Immersive Drone XR Tracking Interaction Based on Game Design Principles

Shiyu Liu

School of Information Science and Engineering, Henan University of Technology, Zhengzhou, 450000, China
ariasasis0619@stu.haut.edu.cn

Abstract. The low-altitude economy is a national strategic emerging industry. UAV is its core ap-plication platform, and XR technology helps to improve the low-altitude experience. The current XR drone interaction usually uses the traditional joystick. These controls lead to problems such as immersion interruption, difficult operation and user fatigue. They are not suitable for non-professional users in the fields of cultural tourism and education. Us-ing the concept of game design, this study proposes a new way to control drones through XR tracking gestures and body movements. A practical gesture-based control scheme has been designed. Technical inspection shows that the plan can be built with existing technology. User tests and surveys show that this method reduces the mental labor of non-professional users and improves the sense of existence in virtual reality space. In short, this study provides a theoretical and practical method to improve the interaction of low-altitude XR drones. It helps to combine low-altitude economy and XR technology.

Keywords: Low-altitude economy, XR technology, drone interaction, gamified design

1 Introduction

The low-altitude economy is a strategic emerging industry. Its market size exceeded 500 billion yuan in 2023 [1]. UAVs are the main tools in this field. XR technical support for better low-altitude use experience. The combination of drones and XR is the key to the digital growth of the low-altitude economy. However, research on current low-altitude tourism projects in cities such as Beijing and Hangzhou shows that they still rely on traditional joystick control.

This method is precise and mature, but it has three main problems. First of all, the control is unnatural, so users need to consider a lot of operations. Second, the user's physical feeling does not match the control action, which destroys the sense of immersion. Third, blindly using the joystick in an immersive environment will increase the chance of mistakes and the risk of flight. These problems bring a bad experience to non-expert users, so better design is needed.

G. E. Atalay and A. Wang (eds.), *Proceedings of the 2026 3rd International Conference on Public Relations and Media Communication (PRMC 2026)*, Advances in Social Science, Education and Humanities Research 1032,
https://doi.org/10.2991/978-2-38476-609-3_66

The research on the interaction between XR and drones has explored many directions. This work provides the technical basis for the new low-altitude XR drone model.

A team at the University of Ottawa pointed out that XR can make remote ma-chine control more natural and effective. They also pointed out that the current XR remote control lacks complete immersion and ease of use. This insight guides the research.

The Spanish National Research Council designed an XR-Drone interface based on human behavior. This allows clear communication between people and machines [2]. This shows that the XR gesture control of the drone is feasible and safe.

The tactile laboratory of Tokyo Electric University has manufactured the drone knight XR system. It combines sports interaction and game-style design. Users can control virtual drones by transferring body weight and moving limbs. It also includes wind and vibration feedback for a deeper experience. Tests show that the method is highly interactive and has almost no motion sickness. It pro-vides a useful example of gamified XR drone interaction.

Therefore, this study explores a new “human-computer interaction model based on game thinking.” The main goals are

First of all, for low-altitude cultural tourism and education and training scenarios, this clef will cardamine the gamification design principle to establish mapping rules to make XR body movements consistent with drone flight control commands, so as to ensure real-time interaction and operation safety.

Secondly, compared with traditional controller-based operations, the drone control interaction model based on XR motion capture has significant advantages in reducing the cognitive load of non-professional users and enhancing the immersive experience.

2 Design Methodology

2.1 Origin of the Concept

This idea comes from people's natural desire to fly freely. It adopts the interactive style of open world exploration games. It avoids the physical restrictions and additional equipment controlled by ordinary drones. Users only need to move their bodies to control the drone and change its field of view. In this way, users can go beyond physical restrictions and explore large-scale mixed reality space by themselves.

2.2 Design Strategy

The design uses the inside-out tracking function of the XR headset to track the user's upper body joints in real time. The data is sent to the flight control soft-ware with low latency through 5G-A or similar networks. The software converts the movement into a standard drone command, as shown in Figure 1.

This concept is expected to be realized in an XR drone interactive game called "low-altitude roaming". Control commands include movement: the arm tilts for-ward or backward to map the drone forward or backward, while the body tilts to the left or right to map to the left or right horizontal movement. Accessibility: Lower the hands to trigger the landing, and the "pinch" gesture triggers the cruise path editing. Interface:

Operation guidance modules such as electronic fences, drone attitude indicators and radar mini-maps are displayed in the VR field of view of Figure 2. Task: The design difficulty of game modes such as "Landmark Tracking" and "Speed Run" is increasing, and practical exercises are integrated into challenging tasks [3].

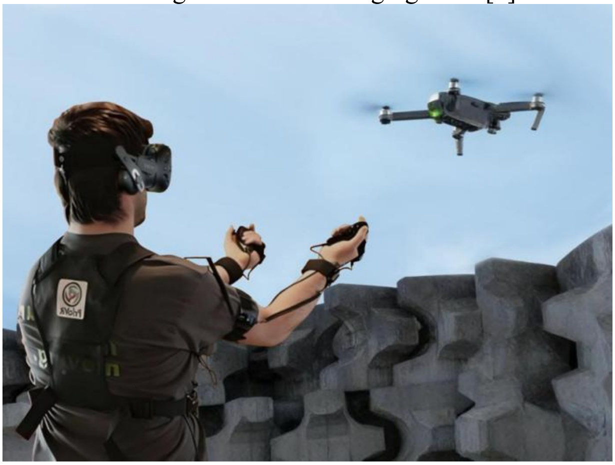

Fig. 1. Diagram of a user operation scenario. (Picture credit: Original)

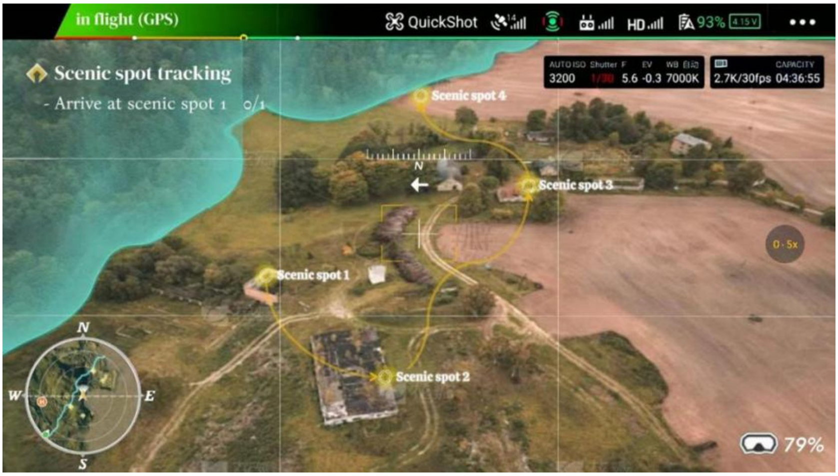

Fig. 2. Schematic diagram of the prototype operating system. (Picture credit: Original)

3 Outcomes of the Plan

3.1 Technical Feasibility Assessment

Using available market technology, public data and standard protocols, the paper checked four key parts: XR motion capture, 5G-A low-latency transmission, flight command reading and game interaction mixing. The plan is highly feasible and there are no major technical obstacles. Prototypes can be quickly manufactured with ready-made parts.

XR Body Motion Capture. The inside-out tracking technology in existing commercial XR headphones (such as Pico 5) is mature and can accurately capture basic body movements [4]. Its sampling rate is ≥90 Hz, which is very suitable for simple movements designed in this study - such as body tilt forward, body lateral tilt and fist clenching - without complex development. Through the Unity engine to call OpenXR and other control middleware, and lightweight filtering of tracking data, effective motion features can be extracted [5], providing a basis for command mapping.

Low-Latency Data Transmission in 5G-A. 5G-A technology has been commercially deployed and network coverage has been achieved in key cultural tourism and educational venues; if there is no 5G-A signal available, users can switch to Wi-Fi 6e as an alternative [6]. In addition, since this study only transmits a small amount of data (such as motion capture function and drone status), and the bandwidth requirements of these data are low, 5G-A and Wi-Fi 6e are enough to transmit low-latency data to local devices.

Analysis of Flight Control Commands. The standardized protocol for drone flight controllers has been established, and major manufacturers such as DJI have released SDKs and APIs to support third-party developers to transmit basic flight commands. Using Python, people can create a mapping table between motion features and flight control commands, and convert the processed tracking data into standardized flight control commands [7]. This method has low development complexity and strong adaptability.

Integration of Gamified Interaction Systems. The integrated Unity engine of the gamified interaction system can be used as a development tool for XR interface interaction. Native support for XR field of view rendering and UI component overlay; gamified interface elements, such as geofences and radar mini maps, can be quickly built using the standard components of the engine. By synchronizing the data transmitted by the drone in real time, the virtual interface can reflect the actual flight status and effectively play the role of an attitude indicator. In addition, due to the low requirements for rendering accuracy in scenes such as cultural tourism and education, lightweight modeling is enough to achieve smooth rendering [8].

3.2 User Experience Analysis

This study focuses on two groups: tourists in low-altitude tourism and teachers and students in learning activities. The paper simulated two cases: digital landscape tourism and scenario-based learning. And a survey was conducted on potential users, covering seven aspects: mental effort, immersion, safety, physical comfort, accuracy of sports detection, game attractiveness and overall willingness to use.

The survey asked about the difficulty of learning, physical fatigue, sense of presence, perceived flight safety, operation stability and fun. The paper expects that the system will bring obvious benefits by directly linking body movement to flight orders. This avoids the disconnection of the joystick and reduces the mental labor of non-experts. Tasks similar to games will also increase participation and fun [9].

This study also pointed out some potential problems. For example, inappropriate amplitude of action may lead to flight failure, and there is also a risk of fatigue after long-term use. To solve these problems, the paper will adjust the action recognition threshold, add additional range tips, and develop a short-break mode and a lightweight operation mode to improve user-friendliness, safety and com-fort.

4 Application Scenarios

This project aims to create a low-altitude immersive experience tour, such as XR tour activities in large parks. Users can control drones in the real environment through physical movements and explore the airspace close to the ground in depth and immersively with the help of interesting treasure hunting games, making park activities more colorful.

This project is also suitable for teaching geography and history. Students can observe topography or historical attractions from the perspective of drones, make abstract content concrete, and improve classroom interactivity and learning efficiency [10].

5 Conclusion

In order to solve the problem of the industry in the field of interaction with low-altitude drones, the study combines the game design principle with XR motion capture technology to establish the correlation rules between drone flight control and human movement. On the basis of existing commercial technology, this paper develops the prototype of the interactive XR drone system "low-altitude roaming", and verifies its technical feasibility and practicality. The results show that the project has no technical barriers and has the potential for rapid industrialization.

Research confirms that compared with the traditional controller-based manip-ulation method, the program effectively reduces the cognitive burden of non-profit users. It enhances immersive low-altitude interactive experiences and pro-vides practical interactive solutions for low-altitude travel, education and other industries. It can realize the two-way realization of entertainment and education-al applications, with broad application prospects and remarkable commercial value.

Looking to the future, this research can further optimize the motion recognition algorithm and improve the control accuracy in complex scenarios. Multi-channel feedback technology can also be integrated to expand collaboration with multiple users and make the experience more realistic. In addition, the operating system can adapt to different user groups, expand the scope of application of the research in the low-altitude economy, and promote the deep integration of XR technology and UAV applications.

References

1. China Air Transport Association: White Paper on the Development of China’s Low-Altitude Economy Industry. China Air Transport Association, (2023).
2. DoDorzhieva, E., Savkin, A., Boukhanovsky, A.: DroneARchery: Human-Drone Interaction through Augmented Reality with Haptic Feedback and Multi-UAV Collision Avoidance. arXiv preprint arXiv:2210.07730, (2022).
3. Bremer, S., Opwis, K.: Design Patterns for Playful Augmented Reality: Enhancing Cultural Heritage Engagement with Game Mechanics. Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems, ACM, 1-14. (2025).
4. Kim, J.H., Park, S.J.: Urban Air Mobility System Testbed using CAVE Virtual Reality Environment with Motion Capture. IEEE Internet of Things Journal, 12(11): 9876-9889. (2025).
5. Wang, J., Li, M., Zhang, T.: Optimization and Engineering Applications of Inside-Out Tracking Technology for XR Headsets. Research on Computer Applications, 41(7): 2109–2114. (2024).
6. Liu, J., Zhao, Y., Huang, L.: Research on Low-Latency Transmission Technologies for 5G-A and Wi-Fi 6E Heterogeneous Networks. Telecommunications Science, 41(2): 89–96. (2025).
7. Chen, Y., Zhou, M., Wu, D.: Secondary Development of UAV Flight Control SDK and Command Mapping Methods. Measurement and Control Technology, 43(5): 78–83. (2024)
8. Zhang, W., Ma, L., Fang, Y.: Lightweight Implementation of the Unity Engine in the Development of XR Gamified Interfaces. Computer Engineering and Design, 45(8): 2456–2462. (2024).
9. Huang, T., Yang, X., Jiang, F.: A Study on Optimizing User Experience in Drone XR Interactions within Low-Altitude Cultural Tourism Scenarios. Journal of Tourism Studies, 40(3): 112–124. (2025).
10. Li, Y., Zhang, L., Chen, H.: Enhancing User Experience in Interactive Virtual Museums for Cultural Heritage Learning Through Extended Reality. IEEE Access, 13: 4589-4602. (2025).