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Editorial: Special Issue on Interactive Unmanned Systems and Intelligent Applications

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Unmanned systems have received much attention in the research community, covering a wide range of vehicular systems, from aerial vehicles, to ground robots, to underwater (marine) systems. The recent trend of study attempts to investigate the autonomy of unmanned systems, including developing automatic machine systems and increasing the level of intelligence by incorporating machine learning and artificial intelligence. Another trend focuses on cooperation and coordination among unmanned systems, often under the theme of multi-agent systems and its related topics. From the systems perspective and the scope of unmanned systems, there exists a need for comprehensive understanding how unmanned systems interact with their environment, with each other, with humans, and so on. The purpose of this special issue is to report recent research work in this direction. After peer review, six high-quality research papers have been collected in this special issue. They represent distinctive work on novel technologies and solutions, or innovative applications with relevant features of interactions and intelligence of unmanned systems.

Representing the robot–environment interaction is the paper by Li *et al.* that studies mobile robot navigation in unknown environments. A behavior-based navigation method is proposed using deep reinforcement learning intelligence. The learned navigation policy can be applied in both single-agent and multi-agent scenarios. In the single-agent case, a robot can learn to navigate autonomously without a map of the environment. In the multi-agent case, robots can learn to avoid collisions with each other. Two basic navigation behaviors are considered, which are goal reaching and collision avoidance. The two behaviors are fused based on the risk level estimation of the current state. The navigation task is decomposed using the behavior-based framework, which is capable to reduce the complexity of the learning process. The simulations and real-world experiments demonstrate that the proposed method can enable the collision-free autonomous navigation of multiple mobile robots in unknown environments.

Next are the works by Liu *et al.* and Huo *et al.* which both use intelligent pigeon-inspired algorithms, however, for different interaction scenarios; one addresses the multi-UAV interaction, while the other treats the human–unmanned systems interaction. The work by Liu *et al.* proposes a Discrete Pigeon-Inspired Optimization-Simulated Annealing algorithm (DPIO-SA) to solve the task assignment problem in a multi-UAV formation system. Then, Genetic Algorithm (GA) is adopted to optimize the UAVs' locations in formation. Experimental investigation demonstrates that 24 fixed-wings can complete the formation assembly quickly. Further, according to the Contract Network Algorithm (CNA), the task scheduling problem is solved by the interaction among fixed-wings. On the other hand, the work by Huo *et al.* addresses manned aircraft and unmanned aerial vehicle heterogeneous formation flight. During the smoothing trajectory, the swarm employs the distributed communication network and event-triggered interactive mechanism. During the turning trajectory, the centralized and distributed communication networks are integrated. Simulation tests demonstrate that the proposed control algorithm is feasible to form a cohesive group and effectively avoid obstacles in unknown environment.

The work by Wang *et al.* deals with a different type of interaction: the case of ground–air vehicle interaction. An autonomous navigation system is developed by the use of Ground-Aerial Vehicle Cooperation. The key features of the development lie in three aspects: (1) a local reliable self-organizing network constructed for data interaction between a small UAV and a reusable ground robot; (2) a new solution is proposed to achieve visual simultaneous localization and mapping (SLAM) where the carrying capacity of both the ground vehicle and UAV are systematically considered; (3) an octomap-based 3D environment reconstruction method developed to achieve map pre-establishment in complex navigation environments, and the improvement of the classic ORB-SLAM2 system to be adaptive to actual environment exploration and perception.

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Indoor flight experiments demonstrate the effectiveness of the proposed solution. More interestingly, by implementing a centroid tracking algorithm, the cooperative system is further capable of tracking a man moving in GNSS-denied environments.

The work by Fu *et al.*, on the other hand, focuses on a new level of hostile interaction, by studying the target defense game among two (slower) defenders and a (faster) intruder. The problem is solved based on the classic differential game theory. In the game, the intruder seeks to enter a circular target area, while the defenders endeavor to capture it outside of the target. Under the faster intruder assumption, the game has two phases, where the optimal trajectories are straight and curved, respectively. In the second phase, a peculiar phenomenon exists where the intruder moves at the edge of one defender's capture region, yet this defender cannot force capture. Because of this, the terminal states of the game are singular, therefore the standard method of integrating optimal trajectories from terminal states is not applicable. The way to circumvent this singularity is to solve the optimal trajectories of a two-player game between the intruder and the closer defender, and assemble them with the trajectory of the other defender. The key contribution of this paper is the solution of the intruder-closer-defender subgame against a circular target area. The proposed solution is verified through a special case where the capture range is zero. This verification also presents a simpler approach of solving the zero capture range problem.

Finally, the work by Tan and Chen provides a comprehensive survey of an innovative application of unmanned systems, a special aerial-aquatic hybrid mobility and interaction. As compared with land-water or land-air hybrids, the design of air-water vehicles are much less straightforward due to the fact that both mediums are three-dimensional fluid spaces and the inherent disparity in fluid properties between them. As such, the development of these vehicles has received limited attention until very recently, as observed in an increasing number of projects working on aerial-aquatic hybrid mobility. This survey paper discusses the fundamental challenges associated with aerial-aquatic hybrid locomotion as well as the necessary trade-offs in design decisions. The existing work and prototypes of aerial-aquatic vehicles are reviewed and summarized, as is the range of solutions that have been adopted to solve the aforementioned challenges. In addition, the limitations of these solutions are analyzed to offer a perspective on how future developments in the area can enable greater functionality for the concept.

All in all, we hope the research works presented in this special issue provide a novel perspective of the study of unmanned systems in terms of systems interactions and corresponding intelligence, including but not limiting to unmanned system or systems interaction with the environment, human–machine intelligence, and interdisciplinary unmanned systems development. We would like to take this opportunity to thank all contributing authors and reviewers for their time and effort in producing high-quality work and we hope the readers enjoy the Special Issue as much as I enjoyed compiling it. Special thanks to co-editors-in-chief, Professors Lihua Xie and Ben M. Chen for giving me the opportunity and continuous support throughout this rewarding journey of turning an idea into a reality.

Guest Editor
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