Research statement

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My research interests are in the mathematical foundations of multi-agent, distributed and networked systems: modeling, analysis, control, and optimization. I am specially interested in control problems with communication constraints, algorithms for robotic networks and sensor networks, modeling and control of natural and artificial swarms. In more detail, I may single out some lines of research.

- Consensus problems over networks.
- Sensor networks: distributed estimation.
- Robotic networks: deployment and coverage problems.
- Group behaviors in nature and engineering.

What is common among these topics is the role of communication constraints in the solution of control and optimization problems. To describe such constraints, it is often useful to resort to graph theory, as a natural model for networks, and to techniques developed in the related field of control with limited communication [13]. I shall now describe the above lines of research in more details.

Consensus problems over networks

Consensus is the problem of making a group of networked agents agree on some common value, in spite of the constraints imposed on their communication, computation and memory capabilities [14]. A special case of significant interest is average consensus, which means computing the average of some priory known values. To date, most of my research has focused on this prototypical problem. In my dissertation and my papers with R. Carli, F. Fagnani, and S. Zampieri [8, 3], I have extensively studied how a consensus algorithm can be implemented on a network whose communication links allow digital communication, hence communication of data with finite precision, noise, and potential losses. Future work in the field will concentrate on two issues. First, understanding the impact of data losses, due to broadcasting interference, on the performance of a consensus algorithm, in terms of speed and achievable asymptotical precision. Second, starting from the work in [2], the design of algorithms for digital noisy network which converge exponentially fast to the average of initial states.

Sensor networks: distributed estimation

Prospective sensor networks are expected to perform in-network computations of quantities of interest, instead of just forwarding data to some central collector [10]. To this goal, consensus algorithms are a building block, which needs to be suitably adapted and implemented: the network indeed will be application-specific. An example, motivated by the application to wildfire monitoring, can be found in [9], which regards the estimation of the parameters of a Gaussian distribution from noisy measurements.

Robotic networks: deployment and coverage problems

Deployment and coverage problems for groups of moving robots consist in optimizing their position in a given environment, with the least use of their communication and sensing capabilities [1]. On this topic, I am currently working with F. Bullo (UCSB) towards a novel approach to these problems, in which the environment is apportioned into respective regions of influence [7, 6]. This approach looks very promising for implementation on real robots, thanks to its low communication requirements (pairwise communications are enough) and its easy adaptation to both continuous and discrete environments.

Group behaviors in nature and engineering

Collective behavior of animal groups have been of interest for decades [12], as well as the related phenomena of vehicular traffic flows [11]. In recent years, this interest has been fostered by engineers aiming to design algorithms to warrant stable flock behaviors in groups of unmanned vehicles or aircrafts. My contributions to this field have been in the physics of traffic [4], and more recently in the analysis of emergent spatial patterns in groups of animals [5]. Future research, in collaboration with B. Piccoli, will apply the insights obtained from animal groups to the design of robust distributed algorithms for vehicles.

Perspectives

All these research lines are rich in potential developments, which I plan to pursue in the next future. Besides those I mentioned above, for instance, the research about consensus is likely to bring novel results in the field of *opinion dynamics*, which is of interest for economics and social sciences. Moreover, I'd also like to broaden my interests about distributed systems: in particular, I will be seeking for interplays between the control-theoretic techniques that I have been using so far, and tools from *game theory*.

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