U2USim - A UAV Telepresence Simulation Platform with Multi-agent Sensing and Dynamic Environment

Feilin Han*
Department of Film and Television Technology, Beijing Film Academy
Beijing, China
hanfeilin@bfa.edu.cn

Leping Zhang
Department of Film and Television Technology, Beijing Film Academy
Beijing, China
zhangleping@mail.bfa.edu.cn

Xin Wang*
Department of Computer Science and Technology, BNRist, Tsinghua University, Beijing, China
xin_wang@tsinghua.edu.cn

Ke-Ao Zhao
China Film High-Tech Research Institute, Beijing Film Academy
Beijing, China
zhaoke-ao@mail.bfa.edu.cn

Ying Zhong
China Film High-Tech Research Institute, Beijing Film Academy
Beijing, China
zhongyingcw@mail.bfa.edu.cn

Ziyi Su
Department of Film and Television Technology, Beijing Film Academy
Beijing, China
suziyi113@gmail.com

Tongtong Feng
Department of Computer Science and Technology, Tsinghua University
Beijing, China
fengtongtong@tsinghua.edu.cn

Wenwu Zhu*
Department of Computer Science and Technology, BNRist, Tsinghua University, Beijing, China
wwzhu@tsinghua.edu.cn

Figure 1: U2USim is a telepresence simulation platform for UAV synthetic data generation. This system provides multiple agents and multi-modal sensors for manipulation, with dynamic real-world weather and environment conditions.

Abstract

Unmanned Aerial Vehicles (UAVs) are necessary across diverse domains, including disaster surveillance and wildlife conservation. However, the development and evaluation of UAV-related algorithms often encounter a significant hurdle: the scarcity of authentic training data. In this paper, we introduce U2USim, a telepresence simulation platform with a dynamic environment, serving as a realistic synthetic data generation, performance evaluation, and visualization tool for UAV-to-UAV (U2U) cooperative learning. This paper presents the architecture, features, and capabilities of U2USim. Leveraging Unreal Engine (UE), AirSim APIs, and ROS (Robot Operating System), our platform enables realistic simulations, mirroring real-world conditions and facilitating research in UAV technology.

CCS Concepts

• **Human-centered computing** → **Visualization systems and tools**; • **Computer systems organization** → **Real-time systems**; • **Information systems** → **Multimedia information systems**.

Keywords

UAV, Simulation Platform, Multi-agent, Dynamic Environment

ACM Reference Format:
Feilin Han*, Leping Zhang, Xin Wang*, Ke-Ao Zhao, Ying Zhong, Ziyi Su, Tongtong Feng, and Wenwu Zhu*. 2024. U2USim - A UAV Telepresence Simulation Platform with Multi-agent Sensing and Dynamic Environment. In *Proceedings of the 32nd ACM International Conference on Multimedia (MM '24), October 28-November 1, 2024, Melbourne, VIC, Australia.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3664647.3684995

*Corresponding authors.

MM '24, October 28-November 1, 2024, Melbourne, VIC, Australia

ACM ISBN 979-8-4007-0686-8/24/10
https://doi.org/10.1145/3664647.3684995

1 Introduction

Multi-rotor unmanned aerial vehicles (UAVs) have transformed into intelligent agents capable of navigating through unknown environments. This evolution underscores their ability to operate autonomously and adapt to diverse and challenging scenarios. UAV-related research frequently faces a significant problem: the lack of authentic and diverse training data. To address this, we introduce U2USim, which is a telepresence simulation platform, designed for realistic synthetic data generation, performance evaluation, and visualization in UAV-to-UAV (U2U) cooperative learning and embodied AI research.

Simulation offers an effective solution to implement real-time capabilities, high maneuverability, high-resolution imagery, and cost-effectiveness [8]. Previous simulation platforms, such as Airsim-W [2], XTDrone [7], SmrtSwarm [1], are limited in mirroring real-world environment. Inspired by the ROS-Gazebo-PX4 toolchain [3], renowned for visual SLAM and navigation, we propose the U2USim platform. This tool utilizes UE [5], Airsim [6], and ROS [4] to construct a real-time interactive platform with a dynamic and realistic virtual environment.

2 System Design

U2USim, as an independent plugin of UE, can obtain rendering information, the position of drones, sensor data, and commands in real-time. Depending on the scope of the simulation, U2USim is integrated with multiple sensor plugins and extensions, to implement perception sensors, UAV control module, dynamic weather module, and 3D scene construction. Plugins extension sensors are used to obtain UAV-related information. Engine extensions are employed to capture environmental data, shown as Figure 2 (left).

U2USim is currently developed with 4 types of visual sensors (RGB, Depth, infrared, and perception), 4 terrains (plains, mountains, forests, lake), and 6 weather conditions (sand storm, fog, rain, snow, overcast, clear sky). U2USim provides various control schemes (by desktop, controller, command line control). Exported visual data and metadata can be saved as specific file format, and directly sent to server, client, and ROS for further processing.

2.1 Multi-agent Sensing

U2USim enables the simultaneous control of multiple UAVs and the acquisition of sensor data, facilitating collaborative operations among multiple intelligent agents. The 3D UAV model can be customized as needed. The animal agents can adaptively adjust their motion according to the landscape. In U2USim, each UAV is equipped with five cameras, whose orientation and positions can be configured in the setting file. Each camera can work as RGB, depth, segmentation, and infrared camera.

The IMU data in U2USim is derived from motion data of the aircraft object within the engine, which is then transformed relative to the U2USim coordinate system before output. The coordinate system in U2USim is a right-handed one with the drone's takeoff coordinates as the origin, oriented such that $+X$ is north, $+Y$ is east, and $+Z$ is downward, measured in meters. The IMUs data is calculated by mapping the longitude and latitude coordinates of the UAVs onto an idealized model of the Earth's magnetic field, where random fluctuations are applied to emulate a complex, realistic geomagnetic environment.

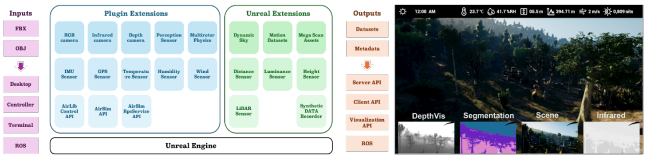

Figure 2: The framework and HUD of U2USim platform.

2.2 Environment Dynamic

With significant advantages in scene development and user-friendly interaction, we employ Unreal Engine to create a dynamic realistic environment. 3D assets can be constructed by Digital Content Creation (DCC), generated by AI and 3D Modeling methods, or copyright assets. Additionally, UE provides ready-made visual effects and physical simulator plugins (eg. Ultra Dynamic Sky and particle system) further augmenting the simulation environment.

The simulation environment in U2USim contains a complex terrain with a maximum relative height difference of 1000m, including mountains, hills, plains, and lakes. There are more than 25 types of plants with varied distributions, referencing the real-world terrain of Yunnan. Environmental data includes luminance, temperature, humidity, altitude, windspeed, fog thickness, timecode, and weather type, which are all shown on the HUD (Head-Up Display) interface (Figure 2 (right)) and recorded in the metadata file.

As UAVs traverse various paths through the scenes, they experience dynamic and track-repeatable variations in weather and terrain conditions. All the weather, temperature, and humidity data in U2USim are derived from real climate data in Yunnan. Weather data is blended with mapping and interpolation of simulation information, coordinating with UAVs' location coordinates. More real-world weather data could be embedded according to the testing requirements.

2.3 Real-time System

In U2USim, the UAV control API is based on Airsim and ROS. Airsim for capturing and manipulating UAVs, and ROS for control interfaces and APIs. Users can manipulate UAVs using desktop, controller, terminal, and ROS. ROS is also employed for UAVs data transmission and processing between servers and clients. The synthetic system can export metadata files and image sequences, with a maximum frame rate of 60 fps. The entire system can run on a PC equipped with an NVIDIA RTX 3090 GPU or higher to ensure real-time interaction, communication, data processing in low latency. The supplementary video is available from project page (https://feilinh.cn/projects/u2usim/).

3 Conclusion

U2USim is designed to support the UAV-to-UAV (U2U) cooperative learning in embodied AI research and address the demand for authentic training data through a sophisticated telepresence platform. In U2Usim, 4 types of visual sensors, 4 terrains, and 6 weather conditions, multiple agents are developed for realistic synthetic data generation, performance evaluation, and data visualization. In the future, we will develop additional plugins and extensions, including more naturalistic and sensitive physical-virtual interaction of U2U control. We would like to develop FPGA-based hardware-in-the-loop simulations for real-time virtual-reality-fusion systems.

4 Acknowledgement

The project is supported by Beijing National Research Center for Information Science and Technology under Grant No. BNR2023RC01003, BNR2023TD03006, BR2023KF02008, and Beijing Key Lab of Networked Multimedia. Our research is also funded by the China Postdoctoral Science Foundation under Grant No. 2024M751688, Postdoctoral Fellowship Program of CPSF under Grant No. GZC20240827.

References

[1] Nikita Bhamu, Harshit Verma, Akanksha Dixit, Barbara Bollard, and Smruti R Sarangi. 2023. SmrtSwarm: A Novel Swarming Model for Real-World Environments. *Drones* 7, 9 (2023), 573.

[2] Elizabeth Bondi, Debadeepta Dey, and et al. 2018. AirSim-W: A Simulation Environment for Wildlife Conservation with UAVs. In *Proceedings of the 1st ACM SIGCAS Conference on Computing and Sustainable Societies*.

[3] Shengyang Chen, Weifeng Zhou, An-Shik Yang, Han Chen, Boyang Li, and Chih-Yung Wen. 2022. An end-to-end UAV simulation platform for visual SLAM and navigation. *Aerospace* 9, 2 (2022), 48.

[4] The ROS Community. 2023. Robot Operating System (ROS). *https://ros. org/* (2023).

[5] Epic Games. 2003. Unreal Engine. *http://www. unrealtechnology. com/* (2003).

[6] Shital Shah, Debadeepta Dey, Chris Lovett, and Ashish Kapoor. 2018. Airsim: High-fidelity visual and physical simulation for autonomous vehicles. In *Field and Service Robotics: Results of the 11th International Conference*. Springer, 621–635.

[7] Kun Xiao, Shaochang Tan, Guohui Wang, Xueyan An, Xiang Wang, and Xiangke Wang. 2020. XTDrone: A Customizable Multi-rotor UAVs Simulation Platform. In *2020 International Conference on Robotics and Automation Sciences*. 55–61.

[8] Dongmei Xie, Ruifeng Hu, Chisheng Wang, Chuanhua Zhu, Hui Xu, and Qipei Li. 2023. A Simulation Framework of Unmanned Aerial Vehicles Route Planning Design and Validation for Landslide Monitoring. *Remote Sensing* 15, 24 (2023), 5758.