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GUEST EDITORIAL

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Special issue on autonomous unmanned aerial/ground vehicles and their applications

Recently, research on autonomous mobility control has been actively and widely conducted for various applications. In particular, autonomous mobility control for unmanned aerial and ground vehicles has been our research interest because it has considerable challenges, such as time-consuming and high-delay computations, complicated functionalities, and dangerous tasks that were previously performed by humans. Furthermore, fully autonomous unmanned aerial and ground vehicles are barely practical and have various operational limitations, such as high-precision sensing, high computational complexity, low autonomy, and restricted mobility. To develop the required technologies to overcome these limitations and achieve full autonomy for unmanned aerial and ground vehicles, various studies have addressed aspects such as precise pose estimation, environment mapping, path planning, trajectory optimization, and 2D/3D object tracking and detection.

With fully autonomous operation and functionalities for unmanned aerial and ground vehicles, emerging applications will become more diverse and include autonomous artificial-intelligence-based surveillance, autonomous disaster prevention broadcasting and control, mobile autonomous aerial and ground wireless/cellular access service provisioning, autonomous multirobot coordination, and cooperation for smart factory management in smart city applications, for which a skilled human operator must currently intervene throughout operation.

For this special issue, we selected 11 key studies on (1) communication, networks, and mobility [1–5] and (2) object detection and tracking in autonomous driving [6–11].

In [1], surveys and discussions are presented on recent deep-learning-based developments to achieve autonomous mobility control and efficient resource management of autonomous vehicles including unmanned aerial vehicles (UAVs). The developments include multiagent reinforcement learning and neural Myerson auction. We believe that integrating multiagent reinforcement learning and neural Myerson auction will be critical for efficient and trustworthy autonomous mobility services.

In [2], a safe landing algorithm is introduced for urban drone delivery. The proposed algorithm generates a safe and efficient vertical landing path for drones, allowing them to avoid obstacles commonly found in urban environments, such as trees, streetlights, utility poles, and wires. To this end, landing-angle control is implemented to land vertically, and a rapidly-exploring random tree (RRT) is used in a collision avoidance algorithm. This combination of methods enables precise and reliable drone delivery in urban settings.

In [3], a loosely coupled relative position estimation method is proposed based on a decentralized ultrawideband global navigation support system and inertial navigation system for flight controllers. Key obstacles to multi-drone collaboration are noted and include relative positional errors and the absence of communication devices. To address such problems, an extended Kalman filter (EKF) is adopted to correct distance errors by fusing ultrawideband data acquired through random communications using a novel UWB communication module.

Unmanned vehicles are being increasingly used for time-consuming, complicated, and dangerous tasks that were previously performed by humans. However, they have limitations for applications like establishing high-speed wireless networks. In [4], a 3D geometry-based stochastic model for UAV multiple-input multiple-output (MIMO) channels is presented. The UAV flying direction and location have a significant impact on MIMO performance. This innovative model of 3D navigation and scattering environments is closely related to the scope of this special issue.

In [5], UAVs are considered essential components in non-terrestrial networks, especially in 5G-and-beyond communication systems. Employing UAVs operated in conjunction with a 4G/5G base station has proven to be a practical solution for providing cellular network services in areas where conventional communication infrastructures are unavailable. This paper introduces the uncrewed aerial vehicle–base station system that utilizes a high-capacity wireless backhaul operating in millimeter wave frequency bands.

In [6], advanced video analytics for tasks such as moving object detection and segmentation are presented, thereby increasing the demand for such methods in unmanned aerial and ground vehicle applications. A novel zero-shot video object segmentation is introduced to focus on the discovery of moving objects in challenging scenarios. This method employs a background memory model for training from sparse annotations over time by using temporal modeling of the background to accurately detect moving objects. In addition, the method addresses the limitations of existing state-of-the-art solutions for detecting salient objects within images regardless of their motion.

In [7], an adaptive UAV-assisted object-recognition algorithm is introduced for urban surveillance scenarios. In a UAV-assisted surveillance system, UAVs are equipped with learning-based object recognition models and can collect surveillance images. Owing to UAV limitations (for example, limited battery and computational capabilities), adaptive control considering these limitations is devised to maximize the time-averaged recognition performance subject to stability through Lyapunov optimization.

In [8], modern semantic segmentation frameworks combining low- and high-level context information are used to improve performance. In addition, post-level context information is considered in a context refinement network (CRFNet). Training for improving the semantic segmentation predictions proceeds through an encoder–decoder structure. This study directly considers the relation between spatially neighboring pixels of a label map using methods such as Markov and conditional random fields.

In [9], real-time accurate 3D multi-pedestrian detection and tracking are achieved using 3D LiDAR point clouds from crowded environments. Pedestrian detection segments a sparse 3D point cloud into individual pedestrians using a lightweight convolutional autoencoder and connected component labeling. Multi-pedestrian tracking associates the same pedestrians by considering motion and appearance cues in continuous frames. In addition, the dynamic movements of pedestrians are estimated with various patterns by adaptively mixing heterogeneous motion models.

In [10], sensor-fusion-based object detection and classification are presented. The proposed method operates in real time, rendering it suitable for integration into autonomous vehicles. It performs well on a custom dataset and publicly available datasets, demonstrating its effectiveness in real-world road environments. In addition, a 3D moving object detection dataset called ETRI 3D MOD, is constructed.

In [11], three techniques for combining information from multiple cameras are proposed, namely, feature, early, and late fusion techniques. Extensive experiments were conducted on pedestrian-view intersection classification. The proposed model with feature fusion provides an area under the curve and an F1-score of 82.00 and 46.48, respectively, outperforming a model trained using only real three-camera data and one-camera models by a large margin.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

KEYWORDS

drones, UAV, unmanned autonomous vehicles, unmanned ground vehicles

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REFERENCES

1. S. Park, H. Lee, C. Park, S. Jung, M. Choi, and J. Kim, *Two tales of platoon intelligence for autonomous mobility control: Enabling deep learning recipes*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0132.
2. H. Lee, S. Cho, and H. Jung, *Real-time collision-free landing path planning for drone deliveries in urban environments*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0129.

3. J. Yang and S. Lee, *Ultra-wideband coupled relative positioning algorithm applicable to flight controller for multi-drone collaboration*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0128.
4. Z. Su, W. Chen, C. Li, J. Yu, G. Gong, and Z. Wang, *A three-dimensional two-hemisphere model for unmanned aerial vehicle multiple-input multiple-output channels*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2022-0456.
5. J. Moon, J. Kim, H. Lee, Y. Moon, Y. Lee, Y. Bang, K. Sohn, J. Bae, K. Kim, and S. Bahng, *Implementation of mmWave long-range backhaul for UAV-BS*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0112.
6. K. Yun, H. Kim, K. Bae, and J. Moon, *Background memory-assisted zero-shot video object segmentation for unmanned aerial and ground vehicles*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0115.
7. G. S. Kim, H. Lee, S. Park, and J. Kim, *Joint frame rate adaptation and object recognition model selection for stabilized unmanned aerial vehicle surveillance*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0121.
8. T. An, J. Kang, D. Choi, and K. -W. Min, *CRFNet: Context ReFinement network for semantic segmentation*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0017.
9. K.-I. Na and B. Park, *Real-time 3D multi-pedestrian detection and tracking using 3D LiDAR point cloud for mobile robot*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0116.
10. D. Lee, S.-J. Han, K.-W. Min, J. Choi, and C. H. Park, *EMOS: Enhanced moving object detection and classification via sensor fusion and noise filtering*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0109.
11. M. Astrid and S.-I. Lee, *Assembling three one-camera images for three-camera intersection classification*, ETRI J. **45** (2023), no. 5. DOI 10.4218/etrij.2023-0100.

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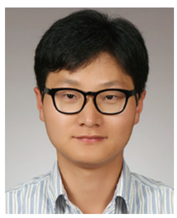

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