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MULTI-ROBOT SYSTEMS

GUEST EDITORIAL

BY

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The field of Multi-Robot Systems has become a popular area of research during the past several years. One reason for this is the idea that cooperative or distributed teams of robots can create synergy – that is, two robots working together effectively can accomplish more than twice as much as two robots working separately. Today, a myriad of approaches exists for tackling problems of multi-robot control for cooperative and coordinated task execution. As of yet, there is no consensus as to how to solve related problems most effectively, which is another reason why multi-robot systems is such an exciting and active research domain. Some of the most common solution approaches include, among others, behavioral-based control, state machines and rule-based control. Some systems rely solely on visual cues to cultivate cooperation, while others depend on specific means of explicit communications between robots. In certain instances the robots are all completely autonomous, while in others a master robot controls one or more slave robots.

Although these efforts are in their infancy, the potential payoff for creating well functioning multi-robot systems is huge. Already, there are near-term needs in space, military and industrial applications. Cooperating robots can be used to help build human habitats in remote locations such as the moon or Mars. Distributed and coordinated teams of military drones can be used for reconnaissance missions, while squads of industrial robots can be used to move merchandise around in a warehouse. In addition, multi-robot systems can be useful in domestic applications. Domestic robot systems, in conjunction with smart appliances and other home automation devices, can help disabled or elderly people live independently or for longer periods of time by performing such tasks as cleaning, cooking, health monitoring, and mobility assistance.

It would seem there are a near-endless combination of possibilities for designing multi-robot systems and applying them in our society. As a contribution to the achievement of potential benefits such as those mentioned above, we must document today's research advances and important developments towards solving fundamental problems of multi-robot systems. The articles presented in this special issue offer recent developments in this regard with new results that are based on physical experiments using real multi-robot systems as well as computer simulations that provide technical insight into various multi-robot problem solutions. Topics covered include collective work by microrobot colonies, coordinated formation control, distributed map building, decentralized reinforcement learning, fuzzy logic-based discrete event handling, and distributed parts assembly.

The article by Giovanni Muscato introduces us to the world of walking microrobots using a team of small, lightweight PLIF (Piezo Light Intelligent Flea) devices. In this case, a team of three PLIF robots is employed in a demonstration of cooperative action to push a box in a desired direction. For this task, a

single robot is incapable of pushing the object alone making cooperation a requirement for successful execution.

Wei Kang, Ning Xi, Jindong Tan and Yuechao Wang tackle the formation control problem by developing a time-independent controller. The controller is first designed in the time domain and then a special transformation, called a reference projection, is used to remove time from the system equations. After the introduction of the theory and design method, the effectiveness of the approach for controlling a variety of formations is demonstrated experimentally using three autonomous wheeled mobile robots.

Kai-Tai Song and Hung-Ting Chen address the problem of indoor map building via distributed sensing by two mobile robots. The robots use computer vision for edge detection on features in the environment. Sensory data from each robot is transmitted to an off-board server where they are fused using Kalman filter techniques to construct a global map, which could be accessed and used for navigation. Experiments demonstrate enhanced estimation of uncertainties in detected map features.

Poj Tangamchit, John M. Dolan and Pradeep K. Khosla address factors associated with extending learning in a single robot environment to a multi-robot environment. In particular, they study reinforcement learning in decentralized multi-robot systems, comparing several different learning environments. They systematically test the effects of various multi-robot learning system design considerations by performing experiments in patrol and object collection tasks. Insights are then offered on what learning techniques work best for achieving optimal cooperative solutions.

Shahab Sheikh-Bahaei, Paolo Lino, Jingyu Liu and Mo Jamshidi present a novel approach to handling discrete events in multi-robot task execution. They propose combining fuzzy logic with the established DEVS (Discrete Event System Specification) procedure for dealing with unpredictable events. This combines the capabilities of fuzzy logic in handling autonomous control with the discrete event handling of DEVS. The article demonstrates how this combination can be implemented in a team of mobile robots performing a task of cooperative object transport.

Yael Edan, Sigal Berman, Ezra Boteach, and Ella Mendelson present a performance comparison of several algorithms for distributed assembly/packaging by multiple robot manipulators. Simulation experiments are reported for five algorithms, two of which are further evaluated experimentally using real robots. The goal was to achieve equal utilization of each robot while maximizing the number of assemblies for the purpose of decreasing mean time between failures. The effectiveness of each algorithm for achieving this goal is reported based on experimental results.

The collection of articles herein reveals the richness of the research being performed on multi-robot systems and is indeed a snapshot of where the field stands today. The results will contribute to continued progress toward understanding and solving the essential problems of cooperation and coordination in systems of robots. This will ultimately enable realization of practical multi-robot systems in everyday applications.

The Guest Editors would like to sincerely thank the authors for their valuable contributions to this special issue. We are also grateful to the Editor-in-Chief, Professor Mo Jamshidi, for supporting the overall effort of bringing these technical contributions to readers of the journal.

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