Guest Editorial Focused Section on Mechatronics in Unmanned Systems

I. Introduction

DURING the past few decades, unmanned systems have widely been applied in the environs of aerospace, ground, surface, and underwater. It is expected that unmanned systems will have more pervasive applications in industry, military, agriculture, logistics, etc., when advanced mechatronic technologies are combined with complex systems engineering. Mechatronic design offers feasible solutions for unmanned systems to operate robustly and efficiently under diverse and difficult environmental conditions, but brings challenges for design, sensing, and control. Facing the growing application demands, this subject has drawn increasing attention in recent years. For this reason, the design, implementation, modeling, control, and optimization of unmanned systems have become urgent issues.

This focused section aims to report the latest research results, both theoretical and application-oriented and to emphasize mechatronics in unmanned systems, including mechanism design and optimization of unmanned systems, modeling and control of unmanned systems, bioinspired mechatronics in unmanned systems, applications of mechatronic for unmanned systems, etc. Topics explored in this focused section include, but be not limited to, theoretical foundations for mechatronics in unmanned systems, mechatronics design of the unmanned systems, mechanism design, fabrication and optimization of unmanned systems, modeling, identification, sensing, and control of unmanned systems, mechatronics in unmanned space/aerial/ground/surface/underwater vehicles, bioinspired mechatronics in unmanned systems, and applications of mechatronics for unmanned systems in industry/military/agriculture/logistics.

II. Highlights of the Focused Section

This focused section received 57 articles on mechatronics in unmanned systems from different countries, of which 12 articles contributed significantly and were accepted for publication in this focused section. The contents of these 12 articles are briefly described in the following.

Many unmanned vehicle designs are significantly important in the automotive industry to the improvement of the safety and the versatility of various vehicle designs. For large-scale deployment, it is crucial to choose the compact uncertainty representation and plant vehicle model no matter what vehicle sizes are. In view of the aforementioned problems, Sun *et al.* focus on a dynamic vehicle model and give a dimensionless representation. The model is suitable for generalized dynamics analysis [Item 1) in the Appendix]. Based on the dimensionless model, an observer is designed to evaluate the motion state, mass, and center of gravity displacement, etc. Simulation and experimental results have shown the effectiveness and sensitivity of the proposal.

Automatic driving, as a promising solution of the mechatronic design, is regarded as a feasible method to reduce traffic accidents and the workload of drivers. Moreover, it also has the ability to enhance the driving quality and experience of vehicles. However, due to the limited intelligence for automatic vehicles, fully autonomous driving cannot be applied in the way of large-scale production and deployment. For the purpose of safe and personalized driving, Huang *et al.* [Item 2) in the Appendix] propose a new lane-change intention generation model and a lane-change decision-making algorithm. The testing results show that the requirements of safety and personalization are met for fully autonomous driving, and the feasibility and the effectiveness of the approach are still satisfactory under dynamic situations.

With the continuous improvement of vehicle mobility and transportation efficiency, amphibious flying vehicles have attracted more and more attention. Tan *et al.* [Item 3) in the Appendix] introduce a new type of fly-drive vehicle driven by the rotor and Ackerman chassis and propose a comprehensive dynamic model to describe multimode motion. Based on the coupled dynamics analysis of the landing process, the suspension vibration is compensated by using an active regulator after the tire hits the ground. The proposed method can improve the comfort and driving safety, which presents a novel scheme for the design of the amphibious intelligent fly-drive vehicle.

In recent years, the occurrence of road traffic accidents has increased significantly, bringing great losses to societies. It is, therefore, of great importance to establish a relationship between the influencing factors and the severity of traffic accidents. An analysis of the relationship can help to predict the severity and the occurrence of traffic accidents. Xie *et al.* [Item 4) in the Appendix] propose an artificial-neural-network-based predictive method to analyze the severity of vehicle accidents. The accuracy and the effectiveness of the policy are analyzed based on a large amount of data of traffic accidents. The test results show that the proposed policy has better accuracy than other methods.

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The tractor-trailer vehicles are one of the most widely used vehicle systems in industry. However, the existing work either needs to accurately understand the state and the parameters of the trailer, or needs to consciously deal with the uncertainty of the trailer. In addition, in practical industrial applications, due to the influence of mass, inertia, and other dynamic parameters, it is difficult to obtain the structure of the trailer. Zhao *et al.* [Item 5) in the Appendix] give the dynamic model for the industrial tractor-trailers vehicle, and based on the model, an adaptive trajectory tracking policy is designed. The robustness and the accuracy of the proposed policy are verified.

The flexible joint robot has superior attractive features because of its high mobility, high load ratio, high torque fidelity, robustness for external disturbance, task adaptability, and safety. Liu *et al.* propose a complete dynamic model of the nonholonomic mobile manipulator including a mobile platform and manipulator with joint flexibility operating simultaneously. It is first time to develop the whole body control through high-dimensional integral Lyapunov functions for sea-based mobile manipulation without using traditional backstepping technology. The feasibility of the proposed method is verified by the extensive trajectory tracking experiment results in the developed flexible joint manipulator [Item 6) in the Appendix].

Obstacle avoidance is one of the fundamental abilities of flying robots. However, to benefit from this ability in an unknown environment, fast and precise sensing is the first requirement as the robot approaches obstacles. When potential dynamic obstacles, such as pedestrians and other robots, exist, the situation becomes even more complex. Inspired by owl, Chen *et al.* [Item 7) in the Appendix] propose a novel vision-based obstacle avoidance system, where a bionic method using a stereo camera with independent rotational degrees of freedom to actively sense obstacles is proposed, which does not need to fuse multiple sensors to expand the field of vision. In order to overcome the limitation of the field of view in visual navigation, the design provides an effective method such that although only one stereo camera is applied, low-cost characteristic can still be obtained.

The humanoid robot, one of the ideal unmanned systems, has wide application prospects in industry, manufacturing, service, and disaster response. In such complicated environments with unknown disturbances, it is very important to keep the balance of the humanoid when performing tasks. Li *et al.* present a dynamic torso compliance method for the position-controlled humanoid robot for adapting to unknown external disturbance when standing or walking. This method decouples the compliance control and balance control so that the position control robot can realize the dynamic compliance and the balance of the trunk when standing and walking. The simulations and the experiments on a position-controlled humanoid robot (BHR-T) verify the effectiveness of the method [Item 8) in the Appendix].

Recently, quadrotor unmanned aerial vehicles (UAVs) have been increasingly and widely applied in civil and military fields. In the UAV flight control, most of the control techniques generate continuous time control signals. However, since computers can only store and calculate the discrete-time digital signals, it is necessary to convert the continuous-time signals into the discrete-time ones when exerting control on UAV systems. Shao *et al.* [Item 9) in the Appendix] study an event-triggered-based neural control that utilizes discrete-time disturbance observers for UAVs under external disturbances and saturated control inputs.

In order to further enhance the reliability and application scope of UAVs, Zhang *et al.* report a nonlinear model predictive control and disturbance rejection strategy for visual servoing of quadrotors. Image kinematics is decoupled in the virtual camera plane by properly defining the image features. By integrating the image kinematics with the quadrotor dynamics, it is demonstrated that the control method developed can handle physical and visibility constraints. The efficacy of the proposed method is verified by conducting simulation studies and experimental tests [Item 10) in the Appendix].

Cooperative control of networked UAVs is an exciting research direction because of its potential application prospects. However, most of the existing studies pay attention to the circular formation, fixed formation center, etc. In order to accomplish more complex tasks in a larger area, Li *et al.* [Item 11) in the Appendix] give a cooperative circumnavigation (CCN) method for groups of networked UAVs, where the CCN drives UAVs to given planar ellipses with desired spatial formation. This method provides a new idea for further research on the problem of detour and can obtain more general geometry without global information and central calculation.

In investigating the ability of vertical takeoff and landing, the existing works often focus on the formation of rotorcrafts. However, the endurance and the load capabilities are limited for rotorcrafts, which means that many complex applications, such as reconnaissance, exploration, search and rescue, air patrol, etc., cannot use rotorcrafts. Fixed-wing UAVs have formidable capabilities in endurance and load capacity, and are, therefore, more suitable for the stated applications. Aiming at the problem of dynamic formation reconfiguration and path replanning when multiple fixed wing UAV formations perform air patrol tasks, Wang *et al.* [Item 12) in the Appendix] propose a strategy to reconstruct the formation in such a way that the objectives can be optimally accomplished.

The guest editors appreciate the contributions submitted to this focused section and thank their authors for sharing the break-through results with us. Finally, they would also like to thank the Editor-in-Chief Prof. Chen and the administrator Mr. K. McArthur for their strong and persistent support during the whole process of preparing this focused section.

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APPENDIX
RELATED WORKS

1) C. Sun, C. Wang, Z. Deng, and D. Cao, "Dimensionless model based system tracking via augmented Kalman filter for multiscale unmanned ground vehicles," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 600–610, Apr. 2021.
2) C. Huang, C. Lv, P. Hang, and Y. Xing, "Towards safe and personalized autonomous driving: Decision-making and motion control with DPF and CDT techniques," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 611–620, Apr. 2021.
3) Q. Tan, X. Zhang, H. Liu, S. Jiao, M. Zhou, and J. Li, "Multimodal dynamics analysis and control for amphibious fly-drive vehicle," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 621–632, Apr. 2021.
4) G. Xie, A. Shangguan, R. Fei, X. Hei, W. Ji, and F. Qian, "Unmanned system safety decision-making support: Analysis and assessment of road traffic accidents," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 633–644, Apr. 2021.
5) H. Zhao, S. Zhou, W. Chen, Z. Miao, and Y.-H. Liu, "Modeling and motion control of industrial tractor-trailers vehicles using force compensation," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 645–656, Apr. 2021.
6) Y. Liu, Z. Li, H. Su, and C.-Y. Su, "Whole body control of an autonomous mobile manipulator using series elastic actuators," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 657–667, Apr. 2021.
7) G. Chen, W. Dong, X. Sheng, X. Zhu, and H. Ding, "An active sense and avoid system for flying robots in dynamic environments," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 668–678, Apr. 2021.
8) Q. Li, F. Meng, Z. Yu, X. Chen, and Q. Huang, "Dynamic torso compliance control for standing and walking balance of position-controlled humanoid robots," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 679–688, Apr. 2021.
9) S. Shao, M. Chen, J. Hou, and Q. Zhao, "Event-triggered-based discrete-time neural control for a quadrotor uav using disturbance observer," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 689–699, Apr. 2021.
10) K. Zhang, Y. Shi, and H. Sheng, "Robust nonlinear model predictive control based visual servoing of quadrotor UAVs," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 700–708, Apr. 2021.
11) D. Li, K. Cao, L. Kong, and H. A. F. T. Yu, "Fully distributed cooperative circumnavigation of networked unmanned aerial vehicles," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 709–718, Apr. 2021.
12) Y. Wang, Y. Yue, M. Shan, L. He, and D. Wang, "Formation reconstruction and trajectory replanning for multi-UAV patrol," *IEEE/ASME Trans. Mechatronics*, vol. 26, no. 2, pp. 719–729, Apr. 2021.

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