Guest Editorial
Introduction to the Special Issue on Swarm Robotics

Jizhong XIAO

The field of robotics has expanded tremendously over last several decades. Researchers' attention has shifted from its early focus on industrial manipulators and individual mobile robot toward today's more challenging topics such as multi-robot systems, mobile sensor networks, and *swarm robotics*. Swarm Robotics is an emerging area which studies novel approaches to coordinate a large number of relatively simple robots to achieve desired collective behaviors and objectives that would not have been possible for individual robots. Swarm robotics emphasizes scalability, local interaction among agents, and fault tolerance. Potential applications for swarm robotics include tasks that demand for distributed sensing such as odor source localization, surveillance coverage, search and rescue.

This special issue presents a collection of 7 papers which investigate different research problems in swarm robotics such as coverage, deployment, distributed control, self-localization, odor source localization, diffusion, and interactive animation. I believe that this special issue, although not cover all the topics in swarm robotics, provides the most recent developments in these selected topics and will be an important source of information for researchers.

The paper by Diana Spears *et al.* presents a physics-based approach inspired by particle motion in a gas for controlling robot swarms to maximize coverage. The algorithm is based on kinetic theory (KT) which provides analysis tools to control, predict and guarantee the swarm behavior within desirable bounds. The approach requires limited sensors and communication between robots and is exceptionally robust. Extensive simulation and comparison studies against the three alternative algorithms designed for coverage tasks (i.e., random controller, trained finite-state machine controller, and Ant algorithm) demonstrate the superiority of the KT approach in terms of sweep time and stealth. It also achieves the second best performance in spatial coverage next to the Ant algorithm. Since KT approach does not have the explicit pheromone trail requirements of Ant algorithm, it is better-suited than Ant algorithm for situations where stealth, and speed of coverage are required.

The paper by Carlo Branca and Rafael Fierro presents hierarchical optimization strategies for deployment of mobile robots in task assignment problem. The algorithm is based on model predictive control (MPC) and mixed integer linear programming (MILP) techniques. MILP allows the encoding of logical rules, decisions, and constraints into the optimization problem, and has the capability to model requirements such as obstacle avoidance or inter-robot collision avoidance. To overcome the NP-hard drawback of MILP and achieve on-line processing of the optimization problem, the authors develop a hierarchical, decentralized structure which replaces a large computationally intractable problem into smaller problems that can be solved in a reasonable amount of time. To improve the efficiency of the algorithm some heuristics are also presented, which drastically reduce the number of constraints and binary variables in the optimization problem. Extensive simulations showcase the flexibility and scalability of the method.

The paper by Xiaohai Li and Jizhong Xiao presents a decentralized nonlinear controller for swarms flocking in dynamic environments. The controller for each agent is inspired by natural swarming phenomena and it enables each swarm member to follow the environmental "path clue" individually, and at the same time interact with its neighbors through virtual forces to adjust its speed. With a new set of virtual force functions and the assumption of strongly connected graph, the controller is proved to achieve stable group behavior (i.e., the velocities of all swarm members converge to a common value with bounded errors) for either fixed or dynamic swarm topology. The discussion on the convergence time of the swarm is also presented. A few sets of simulations, including the case of agents being lost during swarm's motion are presented to verify the feasibility and robustness of the proposed controller.

The paper by Chang-Hua WU, *et al.* presents a mobile assisted localization method based on multi-dimensional scaling (MDS) for robotic sensor networks to solve the self-localization problem. The proposed MA-MDS-MAP(P) algorithm uses one or more mobile sensors to add extra distance constraints to a sparse network, by moving the mobile sensors in the area of deployment and recording distances to neighbors at these intermediate locations. Evaluation of the performance is carried out in Matlab on four types of networks and the results have shown significant improvement over the MDS-MAP(P) approach on static low-degree networks.

The paper by Wisnu Jatmiko *et al.* investigates the odor source localization problem in dynamic environments by using two modified Particle Swarm Optimization (PSO) methods, i.e. the charged PSO (CPSO) and PSO incorporating change detection and responding mechanisms. The two methods overcome the local minimum drawback of standard PSO algorithm and are verified to be efficient by simulation results.

Jizhong Xiao is with the Dept. of Electrical Engineering, The City College, City University of New York, Convent Ave and 140th Street, New York, NY 10031. He can be reached via email at jxiao@ccny.cuny.edu.

The paper by Chao *et al.* investigates the application of mobile actuator/sensor networks (MAS-net) in dynamical pollution diffusion process, where the mesh sensor networks are deployed to measure the density of the pollutant and groups of mobile actuators are used to counteract the pollution by properly releasing the neutralizing chemicals. The authors model the process as partial differential equation (PDE) and apply Central Voronoi Tessellations (CVT) technique in the actuator path planning and control. Extensive simulation is performed to show how different grouping methods can affect the control performance.

The paper by Carmen Monroy *et al.* summarizes the recent control strategies of swarms in a unified framework and introduces a JAVA-based interactive animation tool to visualize the swarm behavior. The software and graphical representation allows the manipulation of control parameters and generates instant feedback on the control effects, thus improves the understanding of swarm tasks such as aggregation, formation and rendezvous.

Jizhong Xiao received the B.S. and M.S. degrees in automatic control in 1990 and 1993 from the East China Institute of Technology, Nanjing, P. R. China; and M. Eng. degree in electrical engineering in 1998 from the Nanyang Technological University, Singapore; and Ph.D. degree in electrical engineering in 2002 from the Michigan State University, USA.
He is an Assistant Professor at the Department of Electrical Engineering of the City College, City University of New York, and a doctoral faculty in engineering program and computer science program at the graduate center of the City University of New York, USA.
He served in organizing committees and/or program committees of major robotics conferences such as 2006, 2005 Int'l Conf. on Intelligent Robots and Systems (IROS'2006, IROS'2005), 2005 IEEE/ASME Int'l. Conf. on Advanced Intelligent Mechatronics (AIM'2005), 2004 Int'l. Conf. on Control, Automation, Robotics and Vision (ICARCV'2004), and 2007 Robotics Science and Systems conference (RSS'2007). He is the recipient of NSF CAREER award in 2007 and CUNY Certificate of Recognition, "Salute to Scholars" Award in 2005 and 2006. He is the finalist for the ICRA'2006 Best Video Award.
Dr. Xiao is a senior member of IEEE, a member of Sigma Xi, and New York Academy of Sciences, USA.