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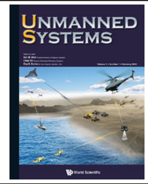

Editorial: Special Issue on Perception, Decision and Control of Unmanned Systems Under Complex Conditions

This special issue on Perception, Decision and Control of Unmanned Systems under Complex Conditions is dedicated to Beijing Institute of Technology (BIT), China for her outstanding contribution to the technological progress of unmanned systems as well as the development of the journal *Unmanned Systems*. As one of the key universities in China, BIT has a high reputation for unmanned systems research, since many renowned research teams from different disciplinaries in BIT have gained a lot of achievements regarding various unmanned systems. This special issue reports a collection of recent research of relevant teams from BIT.

Admittedly, autonomy is an ultimate goal of the research and development of unmanned systems. An extremely important premise for autonomy is that the anticipated unmanned systems can effectively deal with various complex conditions. Generally, the complexity about unmanned systems originates from three elements, including the system itself (or system of systems, e.g. in the case of multi-agent systems), the task and the environment. As for the system, nonlinearity is usually regarded as the primary complexity-inducing factor. In the system of systems, the communication network connecting different systems may further contribute to the complexity, so the effect of many actual factors such as time delay and packet loss, leading to complex communication conditions, will have to be considered. On the other hand, the complexities from tasks and environments also pose great challenges to the practicability of unmanned systems.

This special issue consists of six papers which show different aspects around the theme, including the multi-agent formation control under time-delayed communication conditions [1], the decision in a complex multi-agent game [2], the multi-robot simultaneous localization and mapping in complex environments [3], the actuator fault diagnosis of a multi-legged robot with insufficient data [4], the obstacle avoidance of mobile robots in a complex environment [5], and the flight control of a falcon-inspired morphing UAV in complex flight environments or dynamic tasks [6]. A brief introduction to the six papers is given as follows.

The work by Wang *et al.* [1] studies the affine formation control problem of a general linear multi-agent system (MAS) with leader–follower structure, considering the effects of communication delays. Predictive observers are designed for the followers to predict the agent states, and affine formation control laws without the usage of global information are designed on the basis of the predicted states. Sufficient conditions are derived to ensure the convergence of the formation errors. Under the proposed protocols, the MAS can form a target formation shape and realize time-varying formation continuously. Simulations verified the effectiveness of the theoretical results.

The work by Liang *et al.* [2] studies the decision problem in an interesting multi-agent offense–defense game, namely, targets–attackers–defenders (TAD) game, which involves an attacking team, a target team, and a defending team. The defending team cooperates with the target team against the attacking team whose goal is to capture the targets, implying the existence of both cooperation and confrontation in the game. The defending team protects targets by intercepting attackers or rendezvousing with targets. Based on the solution previously derived by the authors for a basic TAD game with only one target, one attacker and one defender, a maximum matching algorithm is proposed by using relative distance and velocity parameters, transforming the TAD game into a real-time target-assignment problem. An improved variable neighborhood search algorithm is proposed to solve the target assignment problem and give the optimal dynamical strategy for each player. Numerical simulation results show that this method effectively solves the problem of TADs, and it is considerably more scalable with the number of players.

In the work by Xiong *et al.* [3], a multi-uncertainty captured multi-robot lidar odometry and mapping (MUC-LOAM) framework is presented for multi-robot simultaneous localization and mapping (MR-SLAM). The framework features uncertainty quantification and utilization in complex environments, with special focus on uncertainties from distance changing and dynamic objects. A hybrid weighting strategy is developed for pose update to improve the accuracy of localization significantly. A devised Bayesian neural network is proposed to estimate mutual poses with depth and remission and capture the uncertainty. Covariance propagation of quaternions to Euler angles conversion is leveraged to filter out unreliable mutual poses. Another covariance propagation through coordinate transformations in nonlinear optimization improves the accuracy of map merging. The feasibility and enhanced robustness of the proposed framework for large-scale exploration are validated on both public datasets and real-world experiments.

The work of Ma *et al.* [4] provides a novel approach for detecting the actuator faults of a multi-legged robot. The key idea inside the approach is to design the Fault Diagnosis Generative Adversarial Network (FD-GAN) to fully adapt to the fault diagnosis with insufficient data. It provides a straightforward solution by exploiting massive amounts of normal data to drive the diagnostic model. By using frequency domain information and fusing multi-sensor data to increase the features, the difference between normal data and fault data is expanded. A GAN-based framework is designed to calculate the probability that the enhanced data belongs to the normal category. It uses a generator network as a feature extractor, and a discriminator network as a fault probability evaluator, which creates a new use of GAN in the field of fault diagnosis. Among the many learning strategies of GAN, it is found that the two types of data can be distinguished by using the hidden layer noise with appropriate discrimination as the excitation. A fault location method based on binary search is also designed to greatly improve the search efficiency and engineering value of the proposed method. Experiments validate the diagnostic effectiveness of the architecture in various road conditions and working modes, as well as the superiority of FD-GAN over popular diagnostic methods in terms of accuracy and recall rate.

In the work by Lin *et al.* [5], an improved artificial potential field (APF) method is proposed by combining classical APF with a simple behavior-based path planning algorithm named Bug2 for dynamic obstacle avoidance of mobile robots. The improved APF can increase the success rate of obstacle avoidance in a complex working environment surrounded by multiple dynamic and static obstacles. The proposed method makes the angle of the virtual repulsion force tangent to the obstacle, which results in avoidance that the trajectory surrounds the obstacle along the M-line in Bug2. Both simulation and experiment results show that the proposed method can realize safe and autonomous dynamic obstacle avoidance, significantly reduce trajectory oscillation and improve the robot's success rate and obstacle avoidance efficiency.

The work by Ye *et al.* [6] presents a deep reinforcement learning (DRL)-based diving/pull-out cooperative control strategy for the flight control of a falcon-inspired morphing UAV. With agility and efficiency in complex obstructive environments and over open terrains, the UAV is expected to autonomously transform in response to changes in flight environments and tasks, always maintaining an optimal aerodynamic profile. It folds/twists its wings/tail simultaneously to accomplish diving/pull-out flight during the predation process. In the diving/pull-out flight, the UAV is able to balance maneuverability and stability, which is hard to realize by current control methods. Considering the continuity of the state space and the action space of morphing UAV, the deep deterministic policy gradient (DDPG) algorithm based on the actor-critic (AC) network is adapted, and the proposed DRL-based strategy is tasked with controlling multiple data frames of airspeed, altitude and pitch angle to desired reference values so as to ensure the smoothness of the flight action. The results of numerical experiments demonstrate the superiority of the proposed control strategy and its generalizability to the cases where the random white noises are added to gyroscope measurements and wind disturbance in flight.

Lastly, I would like to take this opportunity to thank all contributing authors and reviewers for producing high-quality research works. Special thanks to the co-editors-in-chief, Professors Jie Chen, Ben M. Chen and Lihua Xie, for giving me the opportunity and continuous support in organizing this special issue.

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