INTERNATIONAL JOURNAL OF INTELLIGENT CONTROL AND SYSTEMS
VOL. 13, NO. 1, MARCH 2008, 1-2

Advances in Field Robotics and Intelligent Systems

Cang YE and Edward TUNSTEL

Field robots are intelligent machines that perform their missions in unstructured environments. Field robotics is concerned with the automation of robotic vehicles and platforms operating in unstructured environments, and it covers science and technology for land, sea, air and space platforms with real-world applications such as mining, exploration, surveillance, security, search and rescue, and construction. The following are a few features that are characteristic of field robotics applications: (1) high uncertainty (e.g., in robot location and terrain properties), (2) incompleteness of information (e.g., partially observable surroundings), (3) nonlinear and time-varying factors (e.g., when interacting among humans or dynamic obstacles), and (4) heterogeneity of operating environments (e.g., multiple terrain types). Although mathematical methods and models can be used to formulate the above problems to some extent, they are widely considered insufficient for field robots to make robust decisions in environments with little structure. Intelligent system techniques are well suited for many of the problems in field robotics, as they typically do not require accurate models. For instance, the fuzzy system approach allows a human expert to transfer his knowledge to a fuzzy controller by compiling and tuning the fuzzy rules. Some intelligent systems can even learn and adapt to their operating environments, and thus do not sacrifice their performance if the environmental conditions change.

This special issue reports recent advancements in field robotics and intelligent systems. It consists of 7 papers that investigate various research problems, including stair traversal, wheel slip estimation, dynamic target tracking, 3D modeling and localization, terrain traversability analysis, language and logics for coordinating underwater vehicles, and a self-deployment algorithm for multiple mobile sensors. The research presented in these papers involves wheeled robots, tracked robots, underwater robots, and a planetary rover prototype.

The paper by B. Horan *et al.* presents a haptic control method for teleoperated stair traversal of an articulated track robot. A haptic interface is employed for human-robot interaction based on a proposed haptic cone method, which intuitively indicates to the operator the current robot command velocity and a haptic augmentation approach that provides the operator suggestive control actions for stair traversal. The haptic augmentation mechanism employs fuzzy reasoning and it works together with the haptic cone method to fulfill a stair climbing task.

The paper by G. Reina and K. Yoshida introduces a method for detecting and measuring wheel sideslip of a rover traveling on soft terrain. Their method uses a rearward-facing camera to observe the rover's wheel tracks and employs Hough transform to extract the wheel tracks from the camera's image. Fuzzy inference is used to determine how well each track candidate matches a track model. The best match is selected to estimate the slip angle.

The paper by C.-L. Hwang, *et al.* proposes a fuzzy decentralized sliding-mode control method to enable a mobile robot to track a dynamic target (another mobile robot). Grey theory is used to predict the target's pose to achieve satisfactory tracking performance. Their method integrates sliding-mode control with fuzzy control and thus incorporates the advantages of the former, such as good disturbance immunity and controllable frequency of the closed-loop system, into the latter. The fuzzy sliding-mode control is implemented as a decentralized control scheme, i.e., each wheel has a separate dedicated controller. The controller can track the dynamic target without requiring a mathematical model of its motion. The control system is validated in a so-called sensor-network environment where two CCD cameras are used to determine the poses of the tracking and target mobile robots.

The paper by C. Ye and W. Xie presents a method for navigation of a mobile robot on urban terrain. They introduce a so-called Polar Traversability Index (PTI) to evaluate terrain traversal properties along a specific direction and use the PTI to determine the robot's steering and velocity commands. The PTI embodies the roughness and slope of a terrain patch. As the robot heading direction is considered in computing the terrain slope, the PTI allows the robot to snake through a steep slope and thus enhances its terrain traversal performance. The efficacy of the PTI-based navigation method is verified by simulation and experiments with a real robot in outdoor environments.

The paper by S. Se and P. Jasiobedzki introduces a vision system called Instant Scene Modeler that can generate photo-realistic 3-D models of unknown environments using stereo image sequences. The system uses a set of visual features generated by the Scale Invariant Feature Transform to compute the camera motion that is used to register 3-D data. By mapping the environment's texture onto the registered 3-D data, the system creates photo-realistic 3-D models. The system has been tested on various mobile platforms to model urban, desert, and mine environments.

The paper by J. Tan proposes a distributed model and the control method for a group of wirelessly connected mobile robots. The model uses Delaunay triangulation to describe the geometrical relationships between neighboring mobile nodes, and the control method employs a potential field approach for autonomous self-deployment of the mobile robots. The paper investigates a number of research issues such as the convergence of the self-deployment method with environmental constraints (the presence of obstacles), maximization of network coverage, and reorganization of networks in response to node failures.

The efficacy of the model and the control method are validated by simulation.

Finally, the paper by T. Bean, *et al.* describes a language and logic to enable communication and collaboration among multiple Autonomous Underwater Vehicles (AUVs). The language and the logic allow information (such as vehicle position in a formation, task being performed, etc.) exchange between AUVs and collaborative behavioral responses to the information. The paper presents field experiments of three collaborative behaviors—vehicle replacement, leader replacement, and fleet self-organization—with a fleet of five communicating AUVs.

The guest editors present this special issue on behalf of the *Technical Committee on Robotics & Intelligent Sensing* (TC-RIS) of the IEEE Systems, Man, and Cybernetics Society. Three papers of this special issue are extended from contributions to a TC-RIS special session on Field Robotic Systems and Applications in the 2007 IEEE International Conference on Systems, Man, and Cybernetics. The guest editors would like to thank the special session organizers, Drs. Edward Tunstel and Gary Anderson.

Cang Ye received B.E. and M.E. degree from the University of Science and Technology of China, P. R. China in 1988 and 1991, respectively. He received his Ph.D. degree from the University of Hong Kong in 1999.

He is currently an Assistant Professor in Department of Applied Science, University of Arkansas at Little Rock, AR. He was a research investigator at University of Michigan, Ann Arbor, MI from 2003 to 2005. His research interests are in mobile robot terrain mapping and navigation, fuzzy systems and reinforcement learning.

Dr. Ye is a senior member of IEEE and a member of Technical Committee on Robotics and Manufacturing Automation, IEEE Systems, Man, and Cybernetics Society.

Edward Tunstel earned the Ph.D. in electrical engineering from University of New Mexico in 1996 and a M.E. and B.S. in mechanical engineering from Howard University in 1986 and 1989. He is a Senior Professional Staff member and Space Robotics and Autonomous Control Lead at the Johns Hopkins University Applied Physics Laboratory in Laurel, MD. He spent 18 years at the NASA Jet Propulsion Laboratory most recently serving as Advanced Robotic Controls Group Leader and Lead Engineer for rover mobility and robotic arm subsystems on the NASA Mars Exploration Rovers mission operations team. His expertise is robot control & navigation, soft computing, and robotic systems engineering.

Dr. Tunstel is a senior member of IEEE, IEEE SMC Society Vice President for Conference & Meetings, and chief technologist of the NSBE Space Special Interest Group. He is active in the IEEE RAS Technical Committee on Space Robotics and IEEE SMCS Technical Committee on Robotics & Intelligent Sensing.