. We describe a simple asynchronous solution to this problem. By modelling the resulting process as a suitably defined non-deterministic hybrid system, we are able to prove that proposed solution is correct under mild assumptions.

Closing Ranks: A group of mobile autonomous agents is said to move in formation if the distance between each pair of agents remains unchanged over time. This is typically accomplished by requiring some, but not all agent pairs to maintain fixed distances between them. A formation which can be so maintained is called *rigid* [4]. The closing ranks problem [5] for a given rigid formation which has lost a single agent, is to find new links between some agent pairs which, if maintained cause the resulting formation to again be rigid. In this talk we will discuss this problem within the framework of rigid graph theory [6].

Localization in Ad Hoc Sensor Networks: By an ad hoc network of stationary agents is means a group of agents, fixed in position, which are able to communicate with their "neighbors". Each agent knows the distance to each of its neighbors. Some of the agents also know their positions in world coordinates. The localization problem of interest is for each agent to determine if possible, its position in world coordinates by communicating with its neighbors [7]. In this talk we will briefly sketch how very recent results from global rigid graph theory can be used to decide if a given ad hoc network can be so localized. We also explain briefly how a modification of the algorithm which solves the rendezvous problem leads to a simplification of the localization process [8].

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