COURSE ANNOUNCEMENT FALL 2007

UCSB Mechanical Engineering, Fall 2007, ME 225 FB
Course Title: **Cooperative Control of Robotic Networks**

Francesco Bullo, Mechanical Engineering, UCSB

Course Description: The course is intended primarily for graduate students interested in cooperative control, distributed algorithms, and robotic networks. The purpose is to provide an introduction into the (1) the recent widespread interest in distributed algorithms for consensus and filtering, (2) distributed algorithms in static and robotic networks, and (3) emerging discipline of motion coordination.

A broad introduction to distributed systems will be provided to prepare the students for a final project to be selected among a number of recent exciting developments in this area or to be possibly related to the student's research interests.

A course website will become available shortly.

Lecture Time and Place: Humanities and Social Sciences Building (HSSB) 4202. Tues/Thurs 12:30-1:45pm.

Prerequisites: Competency in linear algebra, nonlinear dynamical systems and linear control systems.

Course credit: Units: 3. Letter grade.

Instructor: Professor Francesco Bullo, Department of Mechanical Engineering
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Textbook and course material: The textbook is a collection of lecture notes being developed by the instructor in collaboration with Professors Jorge Cortés and Sonia Martínez. Copies will be made available to all students enrolled in the class.

Grading: The class will be entirely project-oriented (no exams) and the students are strongly encouraged to choose a project that is relevant to their own area of research.

Lecture topics (organized by week)

Week 1: Graph theory: basic notions, algorithms, and algebraic tools

1. Connectivity notions
2. BFS and DFS trees computation algorithms
3. Adjacency and Laplacian matrices

Week 2: Distributed algorithms on synchronous networks

1. Physical components and computational models
2. Complexity notions
3. The broadcast and BFS tree computation problems
4. Leader election by flooding and comparison

Week 3: Distributed linear algorithms

1. Linear models

2. Convergence of agreement algorithms (flocking)
3. Algorithms defined by Toeplitz and circulant matrices

Week 4: Models and complexity notions for robotic networks

1. A model for synchronous robotic networks
2. Communication models: geometric graphs
3. The agree and pursuit control and communication law
4. Robotic networks with relative sensing
5. Coordination tasks and complexity measures

Week 5: Connectivity maintenance and rendezvous algorithms

1. Problem statement
2. The rendezvous task
3. The connectivity maintenance problem
4. Connectivity maintenance algorithms
5. Rendezvous algorithms

Week 6: Deployment algorithms

1. Deployment notions and multicenter functions
2. Deployment algorithms
3. Convergence and complexity analysis

Week 7, 8 and 9: Advanced motion coordination algorithms

1. Cyclic pursuit (J. A. Marshall, M. E. Broucke, and B. A. Francis. Formations of vehicles in cyclic pursuit. *IEEE Transactions on Automatic Control*, 49(11):1963–1974, 2004)
2. Path coverage (M. Pavone and E. Frazzoli. Decentralized policies for geometric pattern formation and path coverage. *ASME Journal on Dynamic Systems, Measurement, and Control*, 2007. To appear)
3. Motion planning with obstacle avoidance (V. Sharma, M. Savchenko, E. Frazzoli, and P. Voulgaris. Transfer time complexity of conflict-free vehicle routing with no communications. *International Journal of Robotics Research*, 26(3):255–272, 2007)

Week 9 and 10: Subjects for potential student projects

1. Statistical mechanics and random graph theory: R. Albert and A.-L. Barabási. Statistical mechanics of complex networks. *Reviews of Modern Physics*, 74(1):47–97, 2002
2. Wireless networking and random geometric graphs: P. Gupta and P. R. Kumar. The capacity of wireless networks. *IEEE Transactions on Information Theory*, 46(2):388–404, 2000
3. Convergence rates in agreement algorithms: A. Olshevsky and J. N. Tsitsiklis. Convergence rates in distributed consensus and averaging. In *IEEE Conf. on Decision and Control*, pages 3387–3392, San Diego, CA, December 2006
4. Randomness in agreement algorithms: A. Tahbaz-Salehi and A. Jadbabaie. Consensus over random networks. *IEEE Transactions on Automatic Control*, 2007. Submitted
5. Motion patterns: R. Sepulchre, D. Paley, and N. E. Leonard. Stabilization of planar collective motion: All-to-all communication. *IEEE Transactions on Automatic Control*, 52:811–824, 2007
6. Rigidity and localization theory: T. Eren, D. K. Goldenberg, W. Whiteley, Y. R. Yang, A. S. Morse, B. D. O. Anderson, and P. N. Belhumeur. Rigidity, computation, and randomization in network localization. In *IEEE Conference on Computer Communications (INFOCOM)*, 2004
7. Scaling laws: P. Barooah and J. P. Hespanha. Estimation from relative measurements: Algorithms and scaling laws. *IEEE Control Systems Magazine*, 27(4):57–74, 2007
8. Graph grammars: E. Klavins, R. Ghrist, and D. Lipsky. A grammatical approach to self-organizing robotic systems. *IEEE Transactions on Automatic Control*, 51(6):949–962, 2006